Austin Water

WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

A WATER PLAN FOR THE NEXT 100 YEARS

austinwater.org

Water Forward Plan Report

Adopted November 2018

Water Forward, Austin's Integrated Water Resource Plan was recommended for approval by the Water Forward Task Force on October 9, 2018 and by the Austin Water and Wastewater Commission on October 10, 2018. Austin's City Council unanimously approved adoption of Water Forward (with Council Member Troxclair off the dais) on November 29, 2018. As a component of adoption, Council included Council direction, which can be found in the meeting minutes on page 10 at the following link: https://www.austintexas.gov/edims/document.cfm?id=312502. An excerpt from the November 29, 2018 City Council meeting minutes describing the Council direction is included in Appendix N for reference.

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ACKNOWLEDGEMENTS

As a result of more than 3 years of effort, the Water Forward Integrated Water Resource Plan represents a transformational plan for Austin that will guide Austin's water future for the next century. The plan was prepared by Austin Water with support from the Water Forward Task Force, a consultant team, and the Austin community.

We express our appreciation to the many individuals and organizations that helped us build the Water Forward Plan. Your support and input shaped the plan to reflect our community's values. Thank you to those who took time out of their busy schedules to participate in community meetings and workshops, attend events, as well as provide input through surveys and other exercises both online and in person. Your input was thoughtful and reflected our community's passion and enthusiasm regarding water and its great importance to our lives and well-being.

This plan would not be possible without the collaboration and community input from participants throughout the plan development process. Sincerest appreciation goes to the Water Forward Task Force, which provided essential support for working through the plan development steps.

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Acronym	Definition
AC	Air conditioning
AEGB	Austin Energy Green Building
AF	Acre-foot
AFY	Acre-feet per year
AMI	Advanced metering infrastructure
ASR	Aquifer storage and recovery
AW	Austin Water
CII	Commercial, institutional, industrial
COA	City of Austin
COM	Commercial
DDM	Disaggregated demand model
DTI	Delphi, Trends and Imagine Austin
GIS	Geographic information system
GPCD	Gallons per capita day
IPR	Indirect potable reuse
IWRP	Integrated water resources plan
LCRA	Lower Colorado River Authority
MFR	Multi-family residential
MGD	Million gallons per day
PACE	Property Assessed Clean Energy
SFR	Single family residential
WAM	Water Availability Model
WHL	Wholesale customers
WTP	Water treatment plant
WWTP	Wastewater treatment plant

SECTION 1: EXECUTIVE SUMMARY

For more than 100 years, Austin Water has been committed to providing clean, safe, reliable, high quality, sustainable, and affordable water services to our customers. Austin's Water Forward Integrated Water Resource Plan will support that enduring commitment for the next 100 years and beyond. The Water Forward plan recommendations were developed using a holistic planning approach that balances multiple objectives such as water reliability, social, environmental, and economic benefits, and ease of implementation. The guiding principles of Water Forward, which helped inform these objectives and provided direction throughout the planning process, are listed to the right. The Water Forward Plan also sought to align with the Austin City Council's Strategic Outcomes related to Economic Opportunity and Affordability, Safety, Health and Environment, and Government That Works for All.

The recommendation to develop an integrated water resource plan emerged from the historic drought Central Texas endured from 2008-2016. During the drought, the lakes that supply Austin's drinking water fell to historically low levels. While Austin successfully weathered the drought, the event highlighted the need to increase the sustainability, reliability, and diversity of Austin's water supplies through an integrated water resource plan. Water Forward addresses these issues by modeling potential climate change effects on Austin's water supplies and evaluating multiple future scenarios to plan for droughts worse than what we have experienced in the past. The recommended plan is the culmination of a robust effort that involved the Austin community, the Water Forward Task Force, an outside consultant team, City staff, and others.

Water Forward recommended strategies include both major water supply projects and incremental solutions such as demand management or reuse. As Austin grows, new development can help to implement these demand management and reuse strategies to incrementally meet growing demands. The major water supply projects included in the plan are recommended largely to augment Austin's access to water during drought when our core surface water supplies are severely limited.

In a changing climate and growing community, there will always be uncertainty and risks to manage. The Water Forward plan recommendations will be implemented using an adaptive management approach, which means that we will be able to make adjustments to respond to changing conditions. Implementation of Water Forward recommendations will help Austin Water continue its commitment to providing clean, safe, reliable, and affordable water services to our customers.

WATER FORWARD GUIDING PRINCIPLES

Austin's Water Forward is a program to develop a long-term integrated water resources plan for the next 100 years. The following represents the plan's guiding principles:

- *Recognizing that Colorado River water is Austin's core supply, continue a strong partnership between the City and LCRA to assure its reliability*
- *Continue Austin's focus on water conservation and water use efficiency*
- *Strengthen long-term sustainability, reliability, and diversity of Austin's water supply through maximizing local water resources*
- *Avoid severe water shortages during times of drought*
- *Focus on projects that are technically, socially, and economically feasible*
- *Continue to protect Austin's natural environment, including source and receiving water quality*
- *Ensure Austin's water supply continues to meet/exceed all federal, state and local public health regulations*
- *Align with Imagine Austin's "Sustainably Manage Our Water Resources Priority Program"*
- *Maintain coordination and communication with regional partners*
- *Engage the public and stakeholders throughout the plan development process*

1.1 Need for an Integrated Water Resource Plan (IWRP)

Austin's continued population growth and development, the lessons of the historic 2008-2016 drought, and climate change pose challenges that require creative and robust solutions. An integrated water resource plan is an effective tool for planning how to address these challenges. The strength of this holistic planning method is that it allows the community to evaluate tradeoffs between potential solutions and to build solutions that achieve the most benefit in many objectives. To ensure that the plan reflects our community's values, the project team attended over 80 community events to gather feedback to inform the plan recommendations.

1.1.1 Population Growth

Austin has long been one of the fastest-growing cities in America. This growth is reflected in the Water Forward demand projections. Regional growth was also captured in river basin modeling that simulated future demands on the Colorado River and Highland Lakes. Water Forward includes conservation and supply strategies, including reuse, to meet the additional demand created by a growing City of Austin population. One of the ways to gauge the effectiveness of water conservation and reuse is to calculate how much water is used per person per day across the City, a measure known as gallons per capita per day (GPCD). **Figure 1-1** shows the projected Austin Water served population, customer demand, and calculated long-term average GPCDs assuming implementation of the recommended Water Forward strategies.

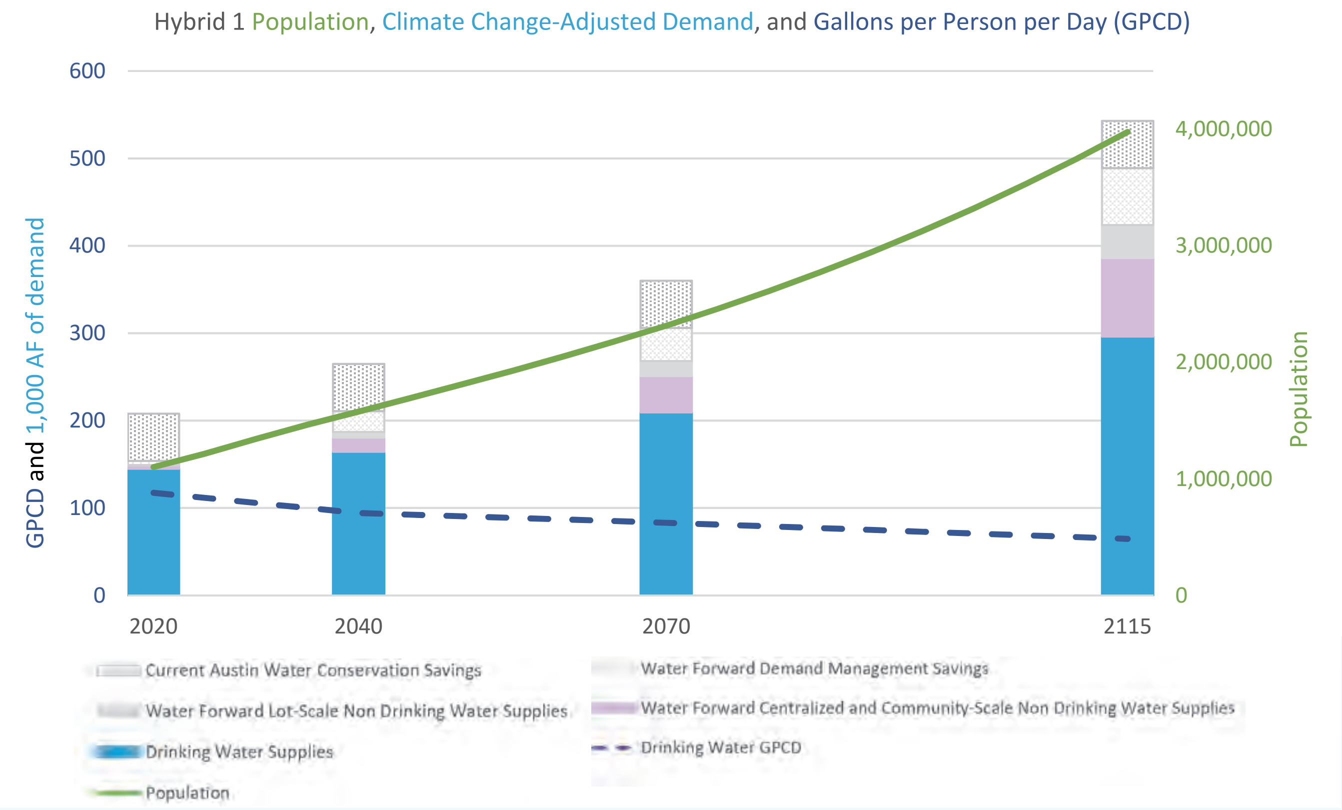


Figure 1-1. Population, climate change-adjusted demand, and GPCD for Water Forward Planning Horizons

The Water Forward plan was developed to meet needs identified through a preliminary analysis of current supplies and potential shortages. Potential future demand management and supply options were then combined to meet those identified needs. After determining the recommended plan strategies, the resulting

GPCD amounts were calculated. The Water Forward plan was not developed to meet specific long-term average GPCD targets, but GPCD can be used to track progress in implementing plan strategies. When evaluating GPCDs, it is important to consider that divergence from projected population growth estimates and climate and weather variation, among other factors, can lead to differences in projected strategy yields, customer demands, and ultimately GPCDs. More information on GPCD as a metric can be found in **Section 9.3.2**.

1.1.2 Drought

During the historic 2008-2016 drought, Austin's water management portfolio was made up of its Colorado River and Highland Lakes supply, reclaimed water supply, conservation water savings, and drought contingency plan water savings. The drought caused storage in the Highland Lakes to drop to near-record lows and the inflows that we rely on to refill the lakes were lower than they had ever been. During the drought, Austin evaluated a number of emergency strategies on an accelerated schedule. With Water Forward, Austin has taken the opportunity to proactively develop future demand management and supply strategies to avoid potential water shortages.

Figure 1-2. Lake Travis during the historic 2008-2016 drought

1.1.3 Climate Change

Climate scientists project that in the future the Austin region will see longer and deeper periods of drought punctuated by heavy rain events. **Figure 1-3** illustrates the projected increase in temperature and changing precipitation in the Austin region, which will likely have profound impacts on flood and drought patterns. Water Forward evaluated multiple future scenarios which considered climate change effects and droughts worse than those experienced in the past to ensure reliability of the plan recommendations through a range of possible futures.

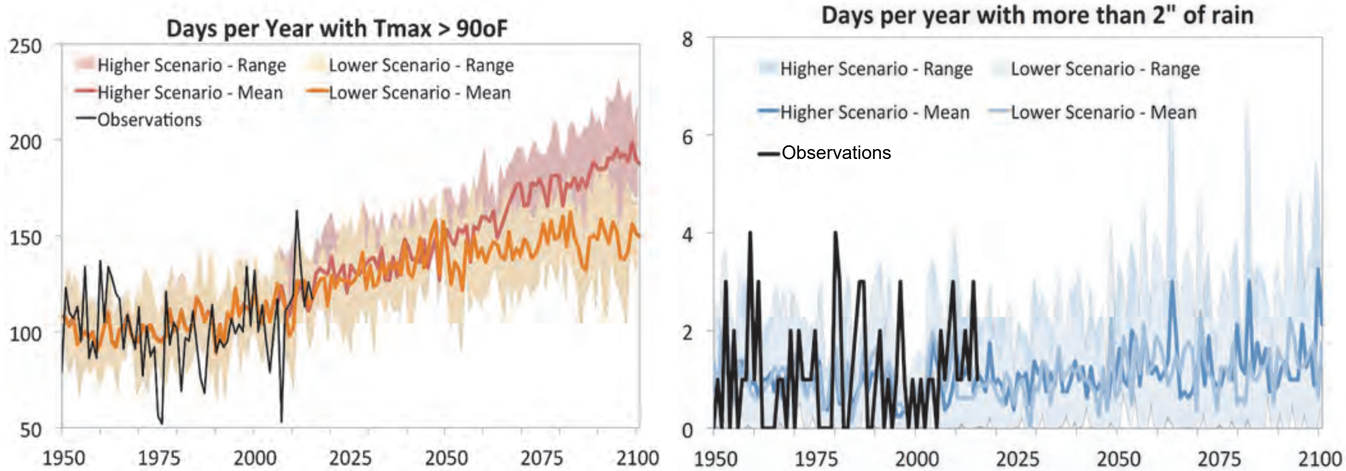


Figure 1-3. Projected increase in temperature and changes in precipitation in the Austin region

1.2 Water Forward Recommendations

The Water Forward plan includes a robust set of strategies to conserve water and make our buildings and landscapes more water efficient. To help reduce leaks on the customer side, the plan recommends using Advanced Metering Infrastructure technology to alert customers to potential leaks and to help them manage their water consumption in close to real time. The plan also recommends reducing losses from pipes in the utility's water distribution system by enhancing Austin Water's current water loss reduction program.

The plan recommends the expansion of several existing Austin Water rebate programs, including programs to assist customers with the costs of "smart" controllers that help to make irrigation systems more efficient and current incentives to existing development to install water-efficient landscapes. The plan also recommends developing an ordinance to require water efficient landscapes for new single-family homes. To achieve efficient water use for many different types of development, the plan recommends developing benchmarks and water budgets that would initially encourage and eventually require customers to meet water usage targets.

Figure 1-4. Advanced Metering Infrastructure and Landscape Transformation

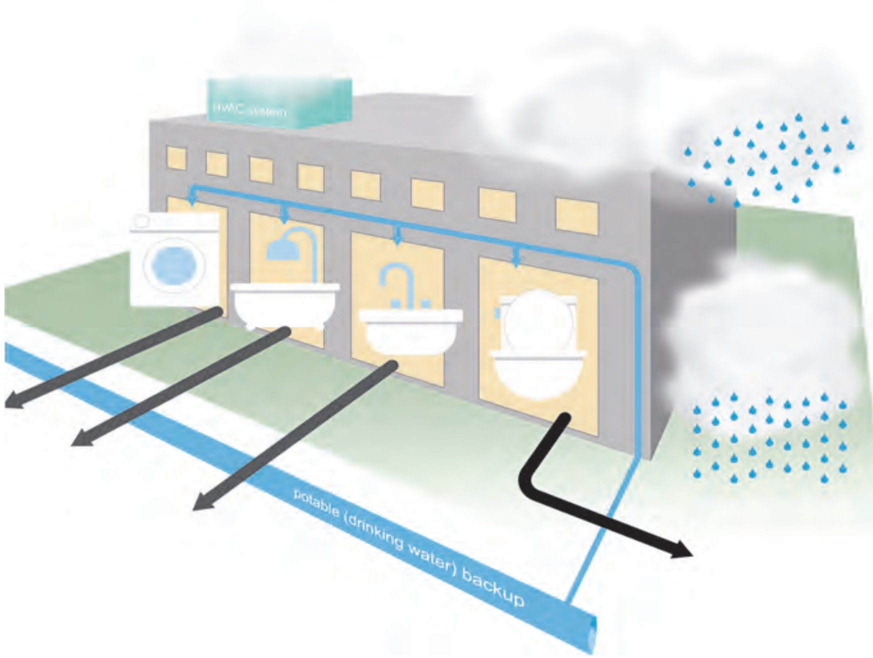


Figure 1-5. Alternative Water Sources Include Rainwater, Stormwater, Graywater, and Wastewater Reuse

The plan also includes strategies to make use of all water, including rainwater, stormwater, graywater, air conditioning condensate, and wastewater (typically called "alternative waters") that can be treated and reused to meet non-drinking water demands (see **Figure 1-6**). To do this, the plan recommends immediately beginning work to develop ordinances to require that new larger commercial and multifamily buildings install dual plumbing and use alternative water generated on-site or from the City's reclaimed water system for both indoor and outdoor non-drinking water purposes. Non-drinking water purposes include demands like toilet flushing and landscape irrigation.

To encourage existing development to use alternative water sources, the plan recommends additional enhancements to Austin Water's current rebate programs. The plan also recommends modifying what is currently in code to require more new developments to connect to the City's reclaimed water system and recommends expansion of the reclaimed water system to meet growing non-drinking water demands in the future.

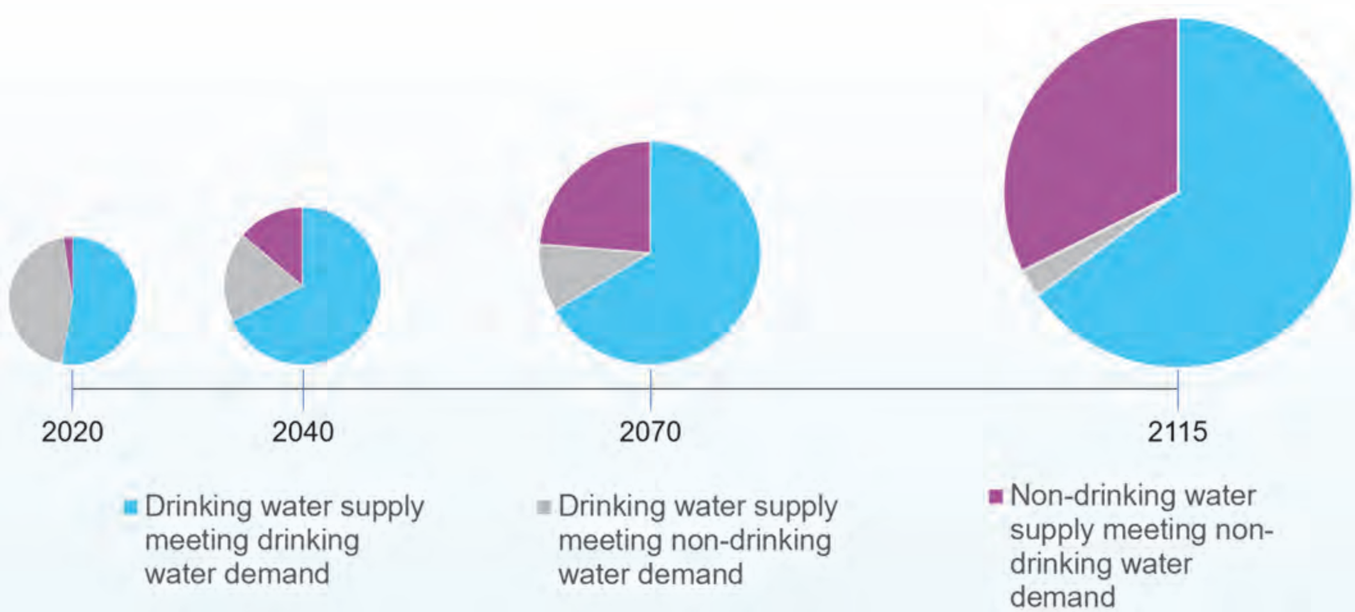
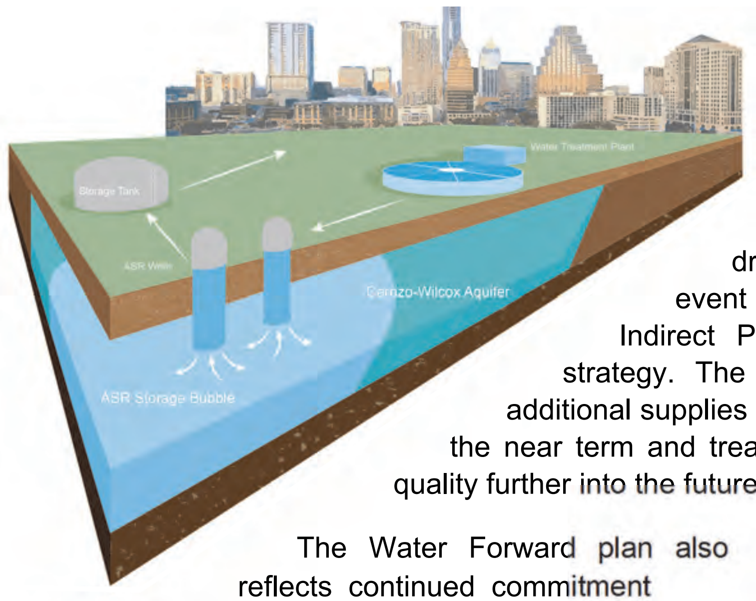


Figure 1-6. Amount of non-drinking water demand being met by non-drinking water sources over time

Figure 1-7. Aquifer Storage and Recovery



To see our community through future droughts, Water Forward recommends implementing storage strategies like Aquifer Storage and Recovery by 2040 and a new Off Channel Reservoir within the next fifty years. Storage strategies will allow Austin to store water available during wet times so that water can be retrieved and used to meet drinking water demands during dry times. In the event of a severe drought, the plan recommends Indirect Potable Reuse as a short-term emergency strategy. The plan also recommends the City bring on additional supplies by capturing local inflows to Lady Bird Lake in the near term and treating Brackish Groundwater to drinking water quality further into the future.

The Water Forward plan also reflects continued commitment to Austin's core Colorado River supplies and implementation of best management practices. All of the Water Forward strategies are recommended as additions to Austin's current supplies, which include our core Colorado River supply, reclaimed water program, water conservation program, and drought contingency plan. As Austin's core supply, the City will continue to work with its regional partners to protect and enhance the Colorado River and Highland Lakes system supply.

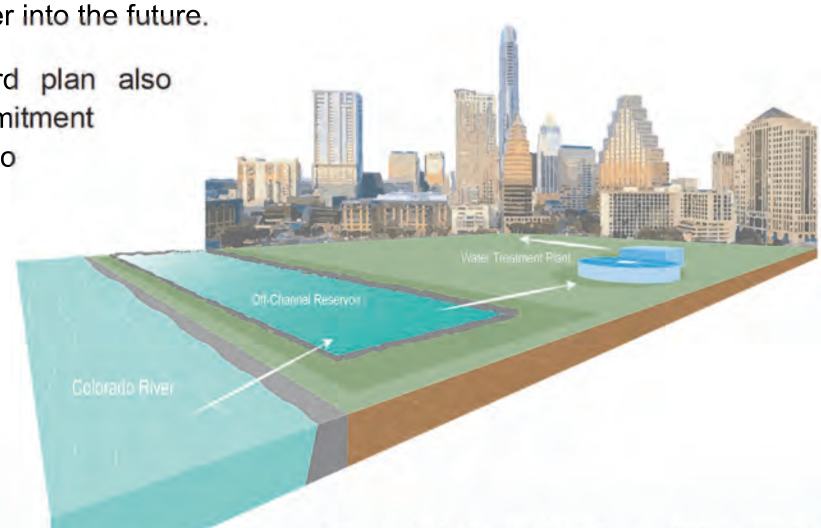
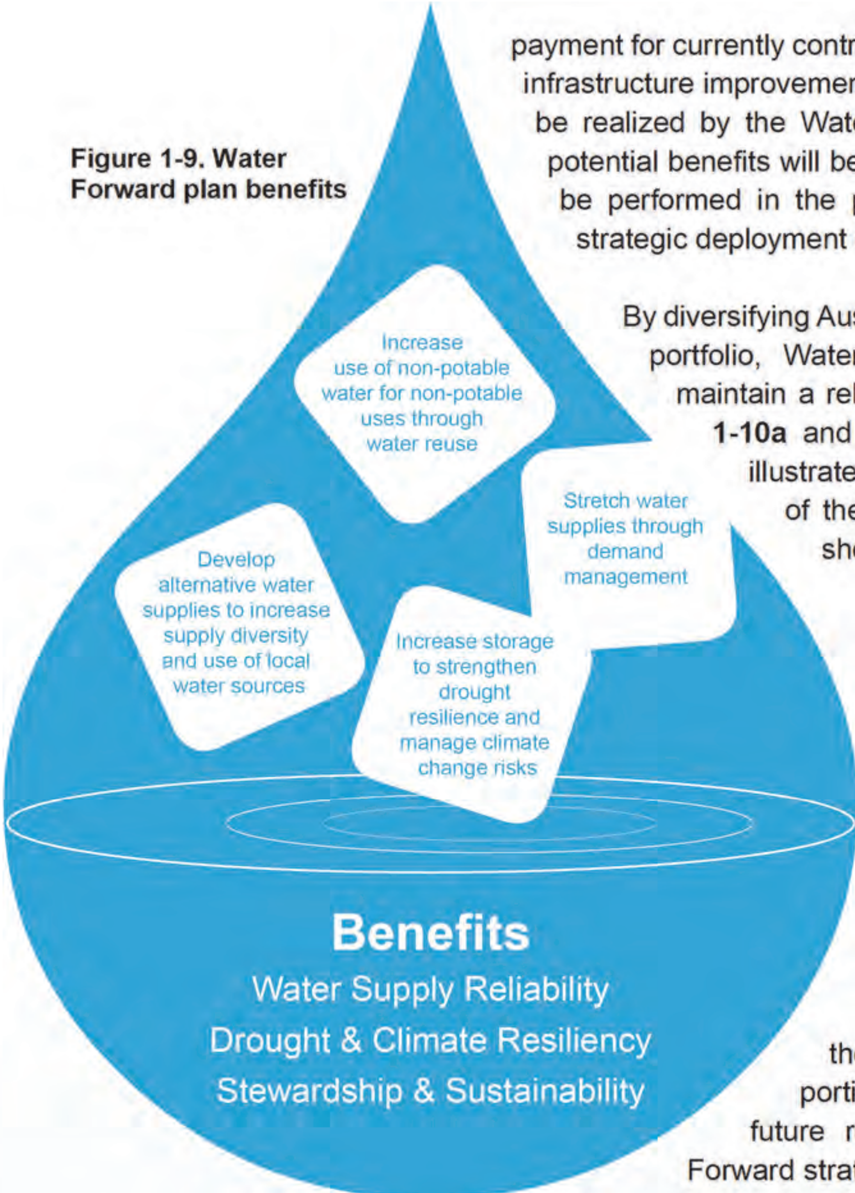


Figure 1-8. New Off Channel Reservoir

1.3 Water Forward Plan Benefits

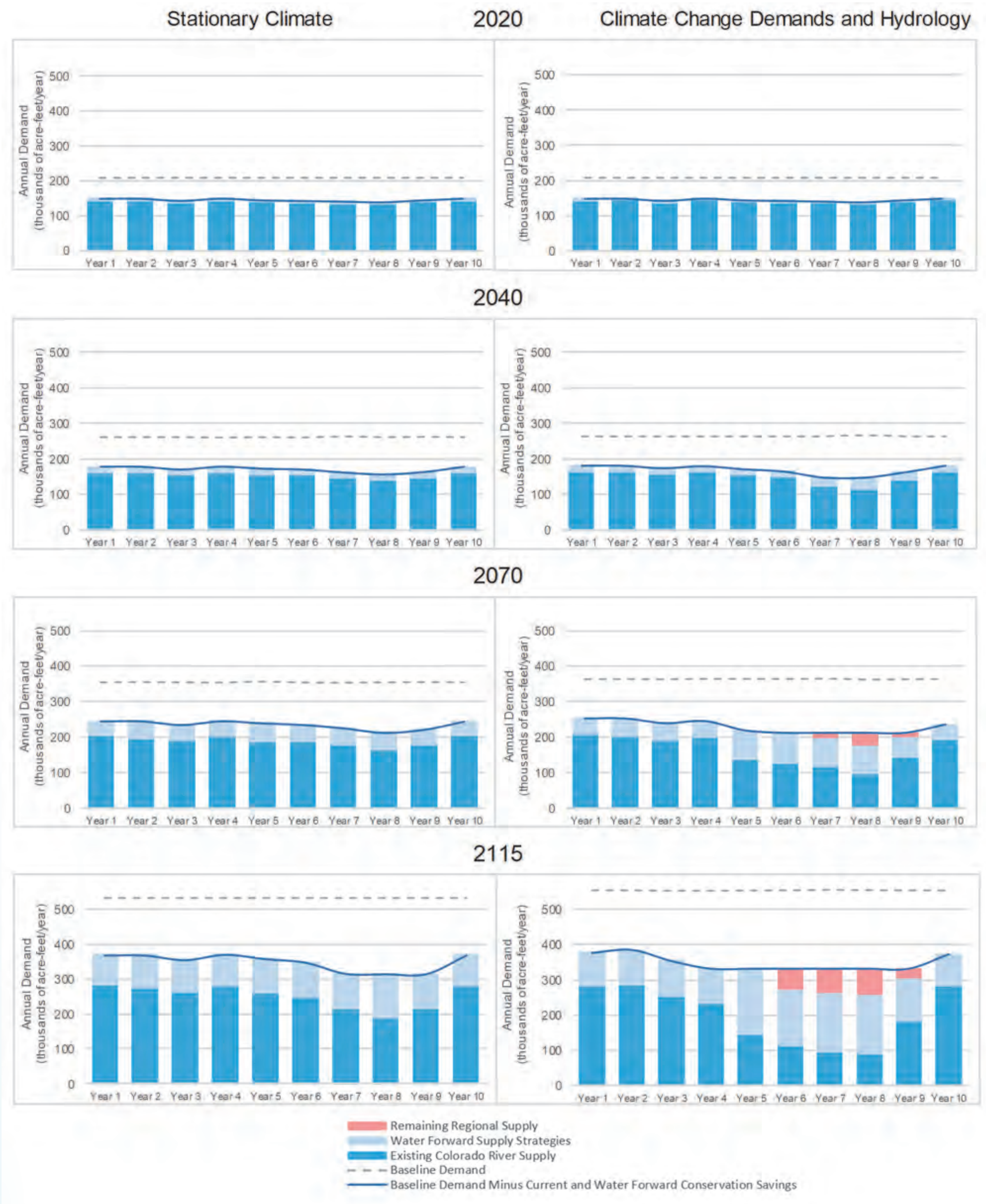
Implementation of the recommended Water Forward strategies will be transformative for the City of Austin and provide many benefits for our community (see **Figure 1-9**). Water Forward's recommended strategies will help Austin stretch existing supplies by reducing overall demands, by being more efficient with the water we do use, and by expanding water reuse. Capturing and reusing water at the point of use increases our community's ability to access all local water sources and adds to supply diversity and resiliency. Expanding reuse supplies, whether at the building scale or from the City's reclaimed water system, allows us to use non-drinking water to meet demands that do not require drinking water quality. This "fit for purpose" approach offsets demand for drinking water supplies while providing a source of supply that is less affected by changes in climate. In addition, increasing water supply reserves through Aquifer Storage and Recovery will help to provide water to the City through the longer periods of drought that we may experience in the future. During the implementation phase, further benefits such as delaying additional payment for currently contracted water supplies and potentially delaying infrastructure improvements may be realized by the Water Forward strategies. The extent of these potential benefits will be explored through modelling and analysis to be performed in the plan implementation phase and will inform strategic deployment of the strategies.

Figure 1-9. Water Forward plan benefits



By diversifying Austin's water supply and demand management portfolio, Water Forward increases the City's ability to maintain a reliable supply for the next 100 years. **Figure 1-10a** and **Figure 1-10b** show modeling results that illustrate how the strategies perform through a repeat of the historic 2008-2016 drought. **Figure 1-10a** shows that the identified needs are met if demands are set at projected 2020 levels and Water Forward strategies are implemented. **Figure 1-10b** shows that with the Water Forward strategies implemented, the City's demands are also met when demands are set at the higher projected 2115 levels. In **Figure 1-10c**, the drought that was simulated to mimic the 2008-2016 drought was made more severe to reflect potential climate change impacts. Using this simulation, with demands set at higher 2115 levels and with the Water Forward strategies implemented, a portion of the City's demands are met with a future regional supply source rather than Water Forward strategies. For the further-out planning horizons, planning to meet a portion of the City's future demands with a regional supply source was an intentional decision that reflects the uncertainty inherent in planning over a 100-year horizon. This reinforces the need to work with the City of Austin's partners in the Colorado River Basin to protect and enhance our future supplies, the results of which will be reflected in future plan updates.

Figure 1-10. Recommended Water Forward strategies modeled through a ten-year drought sequence in stationary and climate change scenarios



1.4 Adaptive Management Plan and Implementation

Austin Water plans to begin the implementation process immediately after City Council approval of the Water Forward Plan. During the next five years Austin Water will take actions that are described in more detail in the sidebar. The Water Forward plan will be updated on a five-year cycle, using new data about changing conditions to inform potential adjustments to the planned implementation strategy and ensuring that we are on a path to meeting our goals.

The Water Forward plan is a high-level strategic plan intended to provide a roadmap to guide development of future programs, projects, and ordinances. The planning-level estimated costs to implement the recommended options through the 2040 planning horizon are presented in **Table 9-3**, and further detail can be found in **Appendix J**. The estimated capital and operations and maintenance (O&M) costs presented reflect community costs, which include costs to be paid by Austin Water and its ratepayers, as well as costs to developers and program participants, with potential cost offsets through utility incentives. The costs are generally grouped into three categories. The cumulative capital cost planning-level estimates between 2019 and 2040 for the three categories are: current utility strategic initiatives in the capital plan—$614M, new utility strategies—$429M, and developer/program participant-owned strategies with potential cost offsets through utility incentives—$274M.

Cost and affordability were key community values communicated to the project team throughout the public input process for Water Forward. The recommended Hybrid 1 portfolio contains several conservation and reuse strategies, which help in stretching our existing supplies through delaying the cost of paying for water under our current municipal water supply contract or purchasing additional supply that would be needed every year. The cost of implementing the recommended strategies could be funded through, among other methods, Austin Water revenues, low-interest bonds or other outside funding, development costs, or shared community investments. In some cases, Austin Water investments could be combined with investments from the community, as in rebates or other incentive programs. Austin Water will work to determine what funding and resource requirements are most suitable to consider for implementing plan strategies and programs. More detailed cost estimates and funding approaches for each recommended strategy will be developed in the implementation phase and will be subject to future Council action as required.

Major Water Forward Implementation Actions in the Next 5 Years

Ordinances (new or changes existing)

- *Alternative water ordinance for new larger commercial and multifamily development*
- *Dual plumbing ordinance for new larger commercial and multifamily development*
- *Expand current reclaimed water system connection requirements*
- *Ordinance to require submittal of water use information for new development*
- *Monitor existing ordinances related to air conditioning condensate reuse and cooling tower and steam boiler efficiency*

Incentives

- *Expand alternative water incentive program*
- *Expand landscape incentive program*
- *Expand irrigation efficiency incentive program*

Projects and Programs

- *Study and begin design, construction, and testing of an Aquifer Storage and Recovery pilot*
- *Implement Advanced Metering Infrastructure*
- *Enhance utility water loss reduction program*
- *Expand the centralized reclaimed water system*
- *Explore community-scale decentralized reclaimed water options*
- *Refinement of Indirect Potable Reuse strategy*
- *Refinement of Capture Lady Bird Lake Inflows strategy*
- *Begin preliminary analyses to support five-year Water Forward plan update*

Social Equity and Affordability

*Water Forward began with the goal of conducting public outreach so that input from our community would equitably reflect the diversity of Austin's population and the utility's customers. The project team worked toward this goal through various means, including in-person outreach at community group meetings and online surveys and webcasts (see **Appendix A** for more information). Social equity was also included as a measure used to evaluate potential Water Forward strategies.*

During the implementation phase, social equity will continue to be a key consideration in the development of ordinances, incentive programs, and water supply projects. The implementation process will also include evaluation of ways to mitigate affordability impacts on ratepayers and residents. Public outreach efforts will continue during implementation to continue community dialogue and engagement.

Implementing the Water Forward recommendations will require a thoughtful approach that protects public health, considers social equity, and maintains affordability and utility financial resilience. Austin Water is committed to implementing the Water Forward plan as quickly as possible, with appropriate time to hear from the community and develop implementation approaches that mitigate unintended consequences.

Future Water Forward efforts will continue the plan's emphasis on public outreach and community involvement. The plan recommends convening the Water Forward Task Force on a quarterly basis to support plan implementation efforts. With hard work and community support, implementation of Water Forward will create a more sustainable, reliable water supply for Austin for the next 100 years and beyond.

The recommended Water Forward strategies are presented in **Table 1-1** and can generally be grouped into two categories: demand management options and supply options. Demand management options are strategies which reduce the demand on Austin's drinking water supply system, either by removing a demand (for example, transforming landscapes to require less water) or by offsetting drinking water demands (for example, collecting rainwater to use for irrigation rather than using drinking water). Certain demand management options, such as lot-scale rainwater harvesting, were generally modeled to provide only the amount of yield that was needed to meet non-potable demands. Supply options are strategies which produce additional water to meet demands. This water includes strategies for drinking water supplies and non-drinking water supplies where appropriate. Supply options that are primarily for use during drought may not contribute yield on a year-to-year basis. In the table, "Estimated Yield" represents the target yields in each planning horizon. Actual yield from the Water Forward strategies will vary based on a number of factors depending on the type of option. Key factors include climate and weather variability, hydrology, and growth in population with subsequent growth in demand.

Table 1-1. Water Forward recommended strategies with planning horizon yields

Option #/ Type	Recommended Strategies	Average/ Drought	Estimated Yield (Acre Feet per Year)[1]			
			2020	2040	2070	2115
	Demand Management Strategies					
D1	Advanced Metering Infrastructure (AMI)	Both	600	3,880	5,770	9,370
D2	Utility Side Water Loss Control	Both	3,110	9,330	10,918	13,060
D3	Commercial, Industrial, and Institutional (CII) Ordinances	Both	1,060	1,060	1,060	1,060
D4	Water Use Benchmarking and Budgeting	Both	-	5,950	11,670	25,230
D5	Landscape Transformation Ordinance	Both	-	3,040	7,430	15,050
D6	Landscape Transformation Incentive	Both	-	320	630	930
D7	Irrigation Efficiency Incentive	Both	40	210	430	390
D8	Lot Scale Stormwater Harvesting	Both	-	330	870	2,280
D9	Lot Scale Rainwater Harvesting	Both	-	1,550	4,030	9,250
D10	Lot Scale Graywater Harvesting	Both	-	2,130	5,620	12,670
D11	Lot/Building Scale Wastewater Reuse	Both	-	1,320	3,670	7,880
D12	Air Conditioning (AC) Condensate Reuse	Both	100	1,080	2,710	5,150
	Demand Management Strategies Sub-Total	-	4,910	30,200	54,810	102,320
	Water Supply Strategies					
S1	Aquifer Storage and Recovery	Drought	-	60,000	60,000	90,000
S2	Brackish Groundwater Desalination	Both	-	-	5,000	16,000
S3	Direct Non-Potable Reuse (Centralized Reclaimed Water System)	Both	500	12,000	25,000	54,600
S5a	Indirect Potable Reuse (IPR) through Lady Bird Lake	Drought	-	11,000	20,000	20,000
S5b	Capture Local Inflows to Lady Bird Lake (infrastructure also included as part of IPR, above)	Average	-	3,000	3,000	3,000
S7	Off Channel Reservoir	Both	-	-	25,000	25,000
S9	Distributed Wastewater Reuse	Both	-	3,150	14,470	30,050
S10	Sewer Mining	Both	-	1,000	2,210	5,280
S11	Community Scale Stormwater Harvesting	Both	-	160	240	500
	Drought Supply Strategies	-	-	71,000	80,000	110,000
	Average/Both Supply Strategies	-	500	19,310	74,910	134,440
	Water Supply Strategies Sub-Total	-	500	90,310	154,910	244,440
	Water Forward Recommend Strategies Overall Total		5,410	120,510	209,720	346,750
	Water Forward Recommended Implementation Strategies to Realize Estimated Yields Above					
	Phase 1 and 2: Water Use Benchmarking and Budgeting Ordinance					
	Phase 1 and 2: Alternative Water Ordinance					
	Expansion of Alternative Water Incentive					
	Phase 1 and 2: Dual Plumbing Ordinance Development					
	Ordinance to Expand Existing Centralized Reclaimed Water Connection Requirements					
	Current Supplies and Conservation					
	Colorado River and Highland Lakes Supply	Both	325,000			
	Drought Contingency Plan	Drought	Varies			
	Austin Water Conservation Programs*	Both	54,320			
	Centralized Reclaimed Water System	Both	3,960			

***Note:** Austin Water conservation program savings were estimated based on savings calculated during 2012-2015

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SECTION 2: INTRODUCTION

Central to Austin's economic vitality and high quality of life is a reliable, safe water supply. Currently, all the city's drinking water comes from the lower Colorado River system, which include Lakes Travis and Buchanan, the region's water supply reservoirs. In the future, the Colorado River system will likely experience climate change impacts, additional droughts, and future uncertainties. Coupled with rapid growth and economic development, these factors make future water planning more challenging than in the past.

Utilizing an adaptive management approach, this Integrated Water Resource Plan provides the essential strategic-level framework for Austin to meet these challenges and ensure a diversified, sustainable, and resilient water future, with a strong emphasis on water conservation.

The City of Austin (the City) is the capital of the State of Texas and is located in the central part of the state. Central Texas falls within a transitional climate zone characterized by hot, humid summers and mild winter temperatures, with an average annual precipitation of 34 inches. There are numerous lakes, rivers, and waterways in the Austin area. The core water body in the region is the Colorado River. Austin sits just east of the 98th meridian, a geographical dividing line that currently represents a divide between areas that get more than 30 inches of rain annually and less than 30 inches annually. With climate change there is scientific concern that the divide between areas getting more than 30 inches of rain annually and less than 30 inches annually is shifting to the east.

The most recent drought, which occurred from approximately 2008 to 2016, was a historic drought and a key driver for the development of this Integrated Water Resource Plan. During the drought, inflows of water and combined storage volumes in Lakes Travis and Buchanan were at historic lows. The Austin community and others throughout the river basin responded to calls for water conservation as a way to extend supplies while the region was gripped by severe drought.

In the future, potential climate change effects, as projected by global climate modeling, are expected to result in increasing average and maximum monthly temperatures and greater variability in precipitation—both of which will likely result in more frequent and longer-duration droughts[1]. With climate change it is also expected that wet periods will be more intense, meaning it is anticipated that overall, dry periods will be hotter and drier and wet periods will be wetter.

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- *Avoid severe water shortages during times of drought*
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- *Ensure Austin's water supply continues to meet/exceed all federal, state and local public health regulations*
- *Align with Imagine Austin's "Sustainably Manage Our Water Resources Priority Program"*
- *Maintain coordination and communication with regional partners*
- *Engage the public and stakeholders throughout the plan development process*

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[1] https://austintexas.gov/sites/default/files/files/Katherine_Hayhoe_Report_-_April_2014.pdf

During the recent historic drought, the City Council convened the Austin Water Resource Planning Task Force in April 2014 to evaluate the City's water needs, to examine and make recommendations regarding future water planning, and to evaluate potential water resource management scenarios for Council consideration. The Task Force was supported by Austin Water and the Watershed Protection Department. The Austin Water Resource Planning Task Force Task Force convened its first meeting on May 5, 2014 and met intensively through June 25, 2014 to execute their charge. The Task Force's findings and recommendations are included in their July 2014 report to Council.

One of the key recommendations of the Austin Water Resource Planning Task Force was the development of an integrated water resource plan to evaluate the City's water needs, to examine and make recommendations on future water planning, and to evaluate potential water-resource management scenarios for Council consideration. On December 11th, 2014, City council passed a resolution (Resolution No. 20141211-119[2]) to create the Austin Integrated Water Resource Planning Community Task Force (referred to as the Water Forward Task Force) to support the development of the integrated water resource plan.

As summarized in **Section 3**, throughout the collaborative and integrated Austin Water-led Water Forward effort, support for the integrated water resource plan development process was provided by the Water Forward Task Force, City staff from other departments—especially the Watershed Protection Department, Office of Sustainability, and Austin Energy—and outside consultant resources. Additionally, considerable input was received from our community through Water Forward public engagement efforts. The recommended plan is the culmination of a robust effort which will support Austin Water's continued commitment to providing clean, safe, reliable, and affordable water services to our customers.

2.1 Water Forward IWRP Mission Statement

Austin Water is an industry leader in the delivery of water, wastewater, and recycled or reclaimed water services. As such, the City is taking a proactive step in developing its Water Forward IWRP which provides a high-level strategy document intended to provide information to decision-makers regarding the tradeoffs of future water resource investments, with a long-range viewpoint through a 2115 planning horizon. The IWRP evaluates water supply and demand management options with consideration of multiple planning objectives, and was developed using an open, participatory planning process. To guide the Water Forward process, Austin Water, in collaboration with the Water Forward Task Force, established a mission statement for the IWRP, as follows:

- The Integrated Water Resource Plan will provide a mid- and long-term evaluation of, and plan for, water supply and demand management options for the City of Austin in a regional water supply context.
- Through public outreach and coordination of efforts between City departments and the Austin Integrated Water Resource Planning Community Task Force (Task Force), the IWRP offers a holistic and inclusive approach to water resource planning.
- The plan embraces an innovative and integrated water management process with the goal of ensuring a diversified, sustainable, and resilient water future, with strong emphasis on water conservation.

[2] http://www.austintexas.gov/edims/document.cfm?id=223726

2.2 Overview of Austin's Water Supply System

For more than 100 years, Austin Water has been committed to providing clean, safe, reliable, high quality, sustainable, and affordable water services to our customers. Austin Water consistently ranks among the best in the country with regard to water quality. Austin Water owns and operates three major water treatment plants (WTPs)—Albert H. Ullrich WTP, Albert R. Davis WTP, and Berl L. Handcox, Sr. WTP—with a combined treatment capacity of 335 million gallons per day (MGD). Austin Water's water distribution system has over 3,900 miles of pipe and 21 major pump stations that deliver water to 9 major pressure zones. Austin Water also operates two major wastewater treatment plants (WWTPs)— South Austin Regional WWTP and Walnut Creek WWTP—which discharge treated effluent into the Colorado River. The combined treatment capacity of these two WWTPs is 150 MGD. In addition, the utility operates multiple smaller wastewater treatment plants throughout the area.

All of Austin's drinking water comes from the lower Colorado River. The lower Colorado River is generally known as the section of the river downstream of Lakes O.H. Ivie and Brownwood down to the Gulf of Mexico. The lower Colorado is dammed several times upstream from Austin, forming the Highland Lakes. Two of the Highland Lakes, Lake Buchanan and Lake Travis, act as the region's water supply and flood control reservoirs.

Water from the Colorado River and the Highland Lakes is available to the City through a combination of state-granted run-of-river water rights and a water supply contract with the Lower Colorado River Authority (LCRA) for firm water, which is water that is expected to be available without shortage through a repeat of the drought of record. The water supply contract began in October 1999, when Austin entered into a key water supply agreement with LCRA. This agreement was an amendment to a previous 1987 agreement and provides firm backup (including stored water from Lakes Travis and Buchanan) for Austin's run-of-river rights and additional firm water totaling up to a combined amount of 325,000 acre-feet per year (AFY). Under the 1999 agreement, Austin prepaid $100 million for supply reservation and use fees. Future water use payments to LCRA will be triggered when the annual average use for two consecutive calendar years exceeds 201,000 AFY. The year after this trigger is reached, Austin will begin paying for water diversion amounts above 150,000 AFY. The term of the 1999 agreement extends through the year 2050 with an option for the City to renew the agreement for an additional 50-year period through the year 2100.

The drought of record in the Lower Colorado River Basin was the 1950's drought for many decades. However, the recent historic drought in this basin (from approximately 2008 to 2016), has become the new critical period for water supply availability determination. Therefore, efforts by the LCRA, through its Water Management Plan, and the Lower Colorado Regional Water Planning Group (Region K) are currently underway to update firm water supply estimates for the Lower Colorado River basin with consideration of the recent drought. As these processes, which city staff participate in, progress, additional information will become available to further quantify firm water supplies in the basin and evaluate the impact that the recent drought has had on firm water supplies.

Figure 2-1 illustrates the regional and local water supplies that currently provide drinking water for Austin. Lakes Travis and Buchanan, the region's flood control and water supply lakes, can be found upstream of Austin in the figure. These lakes are managed by the LCRA, as is the entire lower Colorado River system—from the watersheds flowing into Lake Buchanan, to Matagorda Bay on the Texas coast. Lake Travis is formed by Mansfield Dam and Lake Buchanan by Buchanan Dam. Lake Austin and Lady Bird Lake, which are smaller lakes downstream of Lake Travis, are created by Tom Miller Dam and Longhorn Dam, respectively. Lake Travis and Buchanan vary in lake level and stored water volume depending on the amount of rain, inflow, evaporation, and lake system management including releases of water from the dams. In contrast, Lake Austin and Lady Bird Lake are much smaller and are typically operated at a relatively constant level.

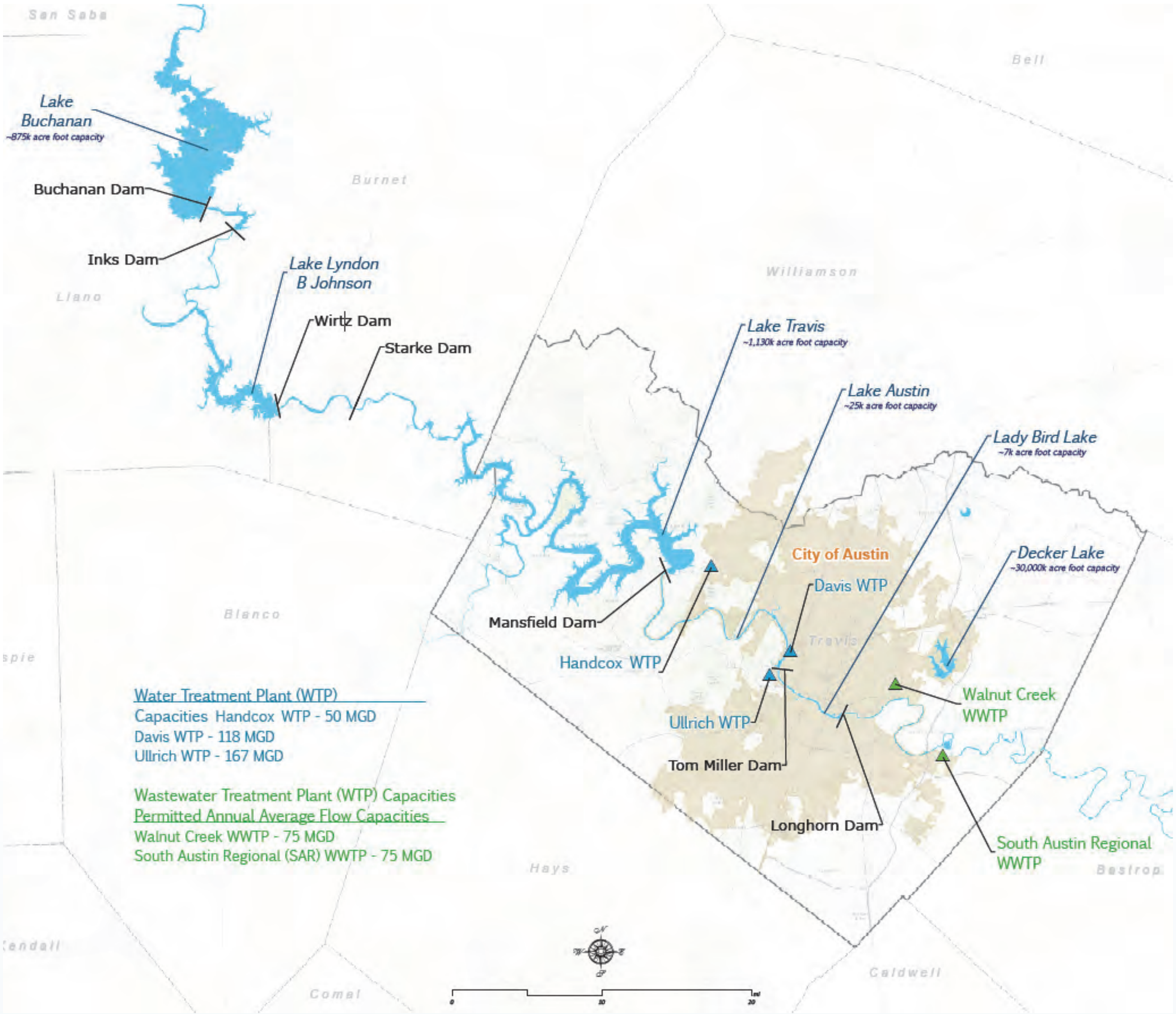

Figure 2-1. Regional and City water system

2.3 Water Supply Conditions and Drought

The availability of water under Austin's water rights and firm water supply contract with LCRA is generally dependent on rainfall, inflows to the storage reservoirs, and LCRA's management of the water stored in Lakes Travis and Buchanan. LCRA manages lakes Travis and Buchanan through a state-approved Water Management Plan, which was last updated in 2015. LCRA initiated another LCRA Water Management Plan update process in 2018.

The Austin area and the rest of Texas went through a historic drought from 2008 to 2016. During the drought the basin experienced the lowest annual inflows (i.e. water flowing into the lakes) since the late 1930's and early 1940's when the lakes were constructed. Prior to the recent historic drought, a drought that occurred in the 1950's was the drought benchmark for the Colorado River basin. Comparing the two droughts shows the greater severity of the recent drought, as the inflows from 2011 (the lowest annual inflow year from the recent drought) were 26% of the lowest annual inflows from the worst year from the 1950's drought. **Table 2-1** shows the lowest annual inflows on record, with years since 2006 highlighted in gray. Inflows from years occurring within the past 12 years make up eight of the top twelve lowest historical inflow years, including the top five.

Table 2-1. Top 12 lowest years of historical Inflows

Rank	Year	Annual Total in Acre-Feet
1	2011	127,802
2	2014	207,642
3	2013	215,138
4	2008	284,462
5	2006	285,229
6	1963	392,589
7	2012	393,163
8	2017	429,959
9	1983	433,312
10	1999	448,162
11	2009	499,732
12	1950	501,926
Average Annual Total from1942 to 2017= 1,208,616 AF		

In addition to **Table 2-1**, another useful comparison to understand the magnitude of the recent drought is to compare the cumulative historical inflows of the recent drought to the cumulative inflow of the 1950's drought, which was the worst recorded drought experienced by the basin prior to 2008 (referred to as the drought of record). For this cumulative inflow comparison, models are used to adjust historical inflows from the 1950's drought to approximate inflows as if the new upstream reservoirs had existed in the 1950's drought. These model-adjusted inflows are referred to as "reference inflows". **Figure 2-2** compares the cumulative historical inflow into lakes Travis and Buchanan for the recent hydrological drought from March 2008 - July 2016 to the cumulative "reference inflows" during the 1950's drought of record. While storm events in 2015 and the spring of 2016 significantly reduced the cumulative inflow difference, the total inflow since the beginning of the recent hydrological drought through June 2018 is still below that of the 1950s drought.

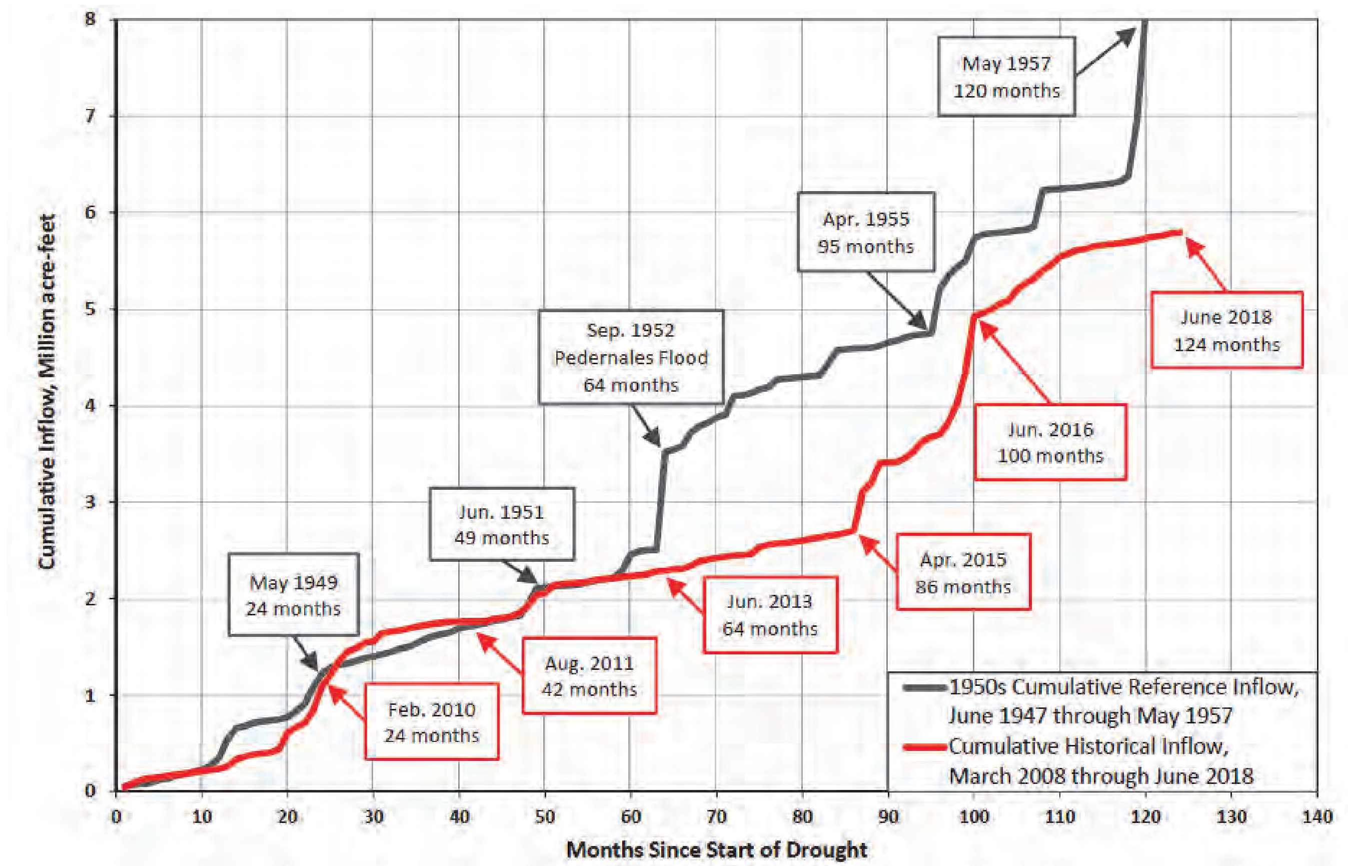

Figure 2-2. Cumulative inflows to Lakes Buchanan and Travis; 1950's versus recent drought

Storm events in 2015 and 2016 significantly increased combined storage of lakes Buchanan and Travis, reaching full levels in April 2016 for the first time since 2008. As shown in **Figure 2-2**, the combined stored water volume in Lakes Travis and Buchanan dropped to 637,123 acre-feet on September 19, 2013, which is 32% of the total combined storage volume. That amount is second only to the minimum in the 1947-1957 drought, which caused the lakes to drop to a record low of 621,221 acre-feet of total combined storage, which is 31% of full.

As can be seen in **Figure 2-3**, the Lower Colorado River Authority released large volumes of water from Lake Travis and Buchanan for downstream rice irrigation operations in the lower three counties in the Colorado River basin. In 2011, the Lower Colorado River Authority released 433,251 AF from Lakes Travis and Buchanan for agricultural irrigation. For comparison, that year, the City's municipal use, under its agreement with LCRA, was 168,334 AF, including 61,712 acre-feet diverted under Austin's water right from the Colorado River and 106,622 AF obtained from stored water in lakes Travis and Buchanan. Also, for comparison, in 2017, Austin used approximately 149,000 AF for municipal purposes. In 2011, an estimated 192,404 acre-feet evaporated from the six Highland Lakes (Buchanan, Inks, LBJ, Marble Falls, Travis, and Austin).

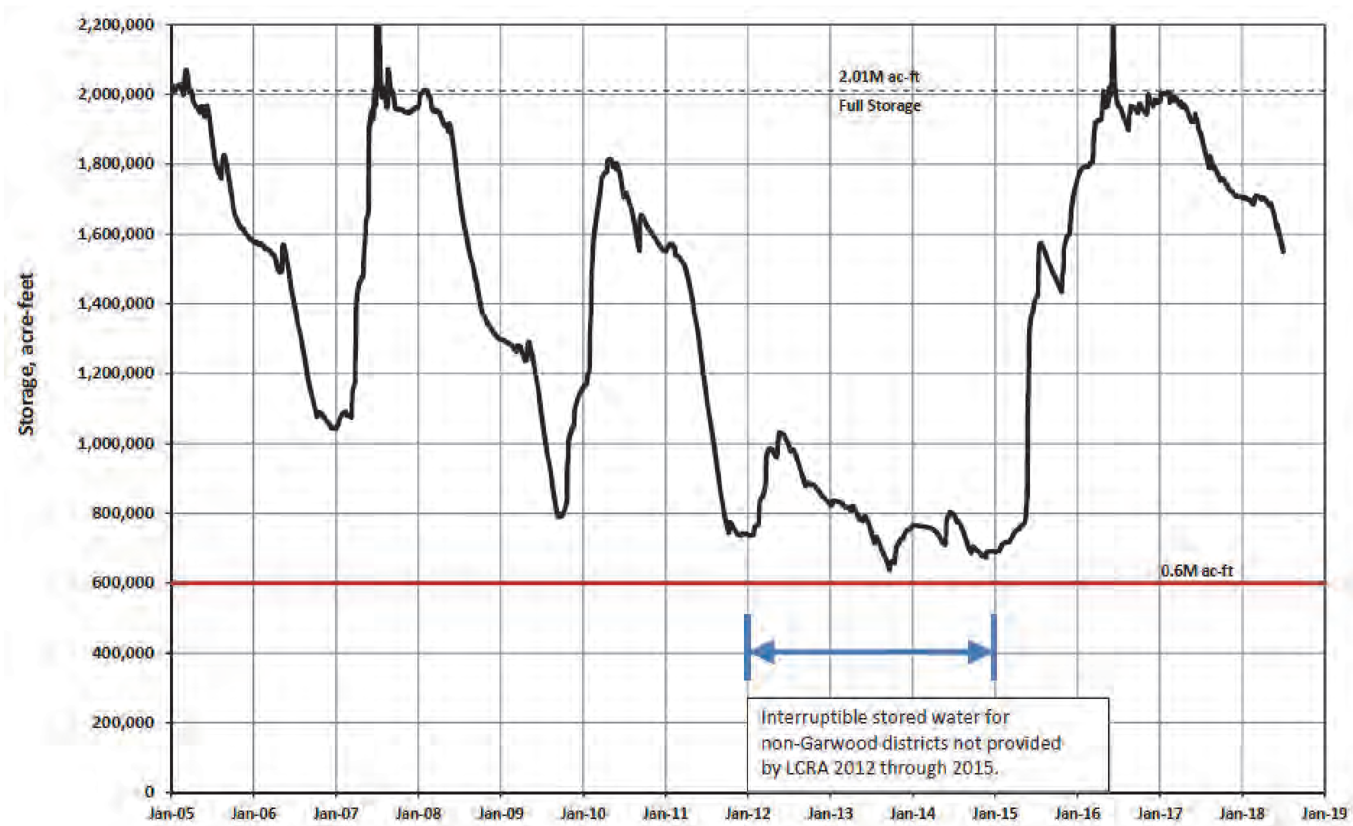

Figure 2-3. Combined storage of Lakes Buchanan and Travis from January 2005 - July 2018

After the large agricultural irrigation releases from lakes Buchanan and Travis in 2011, the Lower Colorado River Authority sought and received approval by the Texas Commission on Environmental Quality Emergency Orders for 2012, 2013, 2014, and 2015 to depart from operating under the Lower Colorado River Authority Water Management Plan that was in effect during that time. Concurrent with the drought and the Texas Commission on Environmental Quality emergency order process, LCRA's Water Management Plan was revised.

The Lower Colorado River Authority's operations and management of the water stored in lakes Travis and Buchanan is guided by the LCRA Water Management Plan, a document approved by the Texas Commission on Environmental Quality. In November 2015, Texas Commission on Environmental Quality approved an updated Water Management Plan that governed the Lower Colorado River Authority's operation of the lakes since the 2016 crop season which started in March. The updated plan better protects the water supply for firm customers, including City of Austin, and allows the Lower Colorado River Authority to more quickly adapt its operations as drought conditions change. Revisions include incorporating procedures for curtailing interruptible water such that combined storage in Lakes Travis and Buchanan is maintained above 600,000 AF through a repeat of historic hydrology through 2013. The revised plan also incorporates a three-tier regime that considers inflows, current storage, and modeled future storage conditions in determining water availability given to interruptible agricultural customers. Additionally, availability of interruptible stored water will be determined separately for each of the two crop seasons, rather than having the determination made once for both crop seasons, as was the case in the previous Water Management Plan. The revised Water Management Plan also places volumetric limits on interruptible stored water that may be released.

With more than a century of reliance and investment, Austin's core supply and infrastructure systems are centered on the Colorado River supply. Austin has senior water rights and firm water supply agreements with LCRA that provide Austin with firm water supplies of up to 325,000 AF per year. Therefore, protection of Colorado River system firm water interests is critical.

Throughout the drought, City of Austin representatives worked diligently through the critical LCRA Water Management Plan revision and Texas Commission on Environmental Quality Emergency Order processes to proactively ensure reservoir management of Lakes Travis and Buchanan is consistent with Austin's firm water interests and with LCRA's lake permit duties and firm customer agreements. LCRA is again revising its Water Management Plan. As part of the approval process for the 2015 LCRA Water Management Plan, a Texas Commission on Environmental Quality ordering provision specified that LCRA would begin an update process in January 2018. The basin naturalized hydrology has been extended through 2016. Austin is participating in this important process and will plan to participate in all future similar processes.

LCRA's Water Management Plan requires pro rata curtailment of 20% for firm water customers if the LCRA Board declares a Drought Worse than the Drought of Record. Preparation for potential implementation of pro rata curtailment in the recent historic drought included a process whereby firm customers, like Austin, could receive credit from LCRA for certain verified water savings from conservation efforts in determining pro rata allotments. The criteria for determining a Drought Worse than the Drought of Record are included in the LCRA Water Management Plan and involve drought duration, intensity, and storage volume (triggered at 600,000 acre-feet or 30% of capacity, a level the combined storage has never reached).

During the recent historic drought, a 2014 Austin Water Resource Planning Task Force was convened by the Austin City Council. This 2014 Task Force was charged with: (1) evaluating the city's water needs; (2) examining and making recommendations regarding future water planning; and (3) evaluating potential water resource management scenarios for council consideration. A key recommendation of the 2014 Task Force was the development of an Integrated Water Resources Plan (IWRP). Austin's Water Forward effort, which began in early 2015, is the process to develop the IWRP.

2.4 Sustainable Water Resource Management Efforts

Austin Water has a long history of sustainable water management. As outlined in **Section 6**, Austin's Water Conservation Program is recognized as an industry leader. Austin also has a reclaimed water system with a growing customer base. Austin Water consistently meets or exceeds state and federal requirements for water quality including drinking water quality standards and treated wastewater discharge standards.

Austin Water actively manages thousands of acres of land, including the Balcones Canyonlands Preserve and Water Quality Protection Lands. Through its Wildland Conservation Division, Austin Water manages approximately 28,000 acres of Water Quality Protection Lands and approximately 14,000 acres of Balcones Canyonland Preserve endangered species habitat land.

In 2017 Austin joined the Water Utility Climate Alliance, a leader in the sustainable water resource management field and currently in its tenth year. The Water Utility Climate Alliance provides a forum for utilities to exchange experiences about climate challenges how utilities are working to meet those challenges. Austin Water is a member of the US Water Alliance, which hosts an annual One Water Summit, which provides a forum for exploring sustainable water. The Austin Delegation participated in the One Water Summit in New Orleans, Louisiana in 2017 and in the Twin Cities, Minnesota in 2018. Through internal staff efforts, coordination with other City departments, development of the Water Forward integrated water resource plan, and participation with various organizations, Austin Water explores on-site, centralized, and decentralized use of alternative water sources, innovative water strategies, and concepts like net zero and net blue on an ongoing basis.

Austin’s Watershed Protection Department has a long history of water quality protection and sustainable water resource management through reducing the impact of flood, erosion, and water pollution. Watershed Protection has been leading efforts to develop green stormwater infrastructure projects, guidance, and proposed ordinance requirements. These efforts have been coordinated with Austin Water and others to explore opportunities to gain multiple beneficial uses of stormwater management strategies. These ongoing efforts are in harmony with Imagine Austin, which includes comprehensive guidance on sustainable management of Austin’s water resources. Imagine Austin encourages use of green infrastructure to protect environmentally sensitive areas and integrate nature into the city.

Both Austin Water and Watershed Protection Department co-lead Imagine Austin’s Sustainably Manage Our Water Resource Priority Program. Through these efforts, Austin Water and Watershed Protection Department coordinate on water resource management efforts from the local to regional scale. The work of this priority program has supported efforts to respond to challenges posed by a changing climate, major flooding, drought, population growth, and other factors that require adaptation and increased planning and coordination. Strengthened communication and coordination between Austin Water, Watershed Protection, and other partner departments over the past six years has been beneficial since the adoption of Imagine Austin in 2012 and its creation of the priority program. More information on Imagine Austin’s Sustainable Manage Our Water Response Priority Program can be found at https://www.austintexas.gov/page/sustainablewater.

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SECTION 3: COLLABORATIVE PLAN DEVELOPMENT PROCESS

Water Forward is an integrated water resources planning process used to evaluate potential water supply and demand management options and develop a plan that is representative of Austin community values. This section describes the overall Water Forward process from development of objectives and performance measures, to option screening and characterization, through to portfolio development and evaluation. This section also summarizes the outcome of efforts to gather meaningful public input to inform each stage of the plan development process.

AT A GLANCE

- *Task Force Involvement*
- *Project Scoping and Team*
- *Public Engagement*
- *Evaluation Process Overview*
- *Plan Objectives and Performance Measures*
- *Options Screening and Characterization*
- *Portfolio Development and Evaluation*

3.1 Task Force Involvement

In 2014, the Austin Water Resource Planning Task Force was convened during the height of the 2008 to 2016 drought and tasked with analyzing the City's water needs and making recommendations on how to augment the City's future water supply (see Resolution No. 20140410-033). On July 10, 2014, the Austin Water Resources Planning Task Force presented their recommendations to the Austin City Council which included recommendations on demand management and water supply strategies. This IWRP was a foremost recommendation of the 2014 Austin Water Resource Planning Task Force.

The Austin Integrated Water Resources Planning Community Task Force was created to support the development of the IWRP (see Resolution No. 20141211-119). The Mayor and Council-appointed Task Force members are shown below:

- Sharlene Leurig (Chair)
  District 4 - Council Member Casar
- Jennifer Walker (Vice-Chair)
  District 9 - Mayor Pro Tem Tovo
- Bill Moriarty
  Mayor Adler
- Clint Dawson
  District 1 - Council Member Houston
- Sarah Richards
  District 2 - Council Member Garza
- Perry Lorenz
  District 3 - Council Member Renteria
- Lauren Ross
  District 5 - Council Member Kitchen
- Todd Bartee
  District 6 - Council Member Flannigan
- Robert Mace
  District 7 - Council Member Pool
- Marianne Dwight
  District 8 - Council Member Troxclair
- Diane Kennedy
  District 10 - Council Member Alter

The Task Force also included Ex Officio members from several City of Austin departments.

- **Austin Water**
  Greg Meszaros, Director
- **Austin Energy**
  Kathleen Garrett, Director of Environmental Services
- **Austin Resource Recovery**
  Tony Davee, Project Manager
- **Neighborhood Housing and Community Development**
  Josh Rudow, Planner Senior
- **Office of Innovation**
  Kerry O'Connor, Chief Innovation Officer
- **Office of Sustainability**
  Lucia Athens, Chief Sustainability Officer
- **Parks and Recreation**
  Sara Hensley, Interim Assistant City Manager
- **Watershed Protection**
  Chris Herrington, Supervising Engineer

The Task Force played an instrumental role in shaping the development of the Water Forward Process, providing input along the way to shape the planning process and recommendations that are included in the plan. Task Force meetings were generally held on a monthly basis from May 2015 through October 2018. To view agendas, approved minutes and supporting documents, please visit: http://austintexas.gov/cityclerk/boards_commissions/meetings/132_1.htm.

3.2 Project Scoping and Team

Austin Water, with input from the Water Forward Task Force, conducted extensive research in developing the scope of work for the plan's development. Additionally, through monthly Water Forward Task Force meetings, among many other relevant topics, information from other cities involved in similar processes was presented and discussed. Additional preparation work included conducting a Water Conservation Study[3] through the Office of Sustainability.

After this groundwork had been laid and the scope of work had been developed, the City conducted a Request for Qualifications-based procurement process for selecting a consulting firm team to support development of the plan. The CDM Smith team, including a number of sub-consultants, was selected through this process as the main consultant team. CDM Smith has direct experience in developing integrated water resource plans for large municipalities, including the Los Angeles Integrated Resources Plan and Long-Range Water Resources Plan for the San Diego Public Utilities Department. CDM Smith's team included GHD, a firm based in Australia with experience in developing the City of Sydney Decentralized Water Master Plan and Development of an Alternative Water Atlas across Melbourne.

In addition to the main consultant team for the IWRP development, Austin Water contracted with Climate Scientist Dr. Katharine Hayhoe (ATMOS Research and Consulting) to develop forecast data to incorporate planning for climate change impacts on basin hydrology into the IWRP. Dr. Hayhoe is a professor in the Department of Political Science and Director of the Climate Science Center at Texas Tech University and a well-known authority on climate change. Consultant resources for the plan development also includes Consulting Hydrologist Dr. Richard Hoffpauir, P.E. (Hoffpauir Consulting) to perform river system water

[3] Water Conservation Study, September 30, 2015, prepared by Maddaus Water Management, Inc, for City of Austin, Office of Sustainability, and Austin Water Utility. Posted in Austin Integrated Water Resource Planning Community Task Force regular meeting materials from October 6, 2015: http://www.austintexas.gov/edims/document.cfm?id=240290

availability modeling (WAM) analyses to evaluate water supply needs and supply and demand management portfolios. Dr. Hoffpauir is considered an expert in WAM modeling. These consultant resource teams worked in collaboration with Austin Water staff and made numerous presentations to the Water Forward Task Force.

In addition to the consulting team, numerous city staff members were involved in developing the plan and information that supported plan development. Austin Water staff led the effort with support from staff from Watershed Protection Department, Austin Energy, Office of Sustainability, and others.

3.3 Public Engagement

Public outreach and education efforts for the IWRP gathered meaningful public input used to develop a plan that is representative of Austin community values. Information on how input was used at key decision points is included in subsequent portions of this section. Water Forward's public involvement sought to address the following core goals, which were identified in the initial Water Forward Public Outreach Framework (see **Appendix A** for more details):

- **Community Values** – Identify community values that should be reflected in the IWRP.
- **Diverse Public Input** – Seek input from the community which reflect the diversity of Austin's population and customers.
- **Public Education** – Inform and educate the community throughout the plan development process.

Since 2016, Austin Water has collected public input through over 80 outreach events, including five Water Forward Public Workshops, four Targeted Stakeholder Meetings, and 10 Summer Series events (one in each City Council district). Austin Water has delivered presentations and/or outreach materials at more than 60 community events, information sharing sessions, community group meetings, seminars/professional events, and district town halls. The input received has been considered throughout the process of developing the plan and preparing the Water Forward Plan Recommendations.

A summary of all 80 outreach activities and more detailed information on public outreach efforts is included in **Appendix A**. A map showing the location of outreach activities through May 2018 is presented in **Figure 3-1**.

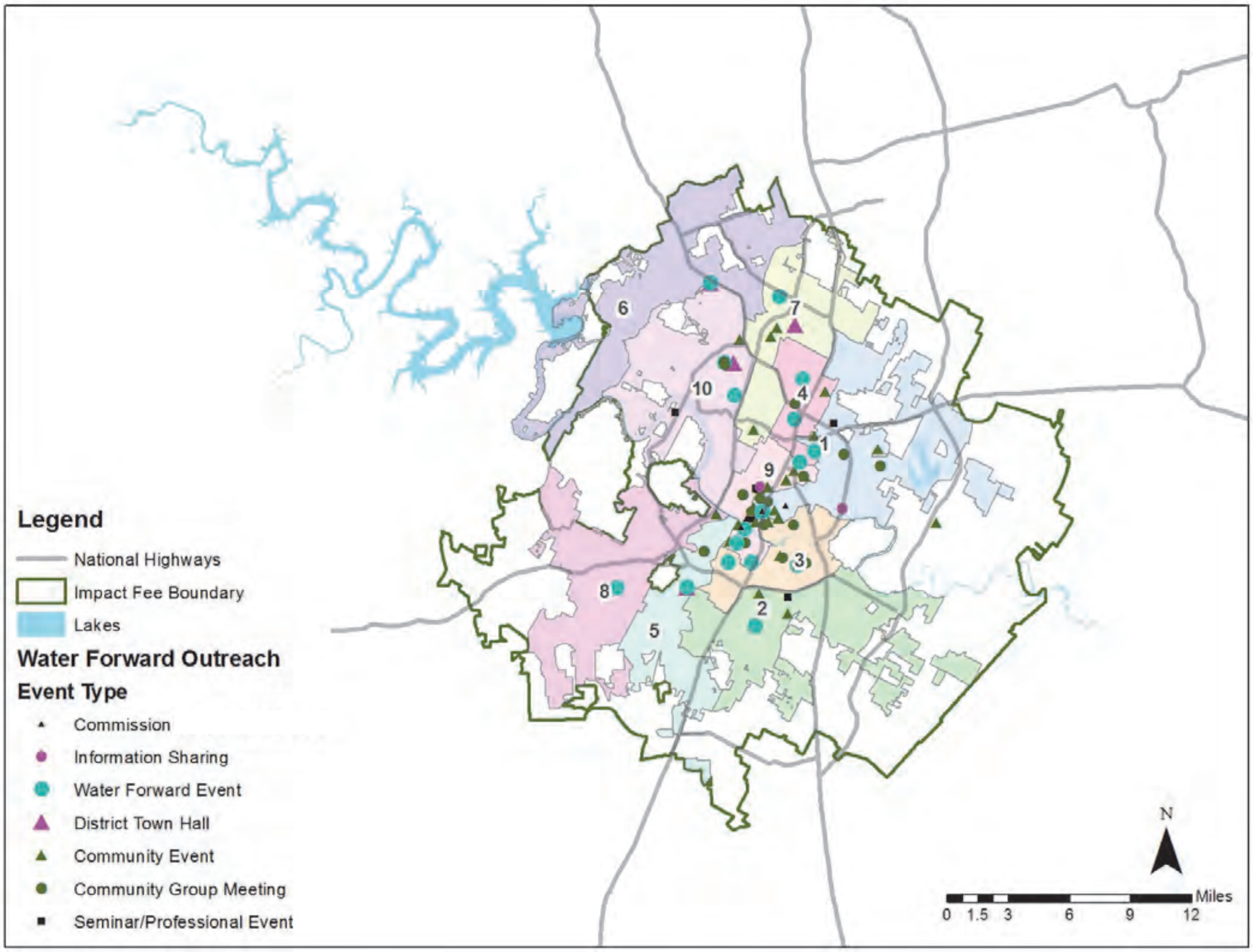

Figure 3-1. Map of outreach activities through May 2018

3.4 Evaluation Process Overview

The IWRP evaluation process was based on a planning process that explored both demand-side and supply-side options in an integrated manner in order to meet multiple objectives. The evaluation process also explored risks and uncertainty related to drought and different potential hydrologic and climatic futures over the next 100 years. The following section provides an overview of the planning process. A comprehensive description can be found in **Appendix B.** Integrated Water Resources Planning terminology is provided in **Figure 3-2**.

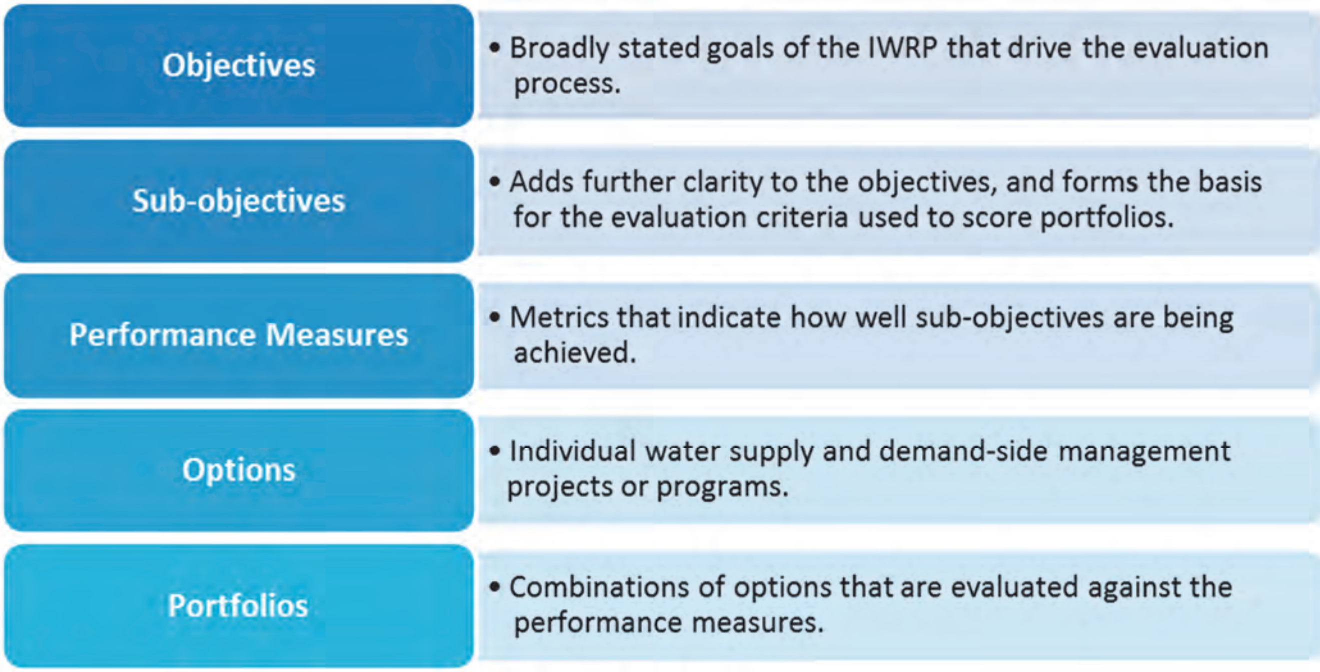

Figure 3-2. Integrated water resource planning terminology

The Water Forward process is summarized in **Figure 3-3**. The process began with defining the objectives, sub-objectives, and performance measures. The sub-objectives together with the performance measures served as the evaluation criteria which Water Forward portfolios were measured against.

The process continued with identification and characterization of various water supply and demand management options. Initially a large number of options were considered. This “blue-sky” list was screened down to a smaller number using a set of criteria. Those options that passed the screening process were characterized, meaning that they were further analyzed to develop more detailed cost, yield, and other information about each option.

In order to meet the goals of the IWRP process, including ensuring long-term resiliency, supply diversification, and sustainability in meeting the identified needs, groupings of options called portfolios were developed and evaluated.

Each portfolio was evaluated in terms of how well it achieved the defined objectives, including under various hydrologic conditions (for example, historical hydrology and climate change scenarios). The initially developed portfolios were scored and ranked, and then additional hybrid portfolios were developed based on what was learned during the initial scoring. The aim of the hybrid portfolios was to improve upon the ability to meet the stated objectives. Following final scoring, a preferred strategy was recommended for implementation. The preferred strategy was a combination of components from several high-ranking portfolios using an adaptive management approach that could implement various options within the portfolios based on triggers, such as demand growth, hydrologic conditions, and other factors.

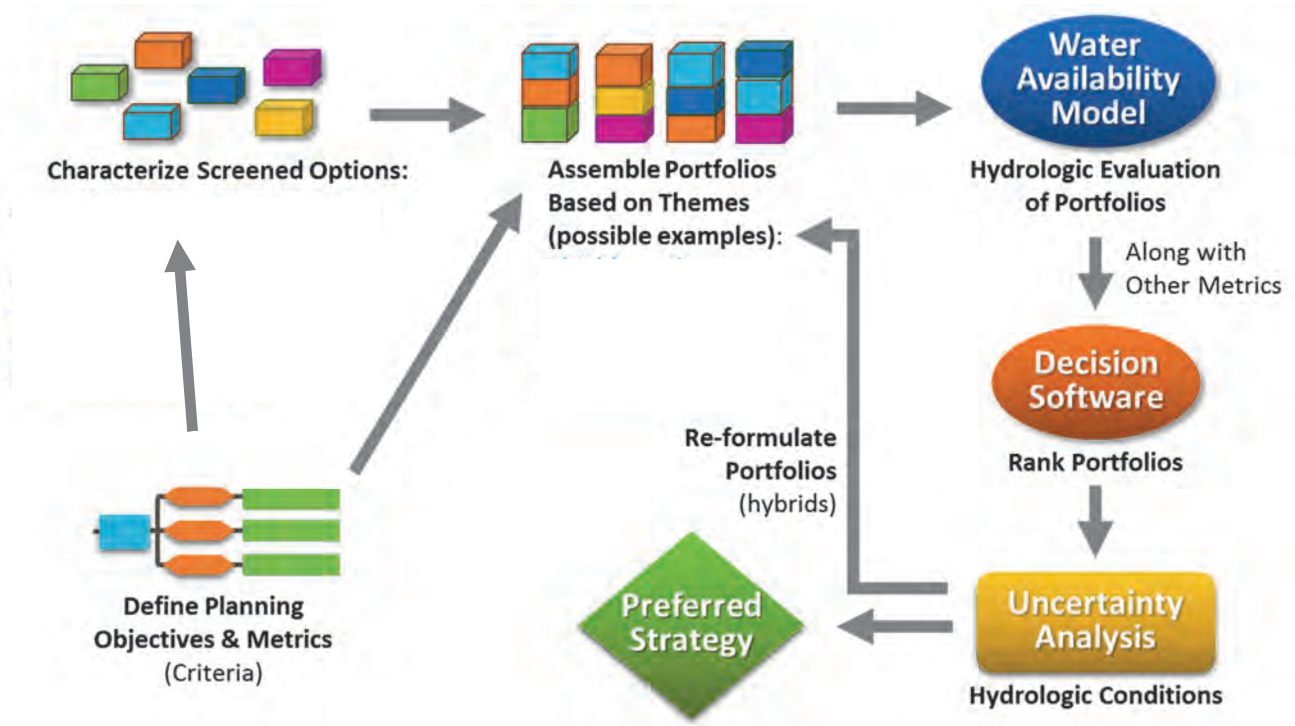

Figure 3-3. IWRP planning process

3.5 Plan Objectives and Performance Measures

The planning objectives serve as the framework for how the Water Forward Plan is developed. Objectives are usually categorized as either primary or secondary (sub-objectives). Primary objectives are more general, while sub-objectives help define the primary objectives in more specific terms. Sub-objectives should have the following attributes:

- **Distinctive:** to distinguish between one portfolio and another
- **Measurable:** to determine if they are being achieved, either through quantitative or qualitative metrics
- **Non-Redundant:** to avoid overlap and avoid bias in ranking the portfolios
- **Understandable:** to be easily explainable and clear
- **Concise:** to focus on what is most important in decision-making

The IWRP objectives and sub-objectives were developed by Austin Water with input from the Task Force. The objectives were formulated based on the previous 2014 Task Force and centered on principles of sustainability (balanced between economic, environmental, social needs). Initial sub-objectives were formulated with a "defining question" to establish the intent of the sub-objective.

For each sub-objective, a performance measure was developed. The performance measure was used to indicate how well a sub-objective is being achieved. Where possible, quantitative performance measures were established based on a review of available data and anticipated output from the various IWRP analyses, tools, and modeling efforts. In certain instances, a qualitative score was determined to be the most suitable performance measure. **Table 3-2** presents the final list of primary objectives, sub-objectives, defining questions, and performance measures.

In any decision-making process, primary objectives are generally not all equally important. Thus, developing a set of weights is necessary to better reflect the difference in values and preferences among the various objectives. **Table 3-1** shows the final weights given to each objective and sub-objective as determined by Austin Water and the consultant team with input from the Water Forward Task Force.

Outreach Highlight: Public Workshop #1
Overview of IWRP and Objectives

Public input from the first Water Forward Public Workshop (held September 2016) informed the development of objectives and sub-objectives. Key feedback from this workshop included a desire to plan for future water supply reliability while maintaining affordability and continuing the community's focus on conservation.

Table 3-1. Objective and sub-objective weights

Primary Objective	Objective Weight	Sub-Objective	Sub-Objective Weight
Water Supply Benefits	35%	Minimize Vulnerability	28%
		Maximize Reliability	7%
Economic Benefits	20%	Maximize Cost-Effectiveness	15%
		Maximize Advantageous External Funding	5%
Environmental Benefits	20%	Minimize Ecosystem Impacts	8%
		Minimize Net Energy Use	6%
		Maximize Water Use Efficiency	6%
Social Benefits	13%	Maximize Multi-Benefit Infrastructure/Programs	5%
		Maximize Net Benefits to Local Economy	4%
		Maximize Social Equity and Environmental Justice	4%
Implementation Benefits	12%	Minimize Risk	7%
		Maximize Local Control / Local Resource	5%
TOTAL	100%	**TOTAL**	100%

Table 3-2. Objectives, sub-objectives, defining questions, and performance measures

Primary Objective	Sub-Objective	Defining Question	Performance Measure
Water Supply Benefits	Minimize Vulnerability	How much of the water needs[1] identified in the IWRP are met during 12-months of worst-case drought? Vulnerability describes the magnitude of shortages relative to defined water needs, if shortages occur.	Geometric mean of model results from different hydrologic scenarios. Percent of volume of water needs[1] met during worst 12-months of drought under various hydrologic scenarios.
	Maximize Reliability	How many months are water needs[1] identified in the IWRP fully met during the period of simulation? Reliability describes the frequency of shortages relative to defined water needs, if shortages occur.	Geometric mean of model results from different hydrologic scenarios. Percent of time water needs[1] were met during the period of record for various hydrologic scenarios.
Economic Benefits	Maximize Cost-Effectiveness	What is the total capital (construction) and operations/maintenance costs of all projects/programs in the portfolio over the lifecycle, divided by the sum of all water yield produced by the portfolio?	Unit cost ($/AF) expressed as a present value sum of all costs over the lifecycle, including utility and customer costs.
	Maximize Advantageous External Funding	Does the portfolio have an opportunity for advantageous external funding from Federal, State, local, and private sources?	External Funding Score (1-5), where 1 = low potential and 5 = high potential
Environmental Benefits	Minimize Ecosystem Impacts	To what extent does the portfolio positively or negatively impact receiving water quality (e.g., streams, river, lakes), terrestrial and aquatic habitats throughout Austin, and net streamflow effects both upstream and downstream from Austin?	Ecosystem Impact Score (1-5), where 1 = high combined negative impacts and 5 = high combined positive impacts
	Minimize Net Energy Use	What is the net energy requirement of the portfolio, considering energy generation?	Incremental net change in kWh
	Maximize Water Use Efficiency	What is the reduction in potable water use from water conservation, reuse and rainwater capture for the portfolio?	Potable per capita water use (gallon/person/day)
Social Benefits	Maximize Multi-Benefit Infrastructure/Programs	To what extent does the portfolio provide secondary benefits such as enhanced community livability/beautification, increased water ethic, ecosystem services, or others?	Multiple Benefits Score (1-5), where 1 = low benefits and 5 = high benefits
	Maximize Net Benefits to Local Economy	To what extent do the supply reliability and water investments of the portfolio protect and improve local economic vitality, including permanent job creation?	Local Economy Score (1-5), where 1 = high negative impact and 5 = high positive impact
	Maximize Social Equity and Environmental Justice	To what extent does the portfolio support social equity and environmental justice, with emphasis on underserved communities?	Social Equity and Environmental Justice Score (1-5), where 1 = significant support and 5 = minimal support
Implementation Benefits	Minimize Risk	How significant are the major risks and uncertainties associated with implementation of projects?	Qualitative score (1-5), where 1=more water supply provided from high risk projects and 5 = less supply provided from high risk projects.
	Maximize Local Control/Local Resource	To what extent does Austin Water control operations of the water resource and is the resource from the local area?	Qualitative score (1-5), where 1=less water under Austin Water's control and from local water sources 5=more water under Austin Water's control and from local water sources.

[1] Water needs identified in the IWRP are referred to as Type 1, 2, and 3 Needs. These needs are described in Section 5 and quantified in Section 8

Outreach Highlight: Targeted Stakeholder Meetings
Demand Management Options

In January 2017, Austin Water hosted a series of three Targeted Stakeholder Meetings. Input from landscape and irrigation professionals, representatives of environmental interest groups, and various professional groups informed refinement of demand management options that were selected for screening.

The combination of the Economic, Environmental, and Social benefits categories comprises the triple bottom line of sustainability. The City of Austin's official definition of sustainability is finding a balance among three sets of goals: 1) prosperity and jobs, 2) conservation and the environment, and 3) community health, equity, and cultural vitality. It means taking positive, proactive steps to protect Austin's quality of life now and for future generations.

3.6 Options Screening and Characterization

Prior to developing portfolios for detailed evaluation, it was important to evaluate individual supply and demand management options to allow for more informed portfolio development and ultimately portfolios that are better suited to meet overall Water Forward objectives. To do this, two key steps were required: options screening and a standardized options characterization process.

3.6.1 Options Screening Method

The blue-sky list of options went through an initial process of combining similar options to create a total of 21 water supply options and 25 demand management options. These were identified for screening by Austin Water. Through a screening process described in more detail below, these 46 options were narrowed down to a total of 13 supply and 12 demand management options that were carried forward for further characterization. The list of options identified for screening fell under the following main categories:

- Water Conservation Options
- Lot-scale Decentralized Options (e.g., rainwater harvesting, stormwater harvesting, graywater reuse, blackwater reuse, or air conditioner (A/C) condensate reuse)
- Centralized and Community-Scale Decentralized Wastewater Reuse Options
- Storage Options (e.g., Aquifer Storage and Recovery or a New Off-Channel Reservoir)
- New Supply Options (e.g., desalination of brackish groundwater)

Outreach Highlight: Public Workshops 2 & 3
Future Water Supply Needs and Strategies to Meet Them

In February and April 2017, Austin Water hosted two public workshops to learn more about community perspectives on potential demand management and supply options. Dot exercises at the workshop allowed participants to indicate options they did or didn't prefer. Feedback from these workshops and from the online surveys posted after the workshops informed the screening of options.

The screening process compared a high-level, order-of-magnitude unit cost of the options to a performance score (combining implementation challenges and hydrologic resiliency) created specifically for option screening. All of the options were then plotted by these two parameters to see where outliers existed. The highest performing options were recommended to move forward for more detailed characterization. More detail about the screening process can be found in **Appendix H** for demand management options and in **Appendix I** for water supply options.

3.6.2 Options Characterization Process

For options carried forward from screening to portfolio evaluation, a summary characterization was developed using a standardized *Options Characterization Template*. During characterization, potential yields were estimated along with capital costs and annual operational costs. Option characterizations were based on the best available technical information; however, more detailed analysis of options will be required prior to implementation. The final set of option characterization sheets can be found in **Appendix J**.

3.7 Portfolio Development and Evaluation

Portfolio development and evaluation was a core part of the integrated water resource plan development process used in the Water Forward planning effort. The portfolio development process created different groupings of options that were composed to meet the identified needs. The options that were grouped together to make each portfolio were in addition to the core water resource strategies including Austin's Colorado River water supply, water savings from the existing water conservation program, and the existing reclaimed water program. This integrated water resource plan approach allows for evaluation of the different portfolios to see how well the sets of new options could come together to develop a plan with diversified strategies. Adding strategies to Austin's water supply and demand management portfolio would strengthen Austin's supply diversification, which aligns with the plan's guiding principles. Benefits of diversification include increased resiliency, strengthening of reliability, and increased preparedness for managing risks associated with future uncertainties.

Options that had been characterized were selected to develop initial Water Forward portfolios. Water supply and demand management options were combined into portfolios that meet the identified water supply needs and targets under different hydrologic scenarios to various degrees of reliability.

Portfolios were developed based on themes (as described in **Section 3.7.2**) important to Austin's community, identified as part of the Water Forward public outreach process. These portfolios were then evaluated against the IWRP sub-objectives using the previously defined performance measures. The IWRP analyses were conducted for the forecast years 2020, 2040, 2070, and 2115, and portfolios were compared and ranked using combined scores factoring in the different forecast years. The planning horizons of 2020, 2040, 2070, and 2115 were selected to provide a range of near to long-term planning horizons to take a snapshot of future projected conditions to plan for. The goal of the process was to develop a 100-year integrated water plan for Austin. As such, 2115 became the most distant planning horizon. To roughly represent a 50-year planning horizon, and sync with the furthest out planning horizon currently used in the

Outreach Highlight: Summer Series and Community Values Survey

During the summer of 2017, Austin Water hosted ten Summer Series meetings (one in each Council District) to gather input on themes to be used to develop initial portfolios. The emerging themes that were discussed in the Summer Series meetings had been identified from Community Values Surveys that Austin Water collected at in-person outreach events and online. Summer Series input informed the final selection of initial portfolio themes.

Texas Water Development Board-administered regional water planning process, 2070 was selected as the next planning horizon. Years 2020 and 2040 (roughly 20 years out) represent two relatively near-term time horizons that frame the near-term steps to be taken to achieve plan goals.

3.7.1 Preliminary Water Needs Assessment

A fundamental objective for the IWRP is that identified future water needs for Austin Water are reliably met. For the purposes of portfolio development, three types of water needs were established: (1) new conservation and/or supply to manage risk associated with drought conditions triggering prolonged prohibition on outdoor water use; (2) new supply to manage risk associated with extremely low Highland Lake levels; and (3) new conservation and/or supply to provide for Austin water demands above the current Lower Colorado River Authority contract of 325,000 AFY.

Section 5.1 includes definitions of the preliminary water needs and how they relate to drought conditions. **Section 8.1** contains estimates of the need amounts using baseline demand conditions before portfolio options are applied and using water availability model hydrologic scenario B (period of record with projected climate change effects). **Appendix F** also includes a more detailed description of the types of water needs identified in the planning process.

3.7.2 Method for Formulation of Portfolios

In order to meet the goals of the IWRP process, including ensuring long-term resiliency, supply diversification, and sustainability in meeting the identified needs (described in **Section 3.7.1**), groupings of options called portfolios were developed and evaluated. Portfolios are developed around major themes that align with the IWRP objectives. By developing these initial portfolios that “push” the limits of achieving each of the most important objectives, trade-offs can be identified in developing “hybrid” portfolios that are more balanced and have a better likelihood of meeting numerous objectives.

Initial portfolio themes included:

- **Minimize Cost:** Options with the lowest unit costs ($/acre-foot/year) were generally selected.
- **Maximize Conservation:** Options that conserve water and maximize the reuse of treated wastewater and stormwater were generally selected.
- **Maximize Reliability:** Options that provide higher supply reliability and resiliency in terms of climate and hydrology were generally selected.
- **Maximize Ease of Implementation:** Options that have a higher degree of potential implementation success were generally selected.
- **Maximize Local Control:** Options in which Austin Water would have control over the projects and the water supplies in terms of cost, yield, development, and operations were generally selected.

3.7.3 Portfolio Evaluation Method

When evaluating a diverse set of portfolios against multiple objectives it is typically difficult to find a single portfolio that meets the needs or priorities of every stakeholder. Instead, the goal is to evaluate trade-offs between options and objectives, which will be used make an informed decision in selecting a preferred portfolio. To do this, the Water Forward process uses multi-criteria decision analysis to evaluate portfolios.

The multi-criteria decision analysis process relies on the performance measures and performance weights (outlined in previous sections) and a suite of computer-based tools. However, it is important to note that the plan recommendations are based on human judgement, not just computer model output. The computer model results helped inform the process of developing plan recommendations.

3.7.3.1 Overview of IWRP Tools

The multi-criteria decision analysis process for evaluating portfolios was dependent upon output from other models and tools, as well as input from participants and subject-matter experts. Each portfolio underwent modeling and assessment that generated raw quantitative and qualitative performance measure scores. **Figure 3-4** shows the portfolio evaluation workflow of IWRP tools. The models and tools used for the Water Forward process are briefly described below:

- **Colorado Basin Water Availability Model (WAM)** – This is a customized version of the computer-based simulation model, originally developed and used by the Texas Commission on Environmental Quality, quantifying the amount of water that would be flowing in the Colorado River and available to meet water rights under a specified set of conditions (e.g. water use, naturalized hydrology, etc.).

- **Disaggregated Demand Forecasting Model** – This is a water demand forecast model that projects demands geospatially by sector (e.g., single-family residential, multi-family, and commercial) and by end uses (e.g., toilet flushing, showers, landscaping, industrial process). The demand model also includes functionality to evaluate impacts of water conservation, weather and climate, and price of water.

- **Geospatial Decentralized Supply Suite of Tools** – These represent a set of geospatial analysis tools which incorporates the end uses of water demands by sector, and evaluates the potential demand met by alternative water options, cost, and avoided costs associated with stormwater and rainwater capture, graywater reuse, and blackwater reuse.

- **Portfolio Evaluation Spreadsheet Tool** – This spreadsheet tool was utilized to assemble options into portfolios based on supply needs and targets (difference between existing supplies and future demands and targets under different hydrologic scenarios); and also, was used to estimate total portfolio costs from individual unit costs for each option.

- **Criterium Decision Plus** – This is an industry-leading commercial multi-criteria decision analysis software to compare and score portfolios (see below for detailed description).

3.7.3.2 Description of Criterium Decision Plus Software

Criterium Decision Plus was used to rank portfolios. This software tool converts raw performance measures for each sub-objective, which each have different measurement units, into standardized scores so that the performance measures can be summarized into an overall value. Through Criterium Decision Plus, a multi-attribute rating technique is applied to score and rank the selected portfolios. **Figure 3-4** summarizes the multi-attribute rating technique that is used by Criterium Decision Plus to compare and score portfolios. The figure represents a generic scoring example and is meant as an illustration of the approach.

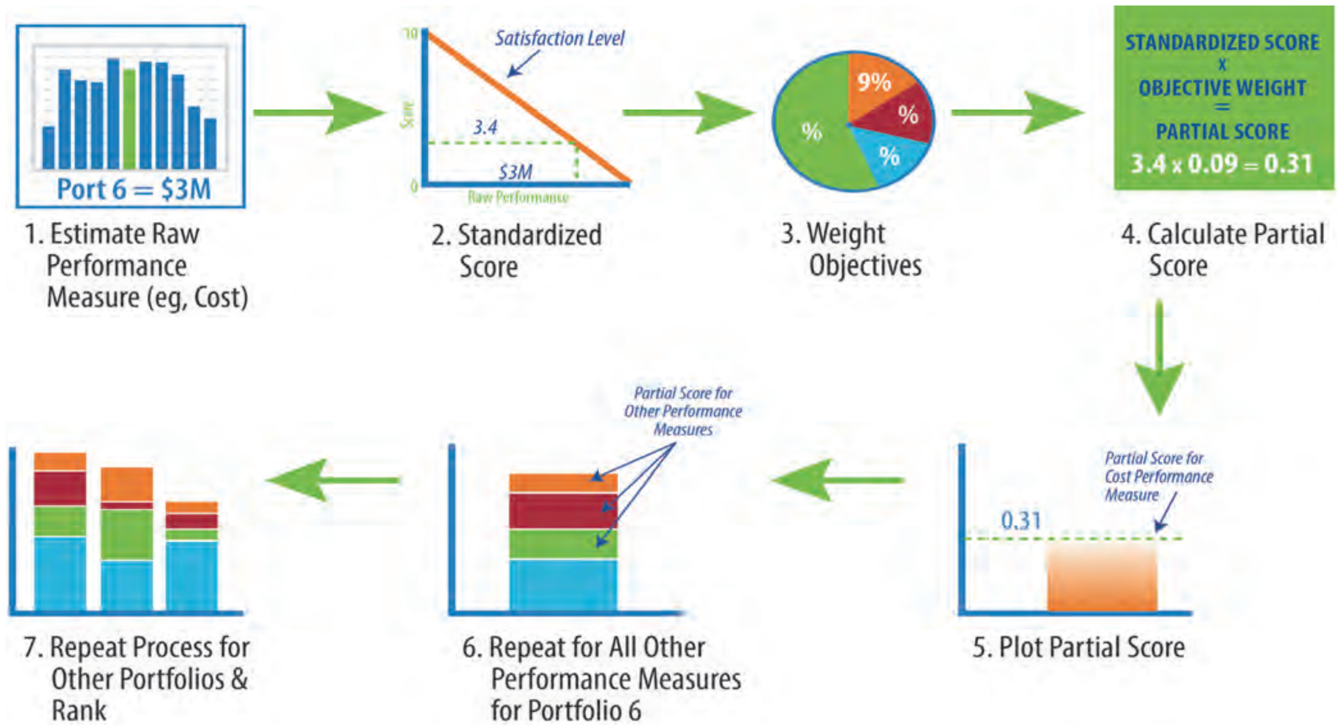

Figure 3-4. Multi-attribute rating technique used by Criterium Decision Plus software to score portfolios

Multi-attribute rating uses seven steps to score and rank portfolios. In step 1, raw performance for all the portfolios is compared for a given criterion (for example, cost). Step 2 standardizes the performance into a score from 0 to 10. In this example, Portfolio 6's cost performance is fairly expensive, so its standardized score is fairly low (e.g., 3.4 out of 10). This step is important because performance is measured in different units (i.e., cost in dollars, energy in kWh). Step 3 assigns weights to the objective and Step 4 calculates a partial score for a given portfolio based on the multiplication of the standardized score (Step 2) and weight (Step 3). The partial score is plotted (Step 5), and then the whole process is repeated for a given portfolio for all the other performance measures (Step 6). This creates a total score that can then be compared to other portfolios. Steps 1-6 are repeated for all portfolios and compared so they can be ranked (Step 7).

3.7.3.3 Description of Colorado River Basin Water Availability Model

The Texas Commission on Environmental Quality Water Availability Model (WAM) is a publicly available computer modeling system for simulating surface water availability. The WAM System covers every river basin in Texas. It was created pursuant to Article VII of the 1997 Senate Bill 1, which required the development of new water availability models for the state's river basins. The WAM system is comprised to two components: generalized computer modeling software known as the Water Rights Analysis Package and a set of basin specific input files and supporting geographic information system (GIS) coverages. The Water Rights Analysis Package was developed and is maintained by Dr. Ralph Wurbs at Texas A&M University. The basin specific input files and GIS coverages were developed in the late 1990's and are updated and maintained by the Texas Commission on Environmental Quality.

The WAM uses monthly naturalized streamflow, net lake evaporation minus precipitation, and a water management scenario as its three main inputs for every river basin. Naturalized streamflows are calculated from historical streamflow gaging records by reversing the historical water diversions, changes in reservoir storages, and return flows of all state granted water rights. The naturalized flows represent the total surface water production of the basin in the absence of state granted water rights. The WAM simulates surface water availability to the basin water rights using the naturalized hydrologic inputs and a water management scenario that specifies a level of water right utilization. Outputs of the WAM include water diversion, reservoir storage content, and remaining streamflow after accounting for the water management activities.

The Colorado River Basin WAM covers the entire portion of the river basin in Texas, from the border of southeast New Mexico downstream approximately 600 miles to the Matagorda Bay. The Colorado basin contains approximately 31,000 square miles of contributing drainage area. There are over 2,000 water rights and over 500 major and minor reservoirs represented within the Colorado WAM. The Colorado WAM uses naturalized hydrology with a period of record from January 1940 through December 2013. Extended synthesized hydrology was developed for Water Forward to cover the additional years of the recent drought through December 2016.

The City of Austin is using the Colorado River Basin WAM as a key modeling tool to examine water available to the City of Austin and the lower Colorado River Basin for the worst drought conditions in the historical period of record, drought conditions that are worse than observed in the period of record, and drought conditions that are reflective of future climate change. Water availability is simulated for a baseline water management scenario (no additional actions) to assess future needs, and a suite of portfolio options to assess the performance to meet those future needs.

SECTION 4: WATER DEMANDS

Integrated water resource planning provides a blueprint that ensures residents and businesses in Austin have sustainable access to clean water now and into the future as the city continues to experience growth. To properly plan and manage Austin's water resources, it is critical to have a reasonable understanding and characterization of how and where water is currently used in the city as well as quantifiable estimates of how much water will be needed in the future. This section describes the primary tool used by Water Forward to characterize and explore water demands, referred to as the Disaggregated Demand Model. This tool was developed by Austin Water staff with indoor end use refinements and other enhancements developed by CDM Smith. Using the tool, current water use is defined, as described in **Section 4.2**, and future demand is projected, as described in **Section 4.3**. These sections describe the City's water demand at the water source (*diversions*), at the water treatment plant (*pumpage*), and at the Austin Water customers' meters (*consumption*). Climate and weather patterns are a major defining factor in water use levels. **Section 5** explores future water demands in relationship with projected climate variations.

AT A GLANCE

- *Disaggregated Demand Model*
- *Current Water Use Summary*
- *Future Baseline Water Demand*

4.1 Disaggregated Demand Model (DDM)

The foundation of the IWRP water demand estimates is the underlying DDM, which was used to produce the baseline water demand assessment, among other things. Austin Water staff began development of the DDM in advance of the IWRP, and refinements to the DDM have continued throughout the process. The DDM is an Excel-based tool that models water use by sector, subsector, and end use at a geographic planning unit scale for current demands as well as for the key planning horizons of 2020, 2040, 2070, and 2115. The DDM provides the analytical environment for assessing potential water savings from demand management measures being evaluated in developing the plan. The DDM also includes functionality to assess water demands under future climatic scenarios and tracks water consumption by end use (such as toilets, sinks, or irrigation), which informs the assessment of yield potential for decentralized supply options. The following sections describe the model attributes, development, and primary data sources.

4.1.1 Demand Model Attributes

For analysis purposes, it is useful to group water demands according to similar user characteristics. These groupings are known as sectors. The DDM model sector classifications are listed below. The water use sectors are further refined into subsectors and outdoor and indoor end uses, as shown in **Figure 4-1**.

DDM Sectors:

- Single family residential (SFR)
- Multi-family residential (MFR)

- Commercial (COM), which includes large volume customers in the Industrial subsector
- Wholesale Customers (WHL)
- City of Austin (COA)

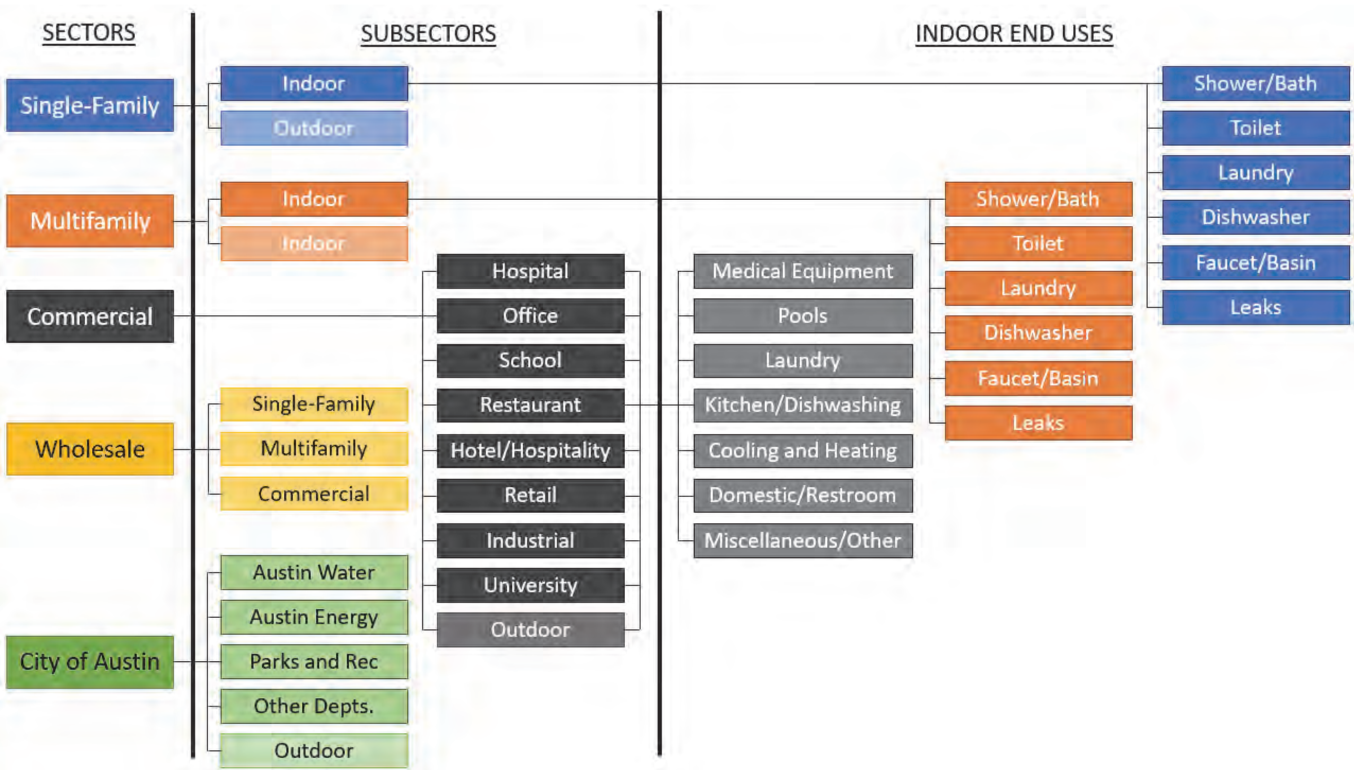

Figure 4-1. Disaggregated demand model sectors, subsectors, and end uses

Analysis was conducted using geographic units developed in harmony with Imagine Austin, Austin's comprehensive plan. The geographic units are known as the Delphi, Trends, and Imagine Austin (DTI) polygons and they divide the city into 230 contiguous polygons. The area coverage by the DTI polygons includes the City of Austin's full and limited purpose jurisdictions as well as the city's extra-territorial jurisdiction, as shown in **Figure 4-2**. The green water planning area boundary represents the potential future service area extent for Austin Water. Census blocks within the DTI polygons were used to create a comprehensive 2010 baseline count of the population and number of residential units in each polygon. Employment estimates were also generated for each polygon. These baseline and projected demographics are the primary drivers of water use in the city. So, for each DTI polygon, an estimate of existing and future water demands by sector, subsector, and end use were able to be developed by the tool. More detail on the development of these estimates can be found in **Appendix C**.

The DDM also produces a number of summary charts, tables, and graphics that support and inform the IWRP. For example, the tool allows for relatively quick assessment of the impact of a demand management measure on overall system, sectoral, or source water demand.

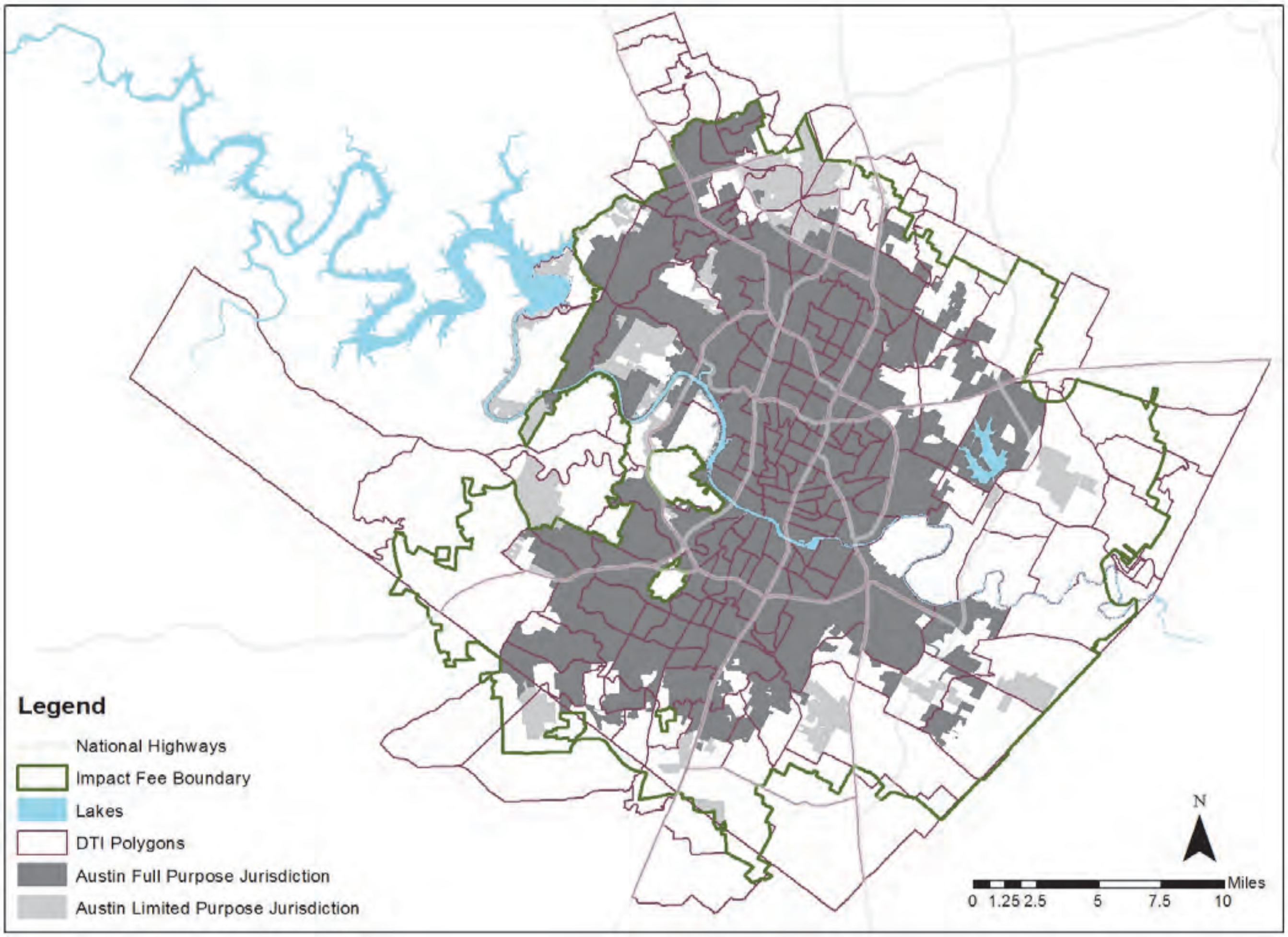

Figure 4-2. Disaggregated demand model DTI geographic units

4.1.2 Model Development

The DDM was developed by Austin Water staff using a bottom-up approach that relied on detailed, account-level billing data from 2010 through 2015. Data from 2011 was not utilized due to a change in billing systems which introduced errors into the data for that year. For each active account, the DTI polygon location was identified. Customer types and rate codes were used to determine the water use sector of the account. All billing sets were normalized to calendar month usage using the daily average of the billing cycle and the number of days in the billing cycle that occurred in each calendar month.

Water use data were then aggregated by subsector, DTI polygon, and month. Using the DTI polygon data for demographics and the aggregated water use, water use factors were calculated for each polygon for each year. Water use for single and multi-family residential customers was based on population within those housing types while commercial and City of Austin water use was based on employment within the sector.

The industry standard minimum month method was used to estimate the portion of monthly water demands that are used for outdoor, seasonal applications. Specifically, the lowest monthly water usage for each parcel without a dedicated irrigation meter was identified. This value was multiplied by 12 to estimate the total annual indoor usage for each parcel. The difference between the total parcel water usage and the calculated indoor usage was identified as annual outdoor usage. In instances where dedicated irrigation meters are present on a parcel for a given sector, all the water use from the meter was assigned the outdoor subsector and the meter representing indoor use was assigned to the indoor subsector.

To estimate current indoor end uses, research was done to identify and use best available data sources. Indoor end uses for single family residences were informed by the Water Research Foundation's Residential End Uses of Water, Version 2 Report[4]. The multi-family residential and commercial indoor end uses were developed based on a comprehensive literature review of available information coupled with insight and guidance from Austin Water staff. Additional details can be found in **Appendix C**.

For forecasting, the average water use factor from 2013 through 2015 was calculated and assumed to be the starting point of the forecast. The water use factors were adjusted in the forecast years based on the given analysis scenario. The baseline scenario includes adjustments to the water use factors based on an assumption that, as a best management practice, Austin Water will incentivize or require installation of water efficient fixtures in homes and businesses throughout the city. This was referred to as "passive conservation" in the model (see **Appendix C** for more detailed information). In addition to passive conservation, the baseline scenario embeds and assumption that active conservation measures taken by Austin in the past, including one-day-per-week watering restrictions, will be maintained in the future. In support of the IWRP, the DDM was enhanced to allow for modeling of future demands under different weather conditions. Details on model enhancements can be found in **Appendix C**.

4.1.3 Data Sources

The primary data sources for developing the DDM are described below:

- Delphi – Trend – Imagine Austin (DTI) Polygons - Geographic unit of analysis for Austin Water DDM. The data include long-range, small-polygon-based population and employment forecasts. The City of Austin Demographer worked closely with Austin Water staff to develop estimates of retail and wholesale water service population that built off of historical 2010-2015 estimates and extended projections through 2115. This dataset contains estimates of water service population, single family and multifamily units, and employment figures for 2010, as well as projections for 2020, 2040, 2070, and 2115 (see **Table 4-1** on the following page for population forecast).
- Standardized Occupational Components for Research and Analysis of Trends in Employment System (SOCRATES) Employment Dataset - Dataset created by the Texas Workforce Commission featuring a complete listing of employers within Austin as well as pertinent data (number of employees, North American Industry Classification System code, sales volumes, etc.) for the year 2010.
- Austin Water Billing Accounts and Consumption Data - Historical billing records (in the form of GIS feature point datasets) for every Austin Water customer in 2010 and 2012-2015. Note that 2011 data were excluded due to errors introduced when the city switched billing systems.
- COA Building Permit Data - All approved building permit data provided by the city's Development Services Department in the form of a database (the Application Management and Data Automation database known as AMANDA) and Shapefiles of permits by year.
- 2010 Land Use GIS polygon.

[4] http://www.waterrf.org/PublicReportLibrary/4309A.pdf

Table 4-1. Long-range population forecast for Austin Water planning area

Year	Austin Water Served Population Forecast – Retail and Wholesale	Annualized Growth Rate
2010	875,936	
2015	977,491	2.2%
2020	1,101,632	2.4%
2025	1,216,291	2.0%
2030	1,342,884	2.0%
2035	1,464,571	1.7%
2040	1,577,760	1.5%
2045	1,692,174	1.4%
2050	1,808,586	1.3%
2055	1,927,901	1.3%
2060	2,051,178	1.2%
2065	2,179,649	1.2%
2070	2,314,769	1.2%
2075	2,458,265	1.2%
2080	2,610,656	1.2%
2085	2,772,495	1.2%
2090	2,944,366	1.2%
2095	3,126,892	1.2%
2100	3,320,732	1.2%
2105	3,526,590	1.2%
2110	3,745,208	1.2%
2115	3,977,380	1.2%

4.2 Current Water Use Summary

Over time, average annual water use on a per capita basis has been declining in Austin. This water use savings is occurring through increased water use efficiency and efforts by the Austin community to conserve and respond to calls for water use reduction during the recent drought. As shown in **Figure 4-3**, through much of the 1990's both water use and population were increasing at similar rates. With the onset of water conservation programs initiated by the City, like conservation-based water rates or outdoor watering schedules, as well as more efficient water fixture standards implemented by first the federal government in 1992, the City in 2007, and then the State of Texas in 2010, water use has declined despite continued population growth. On a per capita basis, annual water pumpage has declined from 190 gallons per capita per day (GPCD) in 2006 to a low of 122 GPCD in 2015 and 2016 as shown in **Figure 4-4**.

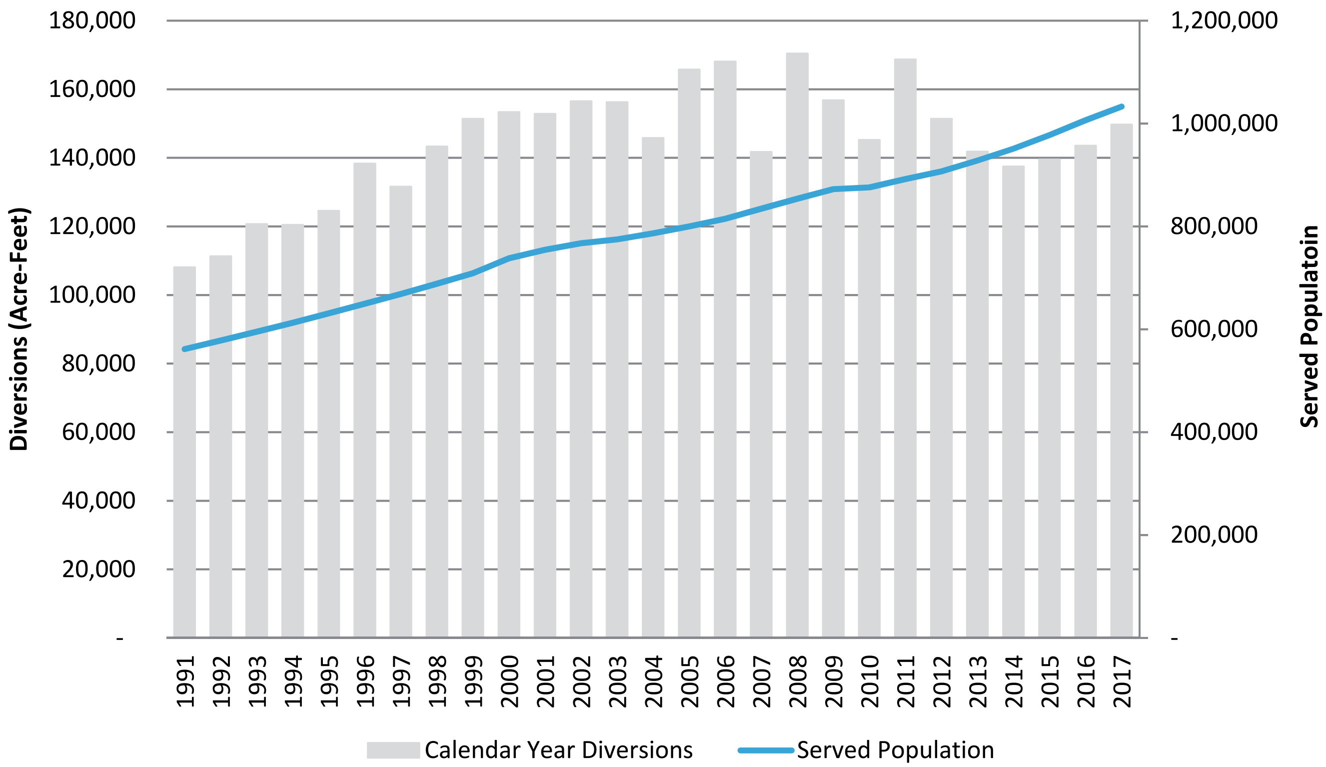

Figure 4-3. Water diversions and population from 1991 through 2017

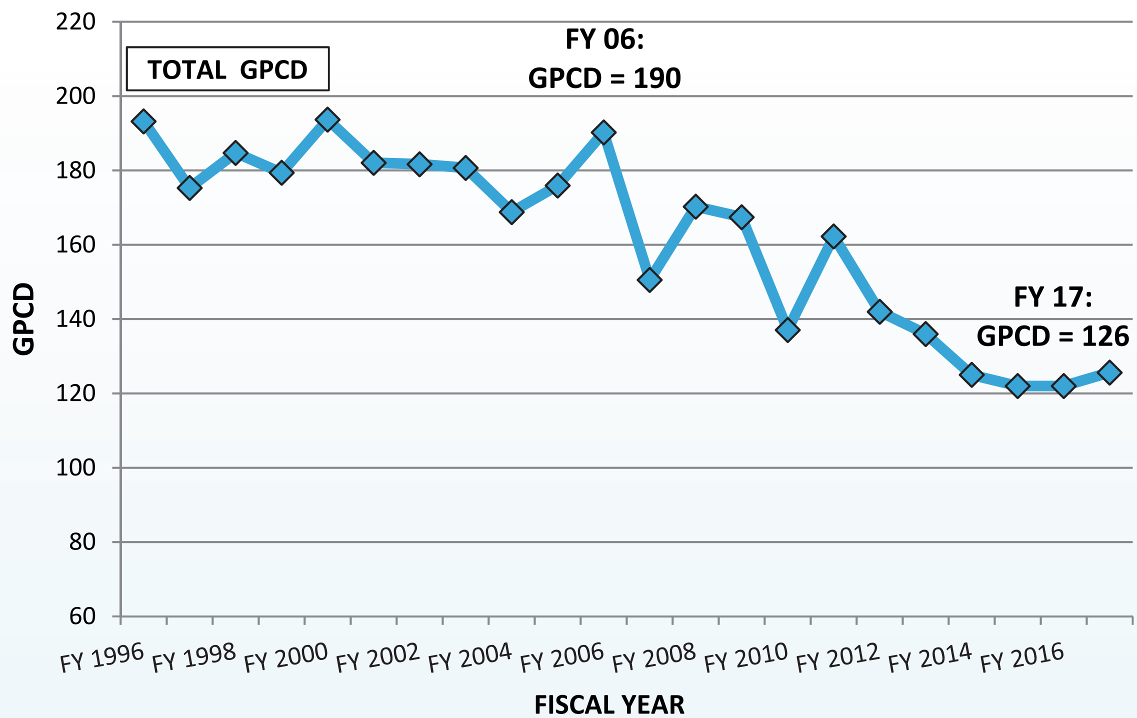

Figure 4-4. Historical per-capita water use

The baseline municipal annual use estimate for an average of 2013, 2014, and 2015 for Austin Water and its customers was approximately 45.4 billion gallons (139,300 acre-feet) of raw water diversions. The baseline total pumpage of treated water into the distribution system per year is approximately 44.1 billion gallons (135,500 acre-feet). The difference between raw water diversions and treated water pumpage is attributable to several factors, including use of some of that water in the treatment process itself, water loss due to evaporation, and metering differences. The baseline amount of water consumed by Austin Water and its customers was approximately 39.29 billion gallons (120,600 acre-feet), based on an average of 2013, 2014, and 2015 water consumption. The difference between treated water pumpage and consumption is known as non-revenue water. Some non-revenue water is lost through leaks in pipes on the way to customers, while other components of non-revenue water include water used for distribution pipe flushing or fighting fires.

Of the water consumed, residential use accounts for 60% and commercial use accounts for 31% (**Figure 4-5**). Currently, outdoor use is estimated to be 27% of all single-family residential use, 16% of all multi-family residential use, and 23% of total commercial use.

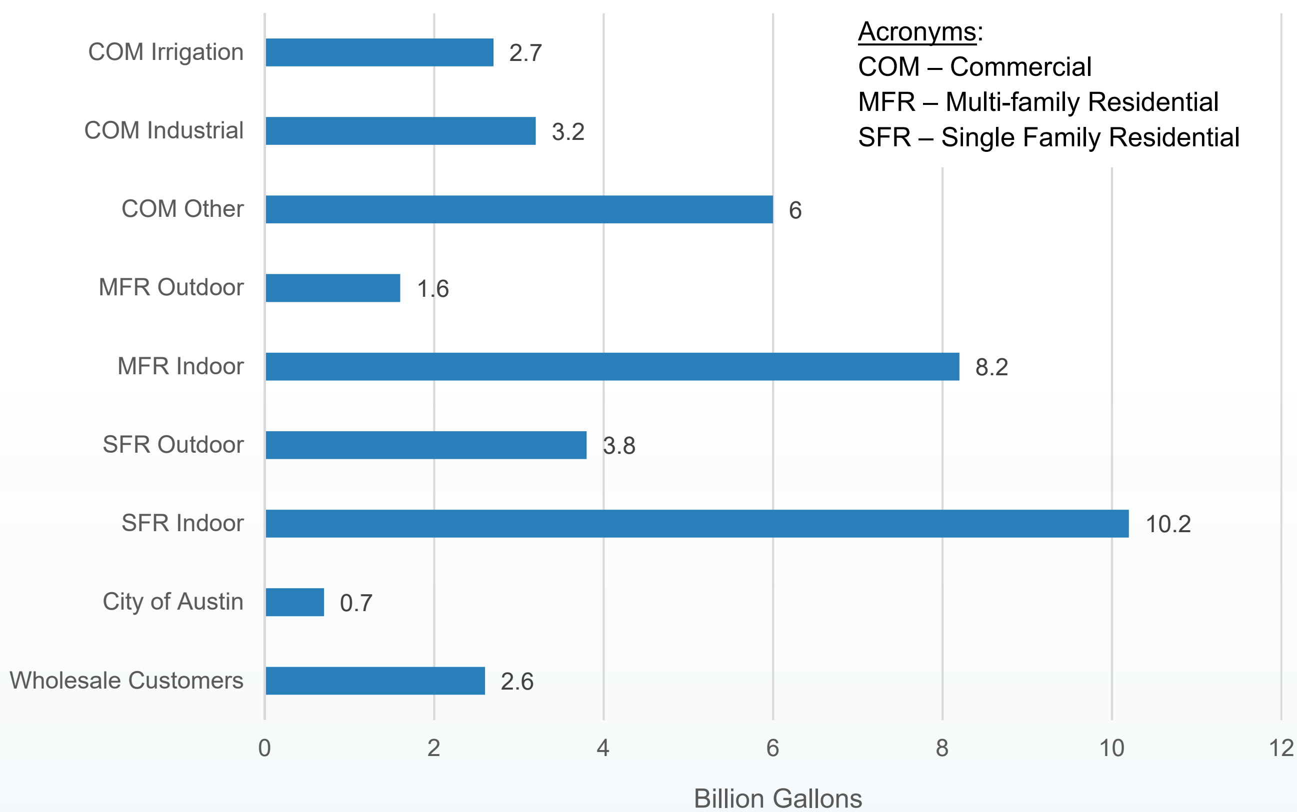

Figure 4-5. Water consumption by sector and subsector

4.3 Future Baseline Water Demand

Baseline future water demands were developed from an average of 2013, 2014, and 2015 water consumption (also known as base year demands) and represent future conditions based on demographic projections of population, housing, and employment in Austin. An average of 2013, 2014, and 2015 water consumption was chosen to develop future demands. Baseline water demands embed recent conservation savings such as Austin's one-day-per week watering for automatic irrigation systems and also incorporate projected passive conservation, which can result from reductions in water use from existing conservation and continued improvements, primarily in indoor water using fixture efficiencies.

As shown in **Figure 4-6**, under current baseline conditions, without potential future water strategies, the City is projected to need 148.13 billion gallons (or 454,600 acre-feet) of water by 2115 to serve a projected population of slightly less than 4 million people. This figure is based on treated water pumpage, under stationary climate conditions. Austin's corresponding baseline water diversion projection, which accounts for water used in the water treatment process, is 467,392 acre-feet by 2115. It is important to note that baseline water demands do not include future conservation savings from additional conservation programs, codes, or ordinances. Additionally, baseline demands do not reflect reductions in potable water demand due to future increases in centralized and decentralized alternative water use. Alternative water sources include highly treated reclaimed water from Austin Water's wastewater treatment plants, and onsite water sources such as rainwater, graywater, blackwater, air conditioner condensate and stormwater. Demand projections that incorporate the implementation of Water Forward plan recommendations show a marked decrease in future projected demands from baseline demands.

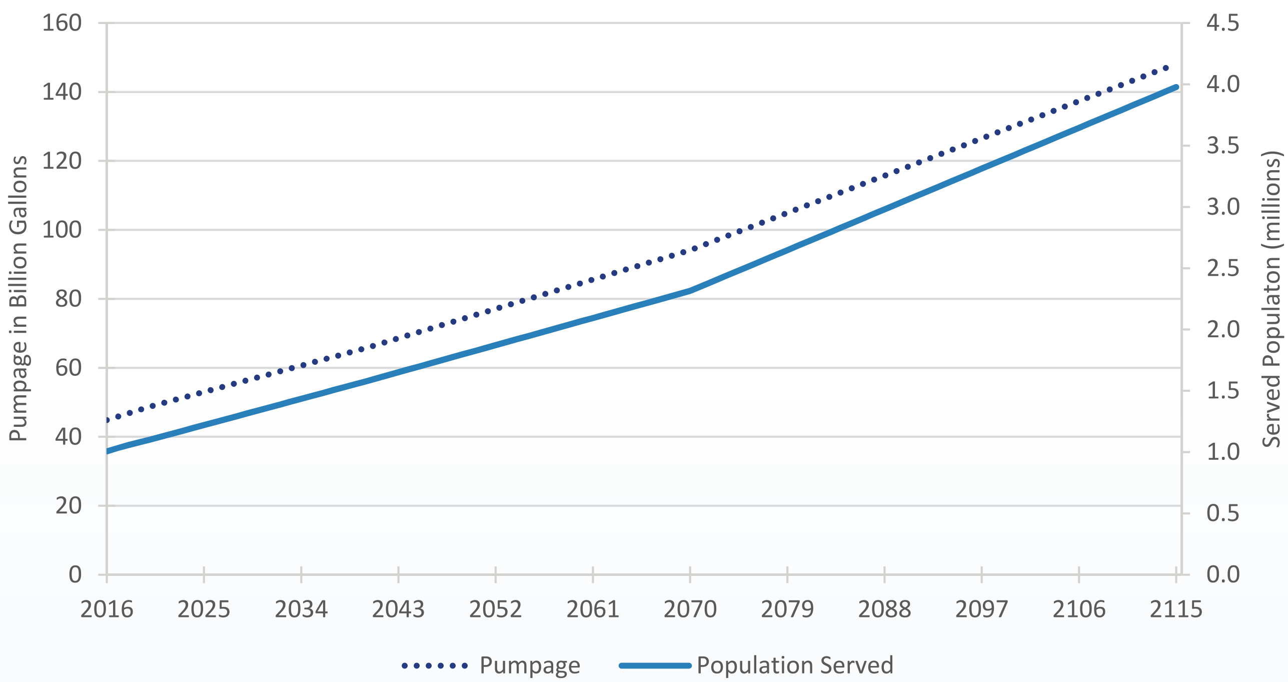

Figure 4-6. Baseline water pumpage forecast with population to 2115

Table 4-2 and **Figure 4-7** present the baseline water demand forecast by sector. Baseline system pumpage is projected to grow by 236% from its current level over the next 100 years. Again, this projection does not include the projected savings of potential future demand management or other strategies that may be recommended as part of this plan. The commercial sector growth rate of nearly 270% captures the trend that employment is projected to grow at a rate greater than population served.

Table 4-2. Baseline water demand forecast by sector to 2115 – consumption, pumpage, and demand

Sector	Base Year Demand (Billion Gallons Per Year)	Future Water Demand (Billion Gallons Per Year)			
		2020	2040	2070	2115
Single family residential	13.99	15.61	19.98	28.22	41.99
Multi-family residential	9.76	11.13	14.81	22.66	42.47
Commercial	12.03	13.16	18.02	27.60	44.39
Wholesale	2.64	2.43	2.79	3.32	3.53
City of Austin	0.70	0.89	1.48	2.05	3.07
Other	0.16	0.18	0.23	0.34	0.55
Consumption Total	39.29	43.40	57.30	84.19	136.0
Difference between Consumption and Pumpage (includes system losses)	4.85	5.36	8.44	9.93	12.12
Pumpage Total	44.14	48.76	65.75	94.12	148.1
Total Baseline Demand[1, 2]	45.39	50.13	67.60	96.78	152.3

[1] Baseline demand amount would equate to raw water diversion at present.

[2] The difference between raw water diversions and treated water pumpage is attributable to several factors including use of some of that water in the treatment process itself, water loss due to evaporation, and metering differences.

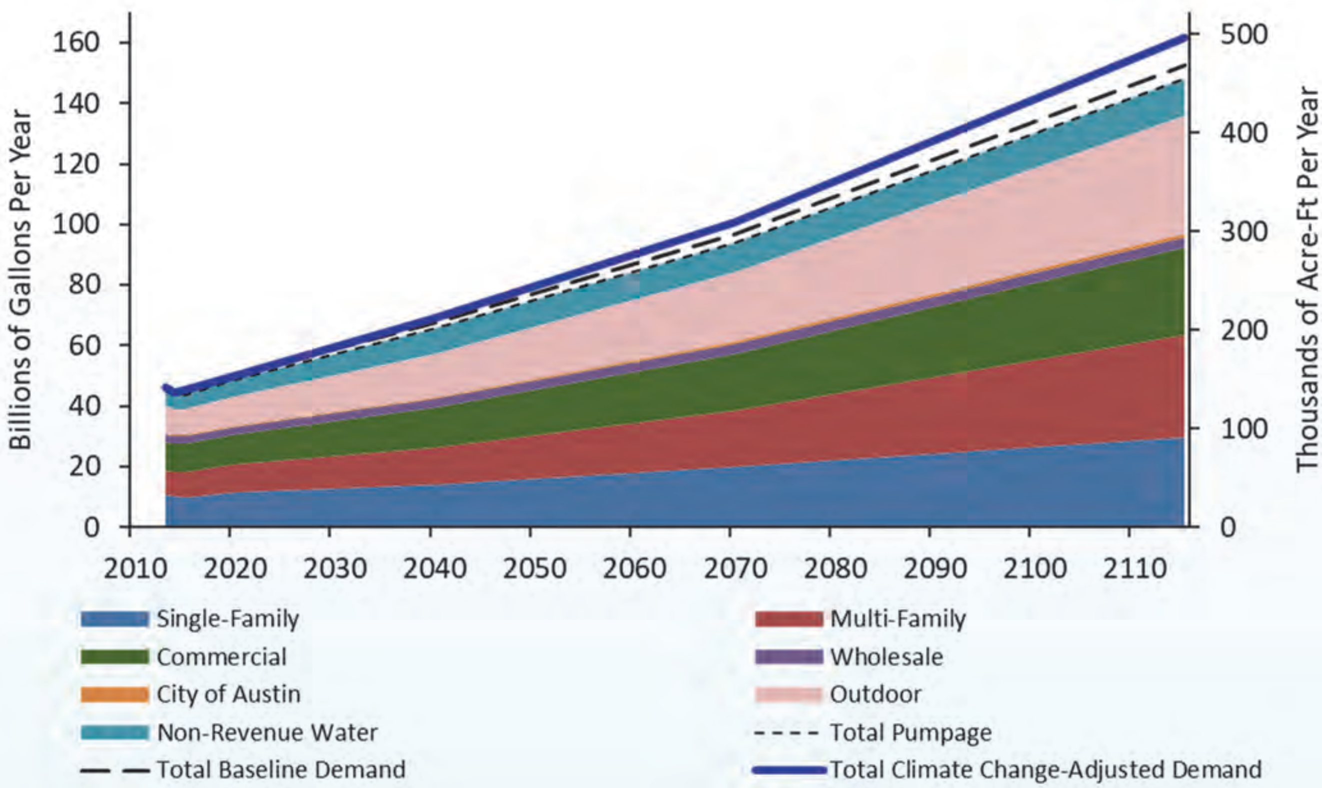

Figure 4-7. Water Forward baseline demand projections by sector

Figure 4-8, Figure 4-9, **Figure 4-10,** and **Figure 4-11,** provide demand schematics for the forecast years. For water demands other than the City of Austin municipal estimates, see **Appendix E**.

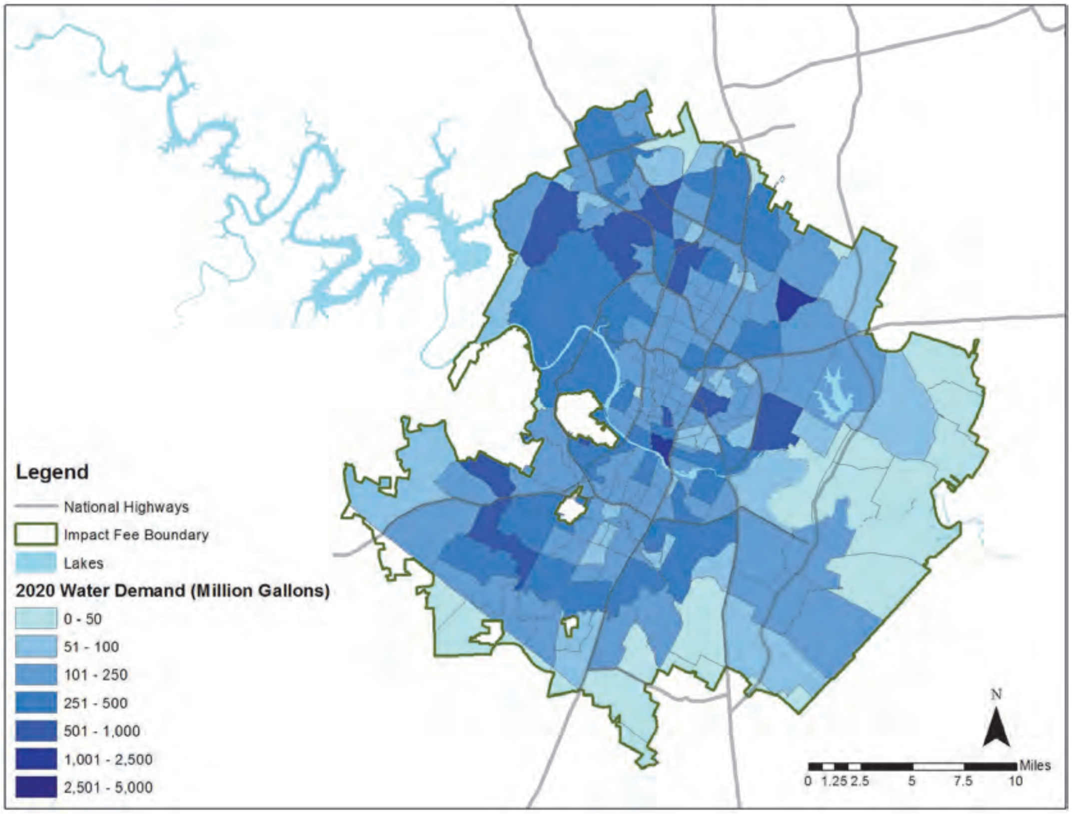

Figure 4-8. Baseline Water Demand Schematic 2020

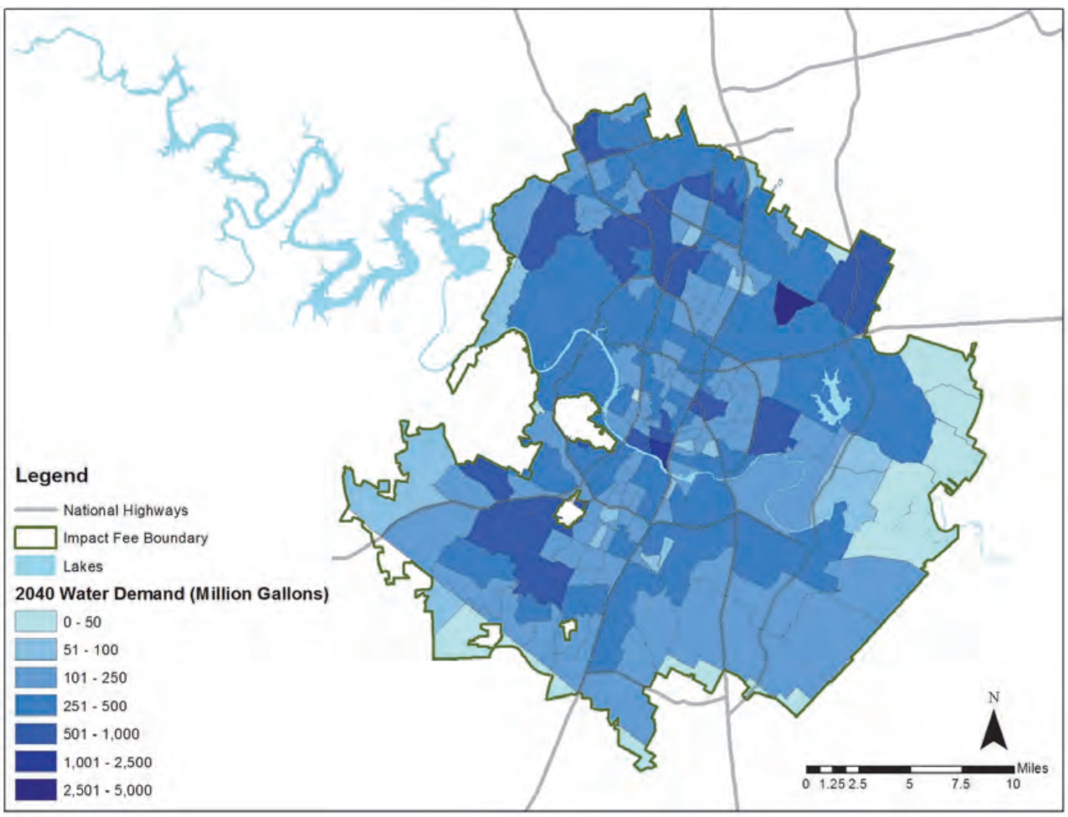

Figure 4-9. Baseline Water Demand Schematic 2040

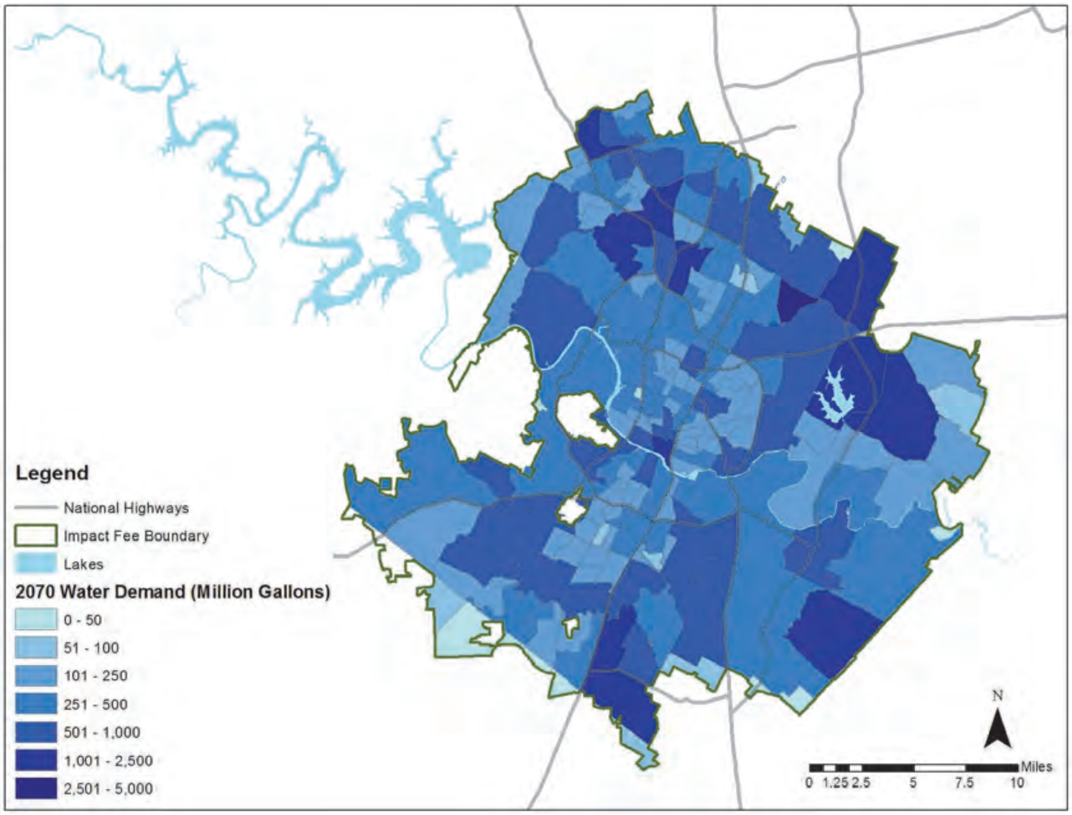

Figure 4-10. Baseline Water Demand Schematic 2070

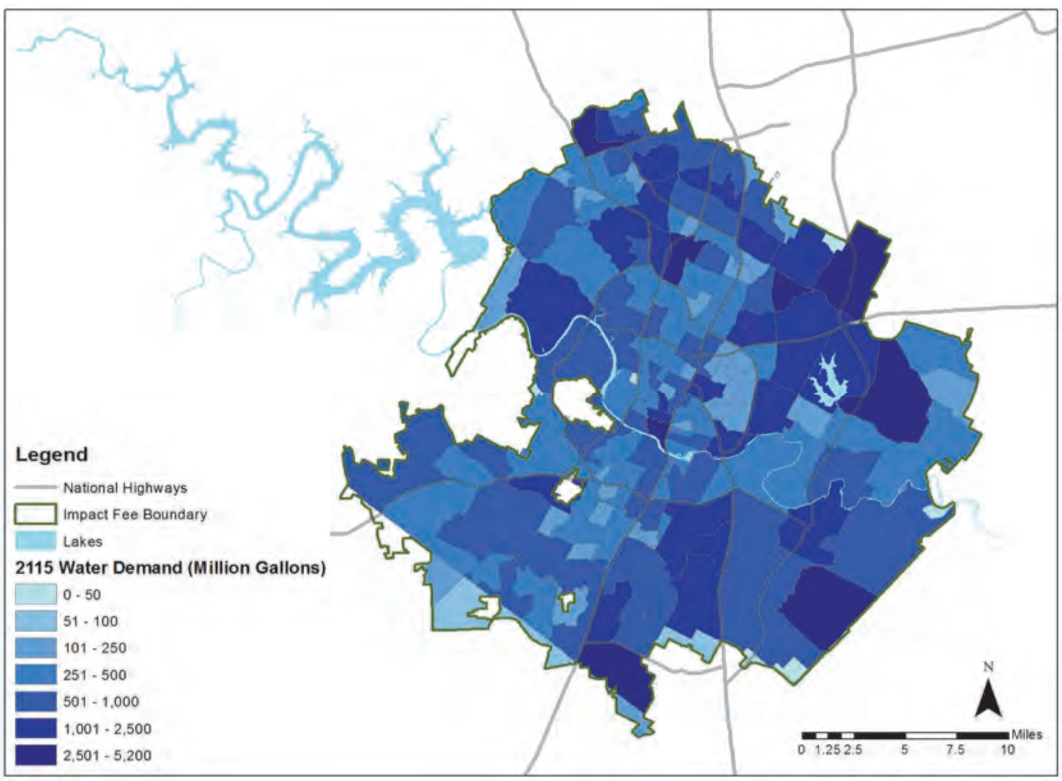

Figure 4-11. Baseline Water Demand Schematic 2115

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SECTION 5: HYDROLOGY, CLIMATE CHANGE, AND WATER AVAILABILITY MODELING

As part of the Water Forward effort, the planning process included evaluation of multiple future conditions. Four hydrologic scenarios that considered climate change and droughts worse than the drought of record were developed to use for needs identification and portfolio evaluation. Planning for multiple future conditions allows the planning process to address uncertainties in the future related to possible changing climate conditions or droughts that may be worse than what we have experienced since the 1940s. January 1940 marks the beginning of the period of record for most of the Texas Commission on Environmental Quality Water Availability Models used across the state, and also coincides with the general timeframe when Lakes Travis and Buchanan were constructed and began filling. Using data from this period of record allows planning for a repeat of what has been experienced in these last 77 years. However, an important part of the Water Forward process involved identifying portfolios that aligned with the Water Forward goal of ensuring a diversified, sustainable, and resilient water future. Therefore, hydrology, climate change, and water availability modeling analyses were performed to evaluate a range of possible scenarios to assess the impact of futures which might be different than what we have experienced.

AT A GLANCE

- *Definition of Water Needs*
- *Hydrologic and Climate Modeling*
- *Summary of Water Needs*

5.1 Definition of Water Needs

To guide the development and evaluation of IWRP portfolios, three types of water needs for the City of Austin were identified and assessed:

- **Type 1 Need**: This is a supply and/or conservation savings need equal to the estimated reduction in potable water demand from implementation of the City's Stage 4 Drought Contingency Plan implementation. Stage 4 water restrictions would include a prohibition on all outdoor water use and would be implemented at very low lake levels (for the purposes of the plan analysis Stage 4 is triggered in the water availability model used for the IWRP at or below 450,000 acre-feet of combined storage in Lakes Travis and Buchanan). This need was established to mitigate societal, environmental, habitat, and economic impacts of staying in Stage 4 during prolonged droughts. Both demand management and water supply options can fill this need.
- **Type 2 Target:** This is a potable supply target developed to mitigate the risk of Austin having very little or no Colorado River supply due to severe drought, including droughts that may be worse than what the region has seen in the past. To ensure that Austin would have access to a potable water supply in a severe drought, the Type 2 target was set equal to 50% of the amount of water Austin would expect to receive from Lower Colorado River Authority stored water, whether or not it was actually available in the model (see **Appendix F** for a detailed description of how Type 2 needs were

calculated). This target is triggered in the model only when combined storage in Lakes Travis and Buchanan is extremely low (less than 450,000 acre-feet or about 22% full). Only options that can readily provide potable water can fill this need.

- **Type 3 Need:** This is a supply and/or conservation savings need that is triggered when Austin's water demands are above its current 325,000 acre-feet firm water supply contract with Lower Colorado River Authority. Both demand management and water supply options can fill this need.

5.2 Hydrologic and Climate Modeling

Austin Water is using a customized version of the Colorado River Basin WAM as a key modeling tool to determine water availability from the Colorado River. For the IWRP, four hydrologic scenarios were examined to estimate the future water needs, these being hydrologic scenarios:

A. Period of record (1940-2016) with historical climate, often referred to as stationary climate

B. Period of record with climate change

C. Simulated extended period with historical climate (the 10,000 years extended period was developed to evaluate potential droughts worse than the drought of record)

D. Simulated extended period with climate change (the 10,000 years extended period was developed to evaluate potential droughts worse than the drought of record)

5.2.1 Climate Change Modeling

Dr. Katharine Hayhoe, climate scientist with ATMOS Research and Consulting, performed the climate change modeling for the Water Forward process. The work Dr. Hayhoe performed for Water Forward built on a previous study performed for Austin's Office of Sustainability[5].

Rising temperatures, increased evaporation rates, and an acceleration of the hydrological cycle is increasing the duration and severity of droughts as well as the intensity of heavy precipitation in many places around the world[6]. These and other changes that have been attributed to human-induced climate change are projected to continue over the remainder of this century and beyond. Climate change effects are expected to be pronounced in Texas by the mid-21st century[7]. Summer daily high temperatures are expected to increase, and winter nightly low temperatures are expected to increase as well. Little change in long-term average annual precipitation is expected. However, it is expected that the duration of consecutive dry days will increase in frequency with punctuation by heavy rainfall events.

The Texas Commission on Environmental Quality Water Availability Model (WAM) for the Colorado River basin includes a historical period of record from 1940 through 2016. The Water Forward WAM contains demand management and water supply scenarios for 2020, 2040, 2070, and 2115. Therefore, to address potential changes to climate in future WAM simulation scenarios, global climate models are used to project hydrologic conditions for 2040, 2070, and 2115. The results of the global climate models form the basis of adjustments to the Water Forward WAM's historical period of record hydrology for these later time

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[5] http://www.austintexas.gov/sites/default/files/files/Katherine_Hayhoe_Report_-_April_2014.pdf

[6] IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

[7] https://austintexas.gov/sites/default/files/files/Katherine_Hayhoe_Report_-_April_2014.pdf

horizons. An overview of the climate change modeling process steps is provided in **Figure 5-1**, and the steps are described further in the following text.

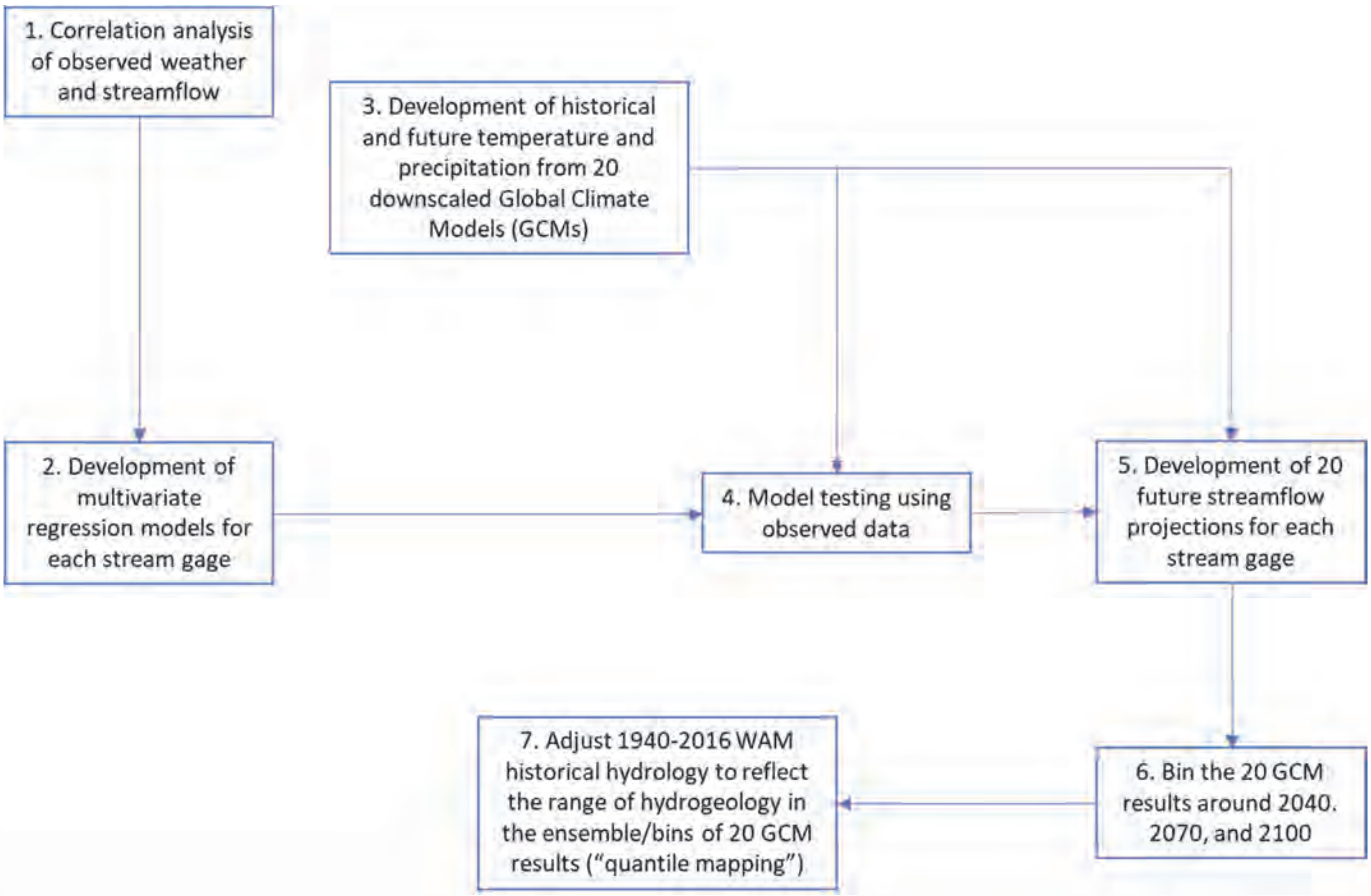

Figure 5-1. Climate and hydrology analysis process graphic

1. Correlation Analysis of Observed Weather and Streamflow

- Observed daily streamflow at 43 gaging locations in the Colorado River basin were correlated with a large number of weather variables (see **Figure 5-2**) reflecting variability in observed temperature and precipitation from 1950 through the present.

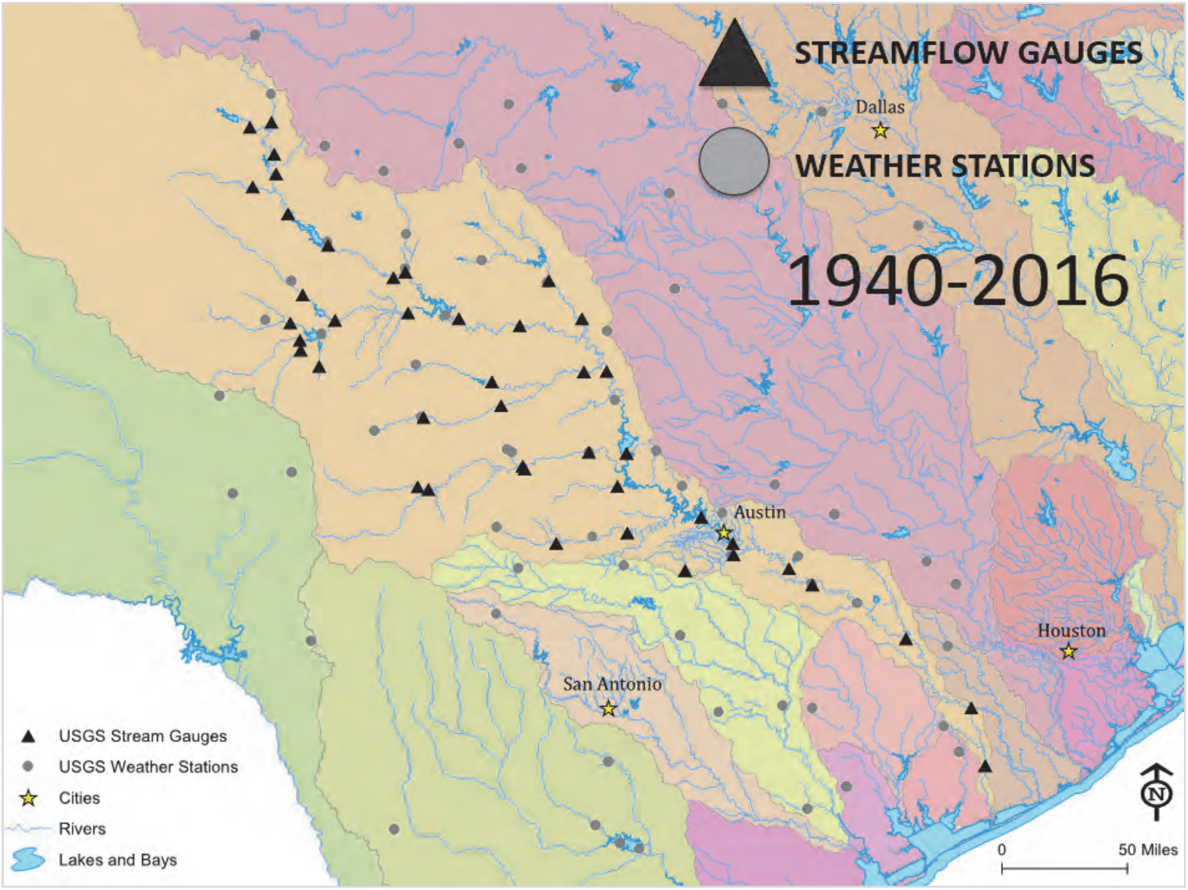

Figure 5-2. Colorado River basin streamflow gages and weather stations

2. Development of Multivariate Regression Models for Each Stream Gage

- Statistical regression models of historical streamflow at each gage were built to predict streamflow as a function of the historical weather variables.

3. Development of Historical and Future Temperature and Precipitation from 20 Downscaled Global Climate Models

- Next, high-resolution climate projections of temperature and precipitation from 20 global climate models under a higher and lower carbon emission scenario were downscaled to the same weather stations used to build the statistical models of streamflow at each gage. The higher emission scenario was selected for use in Water Forward as it represents the current trajectory of carbon emissions and serves as a distinctly different outcome of future hydrologic conditions when compared to the historical observations of basin hydrology.

4. Model Testing Using Observed Data

- Each gage regression model was validated on observed data by dividing the historical data in odd and even years, using one set of the data to build the regression model, and the other for cross-validation, then switching. **Figure 5-3** shows that for these two example stream gage locations, the modelled past and the data observed in the past match fairly well. Additionally, the modelled future is shown for comparison.

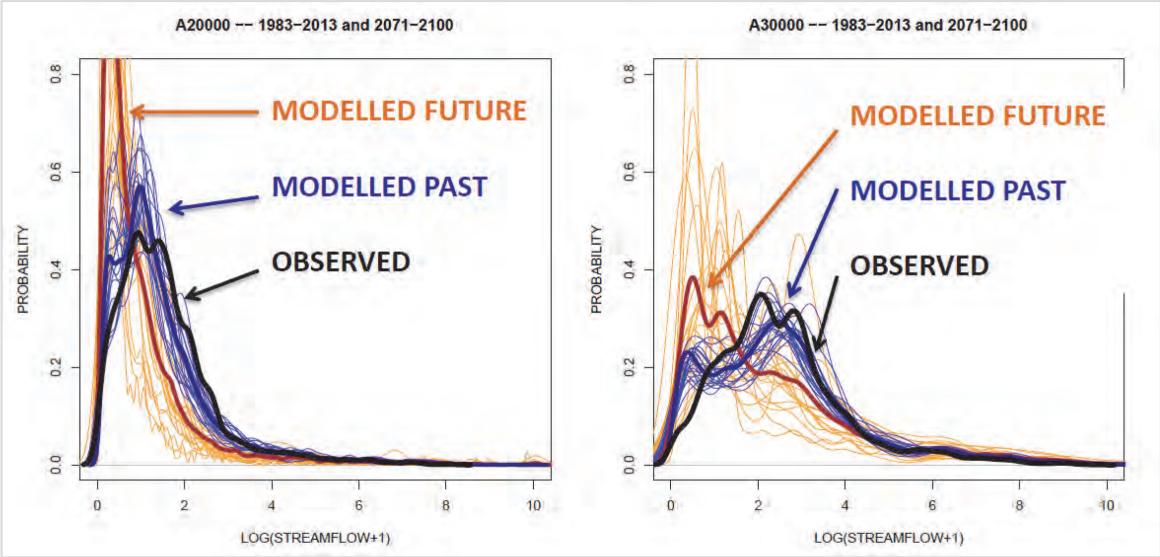

Figure 5-3. Comparison of observed and modelled past and future streamflow for selected stream gage

5. Development of 20 Future Streamflow Projections for Each Stream Gage

The streamflow regression models were driven with the data from the global climate models to create projected streamflow conditions through 2100 (See **Figure 5-4**). The gage-specific streamflow projections as well as evaporation and precipitation projections were used to develop basin-wide inputs to the Water Forward WAM.

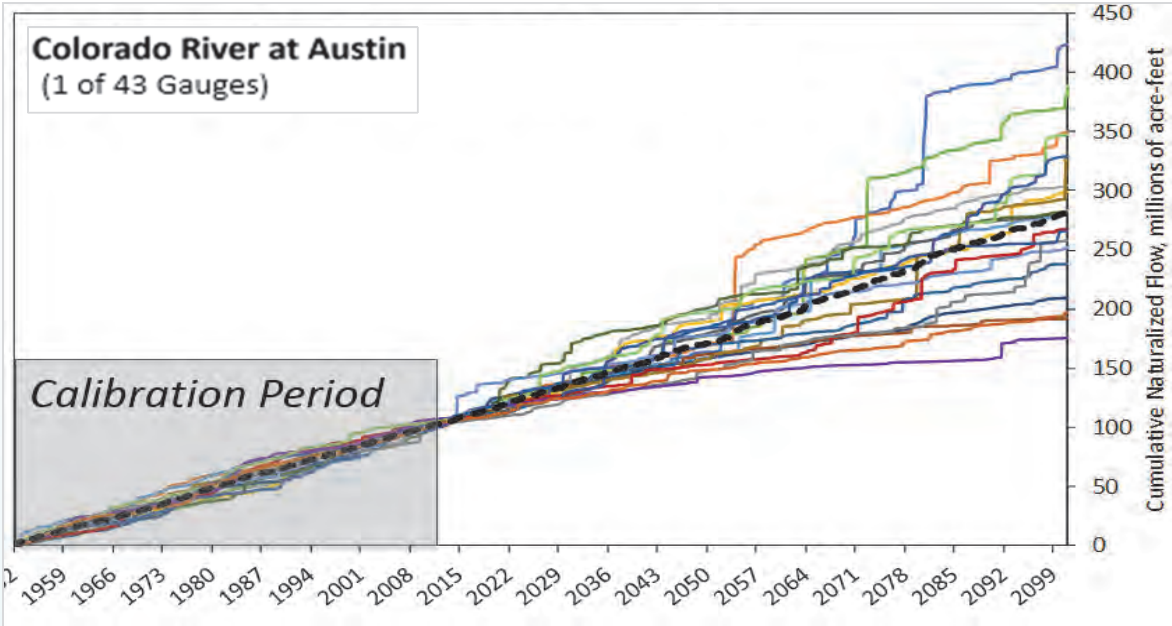

Figure 5-4. Twenty projections of cumulative naturalized flow for the Colorado River at Austin gage

6. Bin the 20 Global Climate Models results around 2040, 2070, and 2100

To develop an ensemble of the 20 different streamflow projections, a process was used to compile all the data points for each stream gage from each of the 20 streamflow projections into a "bin." The bins included data output from the streamflow regression modeling grouped into 21-year spans of time centered around 2040 and 2070. Since data from the global climate models were only available through 2100, the bin to collect data points for the 2115 planning horizon was set as the period of projection from 2080 through 2100. The bins of global climate model derived hydrology are as follows: 2030 through 2050 (21 years centered on 2040), 2060 through 2080 (21 years centered around 2070), and 2080 through 2100 (the last 21 years of global climate model results) (See **Figure 5-5**). Each bin contains downscaled hydrology derived from all 20 climate models which creates 5,040 monthly samples of projected future hydrologic conditions at each gage.

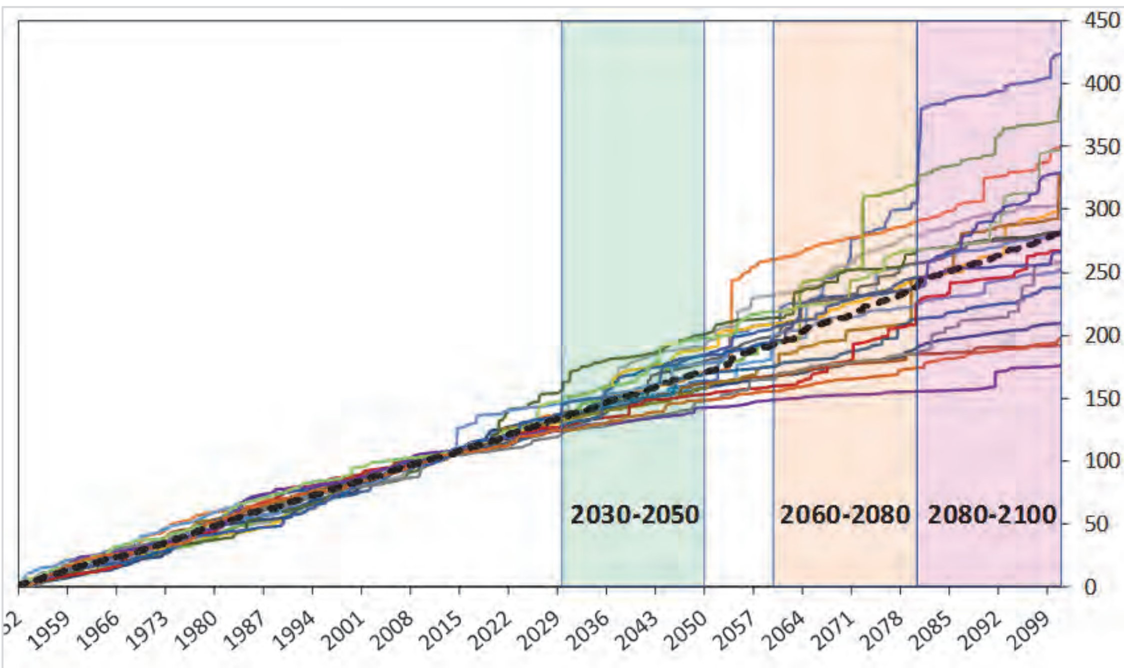

Figure 5-5. Bins used to develop streamflow ensembles (2030-2050, 2060-2080, and 2080-2100)

7. Adjust 1940-2016 WAM historical hydrology to reflect the range of hydrology in the ensemble/bins of 20 Global Climate Models results ("Quantile Mapping")

Adjustments to the historical period of record hydrology were made using the bins of gage-specific streamflow projections. The statistical characteristics of the ensembles of future hydrology were mapped onto the existing historical period of record at each gaging location in the basin using a methodology known as "quantile mapping" (See **Figure 5-6**). Quantile mapping has been applied similarly in other long-term future water planning studies (Wood et al. 2002; Salathe et al. 2007; CH2M Hill 2008; Hamlet et al. 2009; Bureau of Reclamation 2010, California Dept. of Water Resources 2013). The statistical properties of the ensemble, such as the mean and variability, are transferred to the adjusted WAM hydrology, evaporation, and precipitation. Only the sequencing of dry and wet periods of the historical WAM hydrology is retained.

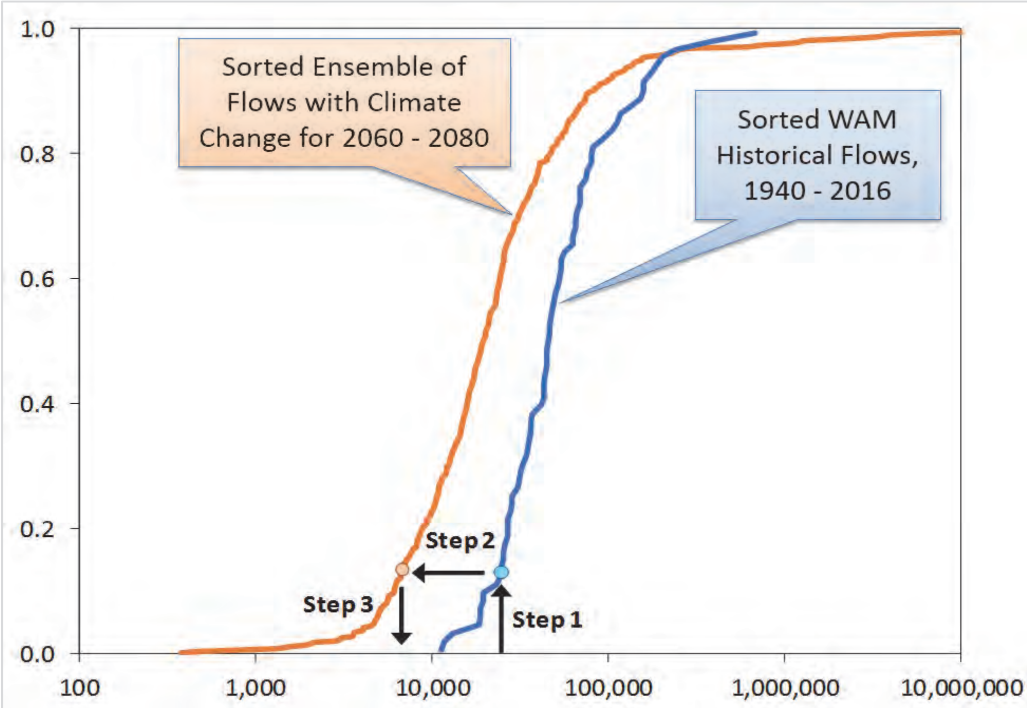

Figure 5-6. Quantile mapping process graphic

To demonstrate the projected impact of climate change, a comparison of annual naturalized flows at the Colorado River at Austin gage with historical hydrology and projected climate changed hydrology is shown in **Figure 5-7**. The figure shows that total range of flows in the further-out horizons increases as period of low flow increase in duration but are punctuated by extreme flow events. The figure also shows a slight downward trend in annual naturalized streamflow towards the later planning horizons.

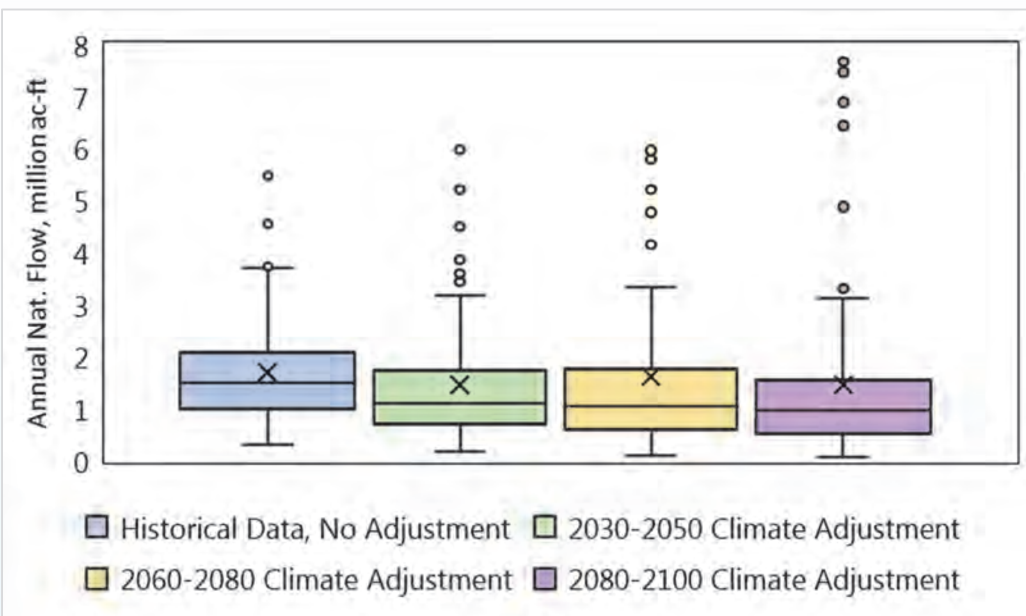

Figure 5-7. Comparison of annual naturalized flows at the Colorado River at Austin gage

5.2.2 Extended Simulation Period

The historical hydrologic period of record for the Water Forward WAM covers 1940 through 2016. Within the historical period are two major droughts that are centered in the 1950's and 2010's. For the purposes of the Water Forward plan, the 2010's drought serves as a new "drought of record" because the hydrologic conditions result in the lowest modelled water supply from the Highland Lakes reservoirs. A water supply modeling objective of Water Forward is to analyze the impacts of droughts that are worse than the drought of record. Though this worse drought is yet to be observed, water supply planning should anticipate the likelihood of such an event occurring, especially over a 100-year planning horizon and against the backdrop of climatic changes.

The methodology used in Water Forward to create plausible hydrologic conditions for modeling droughts worse than the drought of record involves resequencing the period of record. The methodology is formally known as Monte Carlo Markov Chain sampling. Whole years of hydrology from the period of record are randomly selected and connected back-to-back to build a long and hypothetical sequence of monthly flows. The random sampling is the Monte Carlo component of the methodology, though the sampling is not entirely random. The probabilities of transitioning from wet years to dry years, or dry years to average years, for example, in the long sequence of sampled flows matches the same probabilities in the period of record. Maintaining the same probabilities of transition between years is the Markov Chain component of the methodology. Taken together, the random sampling with adherence to transition probabilities allows for the creation of a long and hypothetical sequence of flows that has the same long-term statistical properties of the period of record.

Using a long sequence of extended hydrologic conditions allows for the random occurrence of conditions that are both wetter and drier than contained in the period of record. Multi-year droughts in the extended hydrology can be worse than the 2010's drought. For example, the 2010's drought is punctuated by high flow events in early 2012 and mid-2015. If random sampling replaced the hydrology of 2012 or 2015 with a drier year in the extended hydrology, then the new drought sequence could be worse than the observed 2010's drought. The extended hydrology used for Water Forward covers 10,000 years of simulation. The length of this simulation is intended to be long enough for random chance to produce a large number of candidate droughts that are worse than the period of record. These candidate droughts are further ranked in the degree to which they are worse than the 2010's drought. Identifying new candidate droughts worse than the drought of record in the extended hydrology and ranking them allowed Water Forward to test water availability in a statistical manner under conditions worse than the drought of record. Only certain droughts worse than the drought of record which had a 20% or greater chance of occurring in a 100-year period were chosen as candidate droughts for evaluation.

5.3 Summary of Water Needs

Using the methodology described in **Section 5.2**, the water needs for the IWRP are summarized in **Table 8-2**. Note that to the extent that "Needs Above Contract" (also referred to as Type 3 Needs) are met by demand management, demand management would need to ramp up over the earlier planning horizons to reach plan targets.

SECTION 6: WATER CONSERVATION AND DEMAND MANAGEMENT STRATEGIES

Water conservation programs (i.e., demand management) have long been and will continue to be a critical element in Austin Water's management of water resources. Austin Water also continually evaluates its water conservation programs to determine whether they should be modified, phased out, or new programs implemented to achieve evolving conservation goals and to ensure pursuit of cost-effective strategies that reach all customers. This section describes the history of Austin Water's conservation programs and current water conservation measures. The section also describes the candidate future demand management options that were evaluated and considered as part of the planning process. For information on which candidate demand management options were chosen as recommended strategies, see **Section 9-1**.

AT A GLANCE

- *Water Conservation History*
- *Strengthening of Conservation Programs During Drought*
- *Current Water Conservation Measures*
- *Candidate Future Water Conservation and Demand Management Options Considered*

6.1 Water Conservation History

The first water conservation plan was developed for Austin in 1983. That came in response to dangers of demand exceeding treatment capacity after bonds to expand treatment capacity were not approved by voters and the City kept growing. Per capita water use dropped after the City instituted conservation programs, but total water use continued to rise commensurate with the level of growth. In the 1980s and much of the 1990s conservation was seen more as an emergency measure when there was a danger of exceeding treatment capacity.

Over the years, the City's water conservation efforts have evolved into programs designed to reduce both peak-day demand and average per-capita use, reduce system loss, increase reclaimed and alternative water use, focus more on reducing larger outdoor water use, and encourage innovative technologies and methods.

In 1999 the Austin City Council approved a long-term water supply agreement with the LCRA. That agreement featured a conservation incentive that has proven important as the years have gone by. Under the agreement, Austin prepaid $100 million for water. With this prepayment, the agreement specified that Austin will not pay additional amounts for water until the average of the City's diversions from the Colorado River/Highland Lakes for two consecutive calendar years exceeds 201,000 acre-feet. This was projected to occur around 2016 and the City planned to increase conservation to put the trigger off until at least 2021.

In the years following the LCRA Agreement water usage continued to increase with growth. Per capita usage had dropped during the 1980s, but by the mid- '90s had reached a plateau. This plateau continued into the early years of the next century.

Then came several turning points regarding water conservation in Austin. In 2005 the Water Conservation Division was moved from the Resource Management Department to Austin Water (then still known as the Austin Water and Wastewater Department). Prior to that time the philosophy had been that the conservation function should not be located within the utility because the utility was focused on selling water rather than conserving it.

As the Water Conservation Division was settling in to Austin Water, the utility revived a long-delayed project, Handcox Water Treatment Plant. The City Council, at public urging, wanted to ensure that absolutely every effort was being made to save water before building a new treatment plant. As a result, in 2006 the Council created the Water Conservation Task Force with the charge of reducing peak day water use. The Water Conservation Task Force consisted of the Mayor, two Council Members and four representatives from City boards and commissions (Water Wastewater, Planning, and Resource Management Commissions and the Environmental Board).

The Water Conservation Task Force, working primarily with Austin Water conservation staff, concentrated on reducing peak load and developed 22 new proposed conservation strategies designed to help meet the Water Conservation Task Force's goal of reducing peak demand by one percent (%) per year for 10 years.

The Council ultimately decided to move forward with both the task force recommendations and with building Handcox Water Treatment Plant, after moving the site away from the head waters of Bull Creek. The recommendations of the Water Conservation Task Force were approved by the City Council in May 2007. The Water Conservation Task Force recommendations formed the foundation for dramatic drops in water usage in Austin. In 2008, two-day-per-week watering restrictions went into effect, the citizens of Austin responded, and per capita water use began dropping dramatically.

The Council and the community, however, were determined that Austin's water use drop even faster. In approving the Water Conservation Task Force plan, the Council had created another task force to serve in an advisory role during implementation of the Water Conservation Task Force recommendations. This task force was called the Citizens Water Conservation Implementation Task Force. In 2009 the Council expanded the task force's role, asking it to recommend additional strategies and programs to increase water conservation. The task force subsequently recommended a goal of 140 gallons per capita per day by 2020. Austin Water and the citizens of Austin embraced that goal and it was achieved several years earlier than the 2020 target, as shown in **Figure 6-1**.

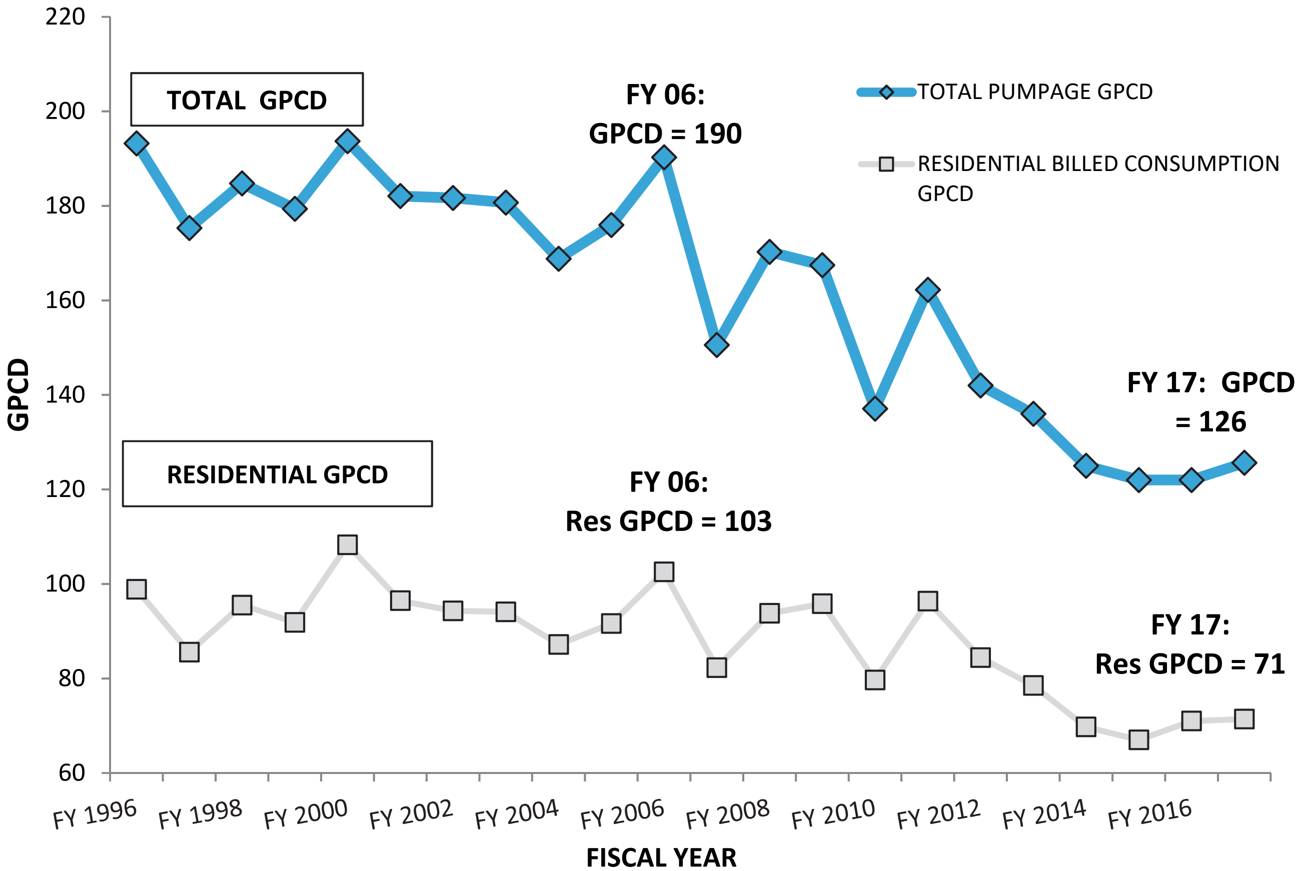

Figure 6-1. City of Austin water use in Gallons Per Capita Per Day (GPCD)

Meanwhile the Central Texas region had entered a historic drought, which began in 2008. Based on the lake level triggers in the Drought Contingency Plan Austin went to Stage 2 one-day-per-week watering restrictions in September 2011 and stayed there until 2016 except for a brief City-Manager ordered return to two-day-per-week in 2012. In 2012 Austin strengthened its Drought Contingency Plan.

The drought represents a new critical period for drought in the basin since the lakes were built. Water volume in the lakes reached the second lowest level in history and would have hit the lowest if not for the conservation response of Austin.

The drought was broken by significant rains in 2015 and 2016. The drought, combined with Austin's strengthened water conservation programs, led to historic drops in water usage in Austin. Since the Water Conservation Task Force recommendations were passed, Austin's per capita water usage has dropped 35%. Even as the City continued its rapid growth, total water use has dropped. The City now uses less water than it did at the turn of the century, although the population has increased by around 300,000 since then. This is illustrated in **Figure 6-2**.

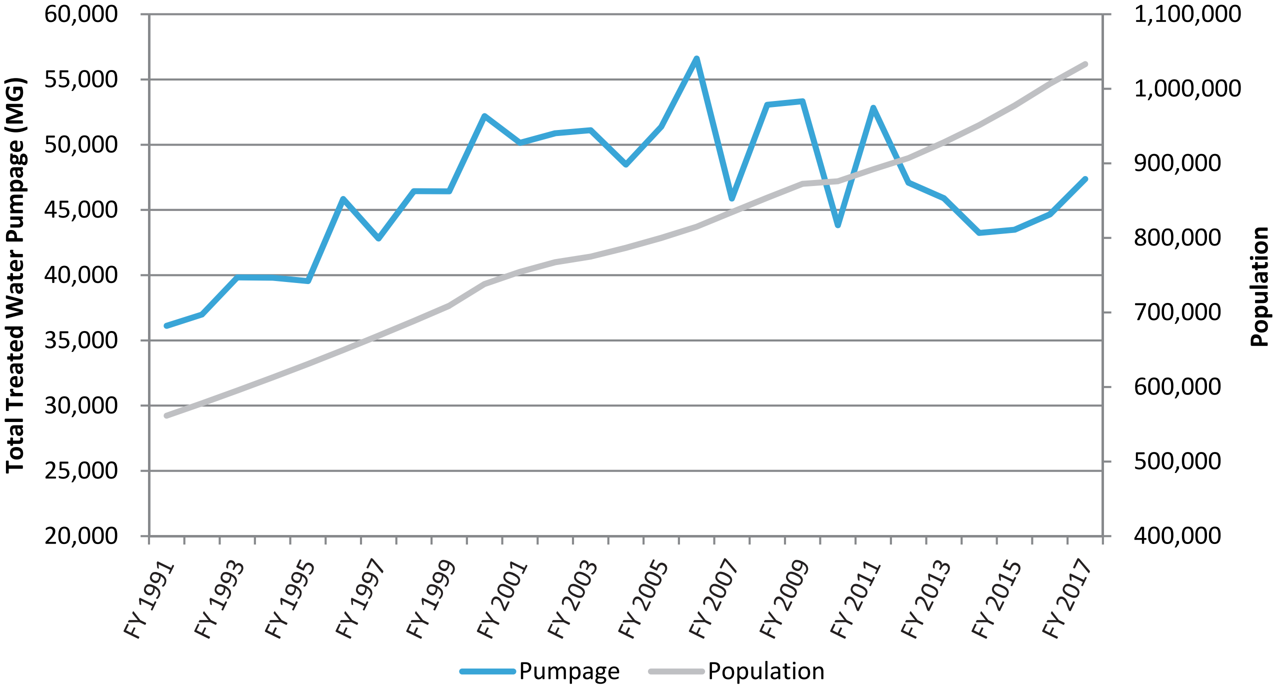

Figure 6-2. Austin's **water demand and population**

After these water conservation gains, the City is not expected to reach the LCRA payment trigger until the 2030s at the earliest – at least 15 years beyond the original projections. Also, the theory that conservation could not be achieved with the Water Conservation function located within the utility proved to not be the case – as all the dramatic water conservation gains occurred after the transfer.

After the drought was broken, Austin Water worked with the citizens of Austin to ensure that per capita water use would never return to pre-drought levels – as has happened in other places. For example, in 2016 Austin Water proposed and the City Council approved maintenance of one-day-per-week restrictions permanently for automatic sprinkler systems, the least efficient form of irrigation. In Conservation stage, the base stage, hose end sprinklers can be used two days per week.

Building on lessons learned during the drought, Austin Water adopted a permanent one-day-per-week watering schedule for automatic irrigation systems. Watering restrictions proved to be the biggest, most reliable water savings measure and the one-day-per-week restrictions, along with positive community response, were critical in keeping the Highland Lakes above emergency levels during the worst parts of the drought. Permanent one-day-per-week restrictions may also be the most cost-effective, long term water demand management strategy to help Austin meet its future water needs, especially if climate change brings more frequent, severe and longer periods of drought. Using conservation to stretch existing water supplies is significantly cheaper and more environmentally sensitive than developing new water supplies and infrastructure. (For more on the rationale of the watering restrictions and savings see **Appendix G**).

6.2 Strengthening of Conservation Programs During Drought

While watering restrictions are the biggest single water saver, Austin Water expanded or created a variety of conservation programs during the drought years. Some of these efforts were directly attributable to the drought. Others were already underway or developed as part of evolving conservation efforts.

In 2010, the Innovative Commercial Landscape Ordinance was brought forward by Austin Water and Watershed Protection and approved by the City Council. The Innovative Commercial Landscape Ordinance serves as both a water quality and conservation tool. As a change to the land development code, it requires new commercial developments to direct stormwater to an area at least 50 percent of the size of the required landscape. Means for conveying stormwater to landscapes vary and range from passive to active methods, several of which can count towards receiving water quality credit. In an effort to limit non-essential irrigation, commercial customers may now choose whether to install permanent irrigation in the peripheral regions of the property, and undisturbed vegetation will count towards the "50 percent requirement."

In 2012, as part of intensified drought response efforts, Austin Water worked with the community, including the car wash industry, to require commercial car washes to meet water efficient equipment standards. Commercial, multi-family, and city municipal facilities with vehicle wash equipment that uses potable water from Austin Water must submit an annual efficiency evaluation. A plumber licensed by the State of Texas must perform the evaluation. Only certified car wash facilities are authorized to operate.

Then in 2014, commercial, multi-family, and city of Austin properties one acre or larger were required to complete an irrigation system inspection every two years. The inspection must be done by an Austin Water authorized Irrigation Inspector.

Also in 2014, Austin adopted several changes to city codes and ordinances to facilitate the use of auxiliary water (e.g., rainwater, gray water, reclaimed water, A/C condensate) while still protecting public health and safety and consistent with state law. The changes were the result of a two-year evaluation that included input from a special task force, the public, and a consultant hired by the city to review these codes recommend changes. Changes included removing unnecessary impediments to the use of alternative onsite and reclaimed water in conjunction with changes to relax backflow protection and permitting requirements for these systems. Code changes also included the mandatory reclaimed water hookup and the installment of AC condensate recovery and use systems for new commercial and multi-family facilities as well as the reuse of cooling tower blowdown water and use of AC condensate for cooling tower makeup water. As a part of implementing these changes, Austin Water developed technical guidance documents for residential and commercial onsite alternative water use systems to help customers install systems consistent with the new provisions and take advantage of available rebate programs and code requirements.

In addition, Austin Water provided comments in support of state legislation in 2015 (HB 1902) and related changes to Texas Commission on Environmental Quality rules contained in 30 Texas Administrative Code 210 adopted in December of 2016 to further facilitate the use of all auxiliary waters, including industrial reclaimed wastewater.

Beginning in 2015, Austin required new commercial developments and redevelopments within 250 feet of a reclaimed water main to connect for irrigation, cooling, and other significant non-potable water uses. Reclaimed water is treated wastewater and is about 20% of the cost of potable water. Those facilities that are "purple pipe" ready can begin to take advantage of the reduced rates, even before the reclaimed water line has reached their location. The reclaimed water initiative is an integral part of the City's water conservation program and saves on average about 1.2 billion gallons of drinking water a year.

Austin Water also has some decentralized wastewater treatment plants and a program to consider and evaluate the use of decentralized and on-site wastewater systems in appropriate situations, including for golf course irrigation.

While the conservation measures discussed in this subsection so far are regulatory in nature, Austin Water also worked to strengthen voluntary programs as well. For example, in 2015, Austin Water worked with the Home Builders Association of Greater Austin and other local entities in developing and publishing "Sensible Landscapes for Central Texas – A Guide for Home Builders and Homeowners." This guidance document includes landscape design, regionally appropriate plant selection, landscape and soil management as well as irrigation design and maintenance for home builders and owners for water efficient lawns and landscapes suitable for the Central Texas region. The guidelines include limiting the amount of unnecessary sod and water-intensive plants commonly included in builders' landscaping packages, and instead, offering more sustainable and environmentally sensitive native and adapted species as an option for homeowners. All Home Builders Association of Greater Austin members have adopted these guidelines and provide this landscape option to new home buyers.

A related, longer running program is Grow Green. It is a partnership between the City of Austin and the Texas AgriLife Extension Services. Grow Green offers fact sheets with landscaping, design, installation, and maintenance recommendations to promote low-water use landscapes. It also provides a Native and Adaptive Plant Guide with information about plants that thrive in the Central Texas climate. Austin Water uses this plant guide in approving suitable plants for its landscape conversion incentive programs.

Continuing to build its conservation efforts after the drought, in 2017, Austin Water launched the Cooling Tower Water Efficiency Program, which includes registration and annual inspection requirements. These actions bring increased awareness of cooling tower requirements, use efficiency, and savings. The program assists in identifying potential water conservation upgrades, promotes reclaimed and alternative on-site sources of water for cooling tower make-up and other non-potable water demands, calls attention to innovative cooling systems that use less or no water, and pinpoints rebates and incentive opportunities. By obtaining baseline information on the number, size, type, water source, and water efficiency compliance requirements, the program aims to assess the effectiveness of the city's cooling tower requirements and identify any needed code or program modifications.

Cooling tower water efficiency standards and equipment requirements have been in place in Austin since 2008. At the time of adoption, it was estimated they would save about 100 million gallons per year—enough to serve 1,500 households, and save approximately $1.6 million per year in water and wastewater charges. Additional incentives and requirements to use reclaimed and alternative on-site sources of water could further reduce potable water demand and its associated costs.

In 2017 the region experienced a dry year and 2018 has been relatively dry as well, meaning the area could be entering another drought. It is such events that Austin's Drought Contingency Plan, its water conservation programs, and the Water Forward plan are intended to address. With one of the most extensive water conservation programs in the nation, Austin plays a leadership role in conservation at the regional, state and national levels, and shares experiences and resources with other water providers to promote conservation innovation and effectiveness. This includes but is not limited to:

- participating in Senate Bill 1 regional planning efforts to meet future water needs in the lower Colorado River basin (Region K);

- developing best management practices and legislative recommendations for the state Water Conservation Advisory Council;
- developing new water supply and reuse strategies through the City of Austin/Lower Colorado River Authority Water Partnership;
- sharing ideas and information among Central Texas Water Efficiency Network members;
- exchanging information with other LCRA Firm Water Customers and providing comment to LCRA on its water supply management and contract programs;
- partnering in research and studies with other entities around the nation under the auspices of the Water Research Foundation and Alliance for Water Efficiency; and
- enhancing programs through education, training and presentations given at conferences and events of the American Water Works Association.

Austin has been engaged in regional partnerships for quite some time and its programs are often emulated by surrounding communities.

Austin Water's conservation program has received numerous awards over the years from state and national organizations. Awards received within the last five years include:

- 2013 Promising New Program from the American Council for an Energy Efficient Economy and the Alliance for Water Efficiency;
- 2014 Water Conservation and Reuse Award, Texas Section of the American Water Works Association
- 2014 Municipal Blue Legacy Award in Municipal Water Conservation, Texas Water Conservation Advisory Council
- 2015 Municipal Blue Legacy Award in Municipal Water Conservation, Texas Water Conservation Advisory Council; and
- 2016 highest scoring water conservation program in Texas, Texas Living Waters Project (Lone Star Chapter of the Sierra Club, the National Wildlife Federation, and Galveston Bay Foundation).
- In July 2018, Austin Water's conservation programs achieved Platinum certification on the Alliance for Water Efficiency's G480 Leaderboard. The Alliance's grade of Platinum certifies that Austin Water is in 100% compliance with all recommended best practices for an effective conservation program. With this certification, Austin Water became only the fifth agency in the nation to complete the rigorous certification process, only the third to achieve Platinum certification, and the largest participating agency to date.
- The G480 standard (Water Conservation Program Operation and Management) is part of the American Water Works Association's G-series of voluntary management standards that demonstrate outcome-oriented practices and policies that go above established regulations and set a benchmark for excellence. As an independent industry advocate, the Alliance for Water Efficiency evaluates submissions from member agencies to award a platinum, gold or silver certification that shows the degree of compliance with AWWA's G480 standard.

An overview of Austin's water conservation incentive programs including those implemented during the early years are summarized below in **Table 6-1**.

Table 6-1. Summary of historical Austin Water conservation incentive programs

Water Conservation Program	Equipment or Service Issued	Program Description	Implementation Date /End Date
Landscape Irrigation Audits	Free Audit and hose timers	The City offers free landscape irrigation audits to both residential and commercial customers who water excessively outdoors. In 1998, the City offered free hose timers to customers who irrigated with hose-end sprinklers.	1985, since modified and still in effect
Toilet Rebate Program	Rebate for Ultra-low flush* toilets	The City offered a rebate to residential customers to encourage replacing old toilets with Ultra-low flush* models. The program initially offered a rebate of $60-$80 per toilet then increased to $200 per toilet depending on the model purchased.	1991 through June 2010
Free Toilet Program	Free Ultra-low flush* toilets	The City offered the Free Toilet Program to encourage the replacement of older less efficient models with Ultra-low flush* models. This program was initially limited to low income residential customers, but was expanded to all residential customers, multi-family and commercial customers.	1994 through December 2011
High-Efficiency Washing Machine Rebate Program	Rebate for high-efficiency washing machines	The City offers the High-Efficiency Washing Machine Rebate for water-and-energy efficient washing machines identified by the Consortium for Energy Efficiency. The initial rebate was for $100 but was lowered to $50 in 2010.	1998 through 2013
Industrial, Commercial, and Institutional Rebate/Bucks for Business	Free audit	The City offers a free service to commercial customers, where water conservation staff auditors would evaluate a business' water consumption and use and suggest ways to reduce water use.	1996, since modified and still in effect
Rainwater Harvesting Rebate/Rain Barrel Sales	Rebate for rain barrels	The City offers rebates for rainwater harvesting, which included a $30 rebate for purchasing approved rain barrels and rebate of up to $500 for implementing higher-volume pressurized rainwater systems. In 2001, the Water Conservation Department started to supply barrels to its customers at a reduced and subsidized price of $60 per barrel. The Rain Barrel Sales Program ended in 2009.	2000, since modified and still in effect
Xeriscape Program/Water Wise Landscape	Rebate for using native plants and turf grasses	The City initially launched an education program to promote the principles of Xeriscaping to emphasize the practice of using plants there were native or adapted to the climate in order to reduce or even eliminate the need for irrigation. In 1994, the program was modified, and a residential rebate was initiated to encourage the installation of plants and turf grasses that were better adapted to the climate.	1984 through 1998
Residential Landscape Conversion Incentive - Lawn Remodel Option	Rebate to replace turf with Bermuda or Buffalo grasses	The City offered residential customers a one-time opportunity to replace water-thirsty turf with Bermuda or Buffalo grasses. Rebates for this program ranged from $10 to $30 for every 100 square feet of turf converted.	October 2011 through September 2013
Restaurant Water Waste Program	Free audit and 1.6 gallons per minute spray valves	Water Conservation Department staff members preformed water audits for restaurants and replaced old spray valves with new 1.6 gallons per minute valves.	2004 through January 2006

*Ultra-low flush toilets use 1.6 gallons per flush or less

6.3 Current Water Conservation Measures

Austin Water achieves water conservation progression through the passing of codified ordinances and a variety of programs implemented through the Water Conservation Division, including, but not limited to: rebates for water-saving equipment; dispersion of free equipment; and activities aimed at increasing public education on the importance of water conservation. The following section provides an overview of current water conservation measures; a more comprehensive summary can be found in **Appendix G.**

6.3.1 Cost-Benefit Methodology and Integration into Water Resource Planning

This section includes an overview of Austin Water's current water conservation cost benchmarks and cost-benefit methodology. With the information developed as part of the Water Forward planning process, Austin Water plans to develop updates to the performance benchmarks and cost-benefit methodology.

Austin Water generally funds the water conservation programs from their annual Operation and Maintenance (O&M) budget through rate revenues collected. Due to the state's cost-of-service requirements for public utilities (see Texas Water Code §§13.182, 13.183, and 13.184), Austin Water generally uses the utility cost-benefit approach when issuing money from customer revenues to private individuals. With the cost-benefit approach, rebate amounts are based on a direct, quantifiable, and comparable benefit to rate payers of the utility. The utility cost-benefit approach is commonly used by major municipal utilities.

Benefits to the utility rate payer from funding conservation rebate programs include reducing cost of service increases due to increased water/wastewater treatment and distribution costs and delaying the cost of securing additional water supplies in response to growth. Programs with a less than favorable quantifiable cost-benefit ratio may still be used on a temporary or pilot basis to evaluate new or innovative technology, penetrate hard-to-reach markets, increase public awareness, or achieve water savings faster in response to drought or other water shortages.

Austin Water quantifies and documents actual or estimated water conservation cost/savings for its various water conservation measures and incentive programs to determine their potential cost-benefit of achieving the City's conservation goals. This includes the development of digest summaries for each program and use of the Alliance for Water Efficiency Conservation Tracking Tool to measure and track the program's effectiveness in meeting these goals. The estimated water savings are not only based on national and state studies (i.e. EPA, Water Research Foundation, Alliance for Water Efficiency, Texas Water Development Board), but heavily reference specific local information. These digests are continually updated as new information becomes available or to reflect changes in the program and/or the City's codes and ordinances. Information from the digests is also used to determine whether to add, modify, or terminate a program. Depending on the study or research conducted in the Austin area, the digest information is ranked according to confidence level, which determines how frequently the information needs to be reviewed and updated. Factors considered by Austin Water when developing a rebate program typically include whether the program achieves following:

- Helps achieve the utility's quantified or qualitative conservation goals;
- Acts as an incentive to get customers to do what they otherwise would not have done without the rebate, rather than simply subsidizing a business or customer sector;
- Provides comparable value to the utility in terms of reduced or avoided costs related to water and wastewater treatment and distribution and development of new supply;

- Is cost-effective to the utility and the customer;
- Gathers needed data on new and innovative technology;
- Facilitates access to limited or hard-to-reach markets;
- Protects water quality and the environment; and,
- Increases public awareness on the need to conserve.

Austin Water evaluates many aspects of encouraging water efficiency, including rebates, tax incentives, free high efficiency plumbing fixtures, behavior modification tools (i.e. 'smart' meters) and related customer portals, as well as the public relations value to the customer. Coordination with other incentive programs offered for economic development or energy conservation also significantly enhances the effectiveness of the program.

Since the 1980's, Austin Water has used integrated water resource planning concepts to evaluate and prioritize water supply options based on the most cost effective, environmentally sensitive strategies. Austin has effectively used water conservation as a strategy to delay and reduce additional water supply contract costs.

Recently, the utility's focus has been on short-term incentives for new water-saving technology and comprehensive changes that have greater water savings, rather than on providing smaller residential rebates. Austin Water developed regulations that embed conservation into new development requirements and discourage excessive water use, created programs targeting high water users, and continues marketing efforts to increase consumer awareness of water use patterns and choices. The utility also conducts pilot projects and participates in national research projects to identify future conservation strategies and savings potential.

The rebate programs and financial incentives are tied to specific conservation goals, such as the reduction of peak-day demand from outdoor usage that results in increased treatment capacity and distribution costs, or reducing average-day demand (year-round indoor and commercial use) to avoid the costs of developing additional, long-term water supplies. Based on 2010 information, Austin Water has calculated the cost in terms of net present value for constructing additional treatment and distribution, which is approximately $4.00 per 1,000 gallons and $0.64 per 1,000 gallons, respectively. As a result, the rebate amount seeks to 'purchase' a comparable benefit from the conservation measure to the rate payer to avoid these costs. Austin Water periodically updates these goals and costs through its water planning efforts.

Austin Water's conservation measures and programs are intended to address the following goals:

- Reducing peak daily demand by one percent per year over a ten-year period or by 22 million gallons per day (MGD) by 2017;
- Reducing average per capita water use to no more than 140 gallons per capita per day (GPCD) by 2020;
- Delaying the annual average use of 201,000 acre-feet of water for two consecutive years to avoid triggering additional payment under the 1999 Lower Colorado River Authority (LCRA) water agreement;
- Reducing summer peaking factor at or below 1.5 by 2035;
- Promoting innovation in water conservation while pursuing cost-effective strategies; and,

- Maintaining an Infrastructure Leak Index below 3.0.

Austin Water has already surpassed a number of their water conservation goals. Austin Water has exceeded the peak day reduction goal of one percent per year and reached a five-year rolling average per capita water use of 126 GPCD in 2017. The utility lowered its average per capita water use to 140 GPCD within three years of adopting the 140 Plan and further decreased the consumption to less than 140 GPCD in 2014. In addition, the 2014 Austin Water Resource Planning Task Force was created by City Council in April 2014 to evaluate the City's water needs, to examine and make recommendations regarding future water planning, and to evaluate potential water resource management scenarios for Council consideration. A key recommendation of the 2014 Task Force was the development of a new integrated water resources plan.

6.3.2 Conservation-Oriented Tiered Rate Structure

To keep costs affordable for essential uses and discourage excessive use, Austin Water has a five-tiered inclining block rate structure for single-family residential customers. Water rates for commercial and multi-family customers do not increase with the volume of water used; however, these customers have peak and off-peak rates to encourage seasonal conservation. Wholesale customers and several large volume/industrial customers have individual rates established through negotiated contracts.

Austin Water has one of the steepest inclining block residential rate structures in the country, which has resulted in a dramatic reduction in the amount of water sold at the highest tiers. This, along with revenue stability fees, have helped Austin Water maintain revenue stability during drought when water demands are reduced by additional restrictions while still allowing customers to save money by reducing water use.

6.3.3 Ordinances

Austin’s water conservation ordinances apply to commercial businesses and residences throughout the city. A comprehensive chronology of Austin’s water conservation codes and ordinances adopted from 2007 through 2017 follows.

2007

- Automatic irrigation systems prohibited from watering between 10:00 a.m. and 7:00 p.m. year-round.
- Allowed no more than two times per week residential watering from May thru September; commercial watering is permitted year-round.

2008

- Submeters required in new multi-family and mixed-use facilities.
- High-efficiency urinals using 0.5 gallons per flush required for new construction and retrofits.
- Commercial food waste and garbage disposal units prohibited.
- Liquid ring surgical and dental vacuum pumps prohibited.
- New or replacement cooling towers must achieve at least five cycles of concentration and have conductivity controllers, makeup and blowdown meters, overflow alarms, and drift eliminators.
- Car wash equipment efficiency and facility certification requirements.
- Automatic irrigation system design standards for new commercial and multi-family residential properties.

- Commercial landscape soil depth and plant requirements adopted.

2009

- Fifth tier residential water rate for use above 25,000 gallons per month.

2010

- High-efficiency toilets using 1.28 gallons per flush or less required for facilities built or renovated on or after October 1, 2010; waterless urinals allowed.
- Innovative Commercial Landscape Ordinance requiring new commercial developments to capture storm water to prevent runoff and for landscape irrigation.

2011

- Stormwater retention and irrigation required for new commercial properties.

2012

- Year round two times per week watering schedule for all customers.
- Morning automatic irrigation system watering times reduced to a window from midnight to 5:00 a.m.
- Mandatory reclaimed water hook-up.
- Graywater Allowances.

2013

- Revised rate structure to compress residential rate tiers including 5th tier to now apply to residential use above 20,000 gallons per month.
- Mandatory irrigation system audits every two years for commercial/multi-family/city properties over one acre.
- Mandatory annual vehicle wash facility efficiency assessment for commercial, multi-family and city facilities and related efficiency requirements.
- Administrative enforcement process/penalties for water use violations.
- Requirement that water be served only at the customer request at restaurants.
- Hotels must have towel/linen exchange programs.

2016

- Year-round watering one time per week for automatic irrigation systems.

2017

- Requirement to install air conditioning (AC) condensate collection systems for new commercial and multi-family development with a combined cooling capacity equal to or greater than 200 tons.
- Require registration and inspection of all cooling towers using potable water to ensure that affected cooling towers are achieving a minimum of five cycles of concentration, have makeup and blowdown sub-meters, a conductivity controller, a drift eliminator, and an overflow alarm. Also ensure that new towers of 100 tons or greater are connected to the Building Energy Management System or Utility Monitoring Dashboard and either using reclaimed or onsite alternative sources such as AC condensate as a part of their makeup water or are beneficially reusing blowdown water.

- Require all steam boilers to have conductivity controllers to control blowdown (for 50 horsepower or greater, this must be connected to the Building Energy Management System or Utility Monitoring Dashboard), a cold-water make-up meter, a steam condensate return system, and a blowdown heat exchanger to transfer heat from blowdown to the feed water.
- Adopted plumbing requirements consistent with the 2015 International Residential Code for residential facilities and the 2015 Uniform Plumbing Code for commercial facilities with local amendments including 1.28 gallons per minute for commercial kitchen pre-rinse spray valves instead of the current requirement of 1.6 gallons per minute.

6.3.4 Proactive Enforcement

In 1983, the City of Austin enacted its first water use management ordinance, which implemented watering restrictions in response to treatment system constraints. In 2001, the City enacted a permanent water waste prohibition making it a Class C misdemeanor (max. $500 fine) to waste water through poorly designed irrigation systems or failure to repair leaks. At that time, Austin Water added enforcement staff to make regular patrols and field inspections to actively enforce water use ordinances. In 2012, Austin enacted administrative penalties to be assessed on water bills after notice and opportunity for an administrative hearing to streamline the enforcement process without the need to go to municipal court.

Austin Water implements and enforces a comprehensive Water Conservation Code (Chapter 6-4 of City Code) that applies to all customers. The goal of this code is to balance conservation of the water supply with the desire to sustain the local economy and the natural surroundings, tree canopy and vegetation, that are unique to Austin. One of its largest water savings measures is a year-round restriction that limits use of automatic irrigation systems to no more than once a week and hose-end sprinklers to no more than twice a week.

6.3.5 Residential Customer Programs

Austin Water currently offers a variety of free indoor and outdoor conservation tools and rebates to help residential customers save water. These free tools include: water-efficient showerheads, kitchen and bathroom faucet aerators, soil moisture meters, water saver hose meters, and sunlight calculators. Rebates and programs offered by Austin Water include:

- "Controller 101" Workshops – Residential customers may attend a free hands-on workshop to review how irrigation controllers work and find out about hidden features and options that can help save water and money.
- Dropcountr - Free home water use reports available by mobile app and/or by internet can help save customers water and money by providing historical water use and rate tiers, comparisons to similar and efficient homes, water saving tips and links to applicable rebate programs.
- Irrigation System Evaluations and Rebates – Free Irrigation System Evaluations by a licensed irrigator from Austin Water for customers with in-ground sprinkler systems that have used either more than 25,000 gallons in one month or more than 20,000 gallons in two consecutive months. Customers can also receive rebates of up to $400 for improving the water efficiency of their irrigation system.
- Landscape Survival Tools Rebate - Residents can receive up to $180 for mulch, compost and yard aeration to help retain soil moisture and more efficiently water their lawns.

- Low Income Water Efficiency Assistance – Austin Water partners with Austin Energy to provide free high efficiency aerators and showerheads to low income customers through AE's Weatherization Assistance Program. AW is currently developing its own direct assistance plumbing repair program for low-income single-family customers as well as a new grant program for water lateral repair for low income single family customers similar to the current program for wastewater laterals.
- Pool Cover Rebate – Residents can receive a rebate for half of the purchase price up to $50 for a new manual pool cover or solar rings, or $200 for a new permanent, mechanical pool cover.
- Pressure Regulating Valve Rebate – Residents can receive a rebate of up to $100 for the purchase and installation of a Pressure Regulating Valve.
- Rainwater Harvesting Rebate – Residential, multi-family, and commercial customers or qualifying water providers can receive up to $5,000 for purchasing equipment to capture rainwater.
- Watering Timer Rebate – Residents can receive a rebate of $40 or 50% of the cost of purchasing up to two hose timers.
- WaterWise Landscape Rebate – Residential customers may receive $35 for every 100 square feet (minimum 500 square feet) of converted landscape with a maximum rebate of $1,750.
- WaterWise Rainscape Rebate – Schools and homeowners can receive up to $500 for installing landscape features that direct and retain rainwater/runoff, such as berms, terraces, swales, rain gardens, porous pavement, and infiltration trenches.

6.3.6 Incentive Programs for Homeowner Associations and Multi-Family Facilities

Austin Water offers the following incentive programs for homeowner associations and multi-family facilities:

- Multi-Family Efficiency Program – Austin Water partners with Austin Energy to provide free high efficiency aerators and showerheads to multi-family facilities with low income tenants through AE's Multifamily Efficiency Program.
- Pressure Reduction Valve Rebate – Multi-family Facilities can receive a rebate of up to $500 for the purchase and installation of Pressure Reduction Valves.
- Rainwater Harvesting System Rebate - Multi-family facilities can receive up to $5,000 for purchasing equipment to capture and use rainwater.
- Waterwise Landscape Rebate – homeowner associations may receive $35 for every 100 square feet (minimum 500 square feet) of converted landscape with a maximum rebate of $1,750.

6.3.7 Incentive Programs for Businesses

Austin Water offers a variety of water conservation incentive programs for businesses.

- 3C Business Challenge - A "desk top" water efficiency auditing tool that allows businesses the opportunity to show their commitment to saving water and gain information about ways to reduce water usage. The challenge also provides tools and information to help them incorporate sustainable practices and links to related rebate programs.
- "Bucks for Business" Commercial Rebate - This program offers rebates for equipment and process upgrades that save water and exceed city water efficiency requirements of up to $100,000. Rebates offered under this program include but are not limited to: air conditioner (AC) condensate recovery,

ozone treatment systems for large commercial laundry facilities, cooling tower efficiency upgrades, process water reuse and recycling systems.

- Commercial Kitchen Rebate – This program offers up to $2,500 for Environmental Protection Agency WaterSense/Energy Star labeled commercial kitchen equipment.
- Green Building Program – AW participates in Austin Energy's Green Building (AEGB) Program by providing information on water efficiency related code requirements, potential water use efficiency best management practices, alternative water recommendations, water use benchmarking data, and information on available incentive and rebate programs that can be used to achieve the desired or required rating. Certain City of Austin ordinances and programs (for example, the S.M.A.R.T. Housing Program) mandate that a particular AEGB star rating be achieved. In addition, an AEGB rating can be required through zoning ordinances of projects located in defined areas of the city such as high density/growth areas.
- Industrial, Commercial and Institutional Audit Rebate – Industrial, commercial and institutional customers may receive up to $5,000 for an independent audit of their facility to identify potential water and cost savings.
- Irrigation System Improvement Rebates – Austin Water offers a rebate of up to $5,000 for a central computer irrigation controller system. Additional rebates are available under this program for flow sensors, multi-stream nozzles, and master valves.
- Property Assessed Clean Energy (PACE) - Austin Water assists the Travis County Property Assessed Clean Energy loan program in identifying eligible water conservation opportunities and retrofits that also qualify for an Austin Water rebate.
- Rainwater Harvesting System Rebate – Industrial, commercial and constitutional customers may receive up to $5,000 for purchasing equipment to capture and use rainwater.
- Reclaimed Water – Austin Water is expending its distribution system to provide less expensive municipal treated wastewater rather than potable water to meet non-potable water needs such as irrigation and cooling towers.
- Small Business – AW partners with Austin Energy's Small Business Program that helps identify ways for small commercial and non-profit customers to reduce water and energy use and related rebate programs.
- WaterWise Hotel Partnership Program - Offers free recognition for lodging facilities that use water-efficient measures and practices.

6.3.8 Water Loss Control

One of the primary conservation goals of Austin Water's utility is to manage water loss due to leaks in their distribution system. Austin Water launched "Renewing Austin" which invests $125 million in a five-year program to replace aging water lines. Austin Water has experienced a record number of water leaks because of extreme drought conditions. Austin Water has inspected more than 1,500 miles of water lines for leaks using acoustic technology. A five-year program of inspecting the entire distribution system has been completed and the information gained from these inspections is now being used to enhance Austin Water's active leak detection program. Austin Water has also initiated an accelerated leak response and repair program that has proven highly successful, with most leaks now repaired in one day or less and almost 90% of emergency leaks responded to within three hours.

A common performance indicator for real water losses from a supply network is the Infrastructure Leakage Index. The Texas Water Development Board recommends an Infrastructure Leakage Index between 3.0 and 5.0. Austin Water currently maintains a goal to achieve an Infrastructure Leakage Index of 3.0 or less (lower scores are better).

6.3.9 Advanced Metering Infrastructure Pilot Program

Recently, Austin Water has been investigating and studying the cost and feasibility of implementing Advanced Metering Infrastructure (AMI) and has implemented a pilot program, which involves installing 'smart' meters in a small portion of the city which can automatically report daily, hourly, or more frequent water usage to the utility and the customer. AMI can identify customers with the largest potential to conserve water by evaluating advanced analytics to provide precise water conservation targets. These calculations provide individual water conservation recommendations directly to customers based on climate, parcel size, vegetation coverage and other information derived from aerial imaging surveys. Austin Water has procured a consultant to assist in scoping the replacement of all retail customer meters with smart meters. Additionally, Austin Water has applied for low-interest loan funding for AMI through the State Water Implementation Fund for Texas.

6.3.10 Water Conservation Public Education Programs

Austin Water has several public educational programs to promote the City's conservation incentive programs and water efficiency measures, as well as increase customer awareness of water usage and leaks. The following list provides a summary of the water conservation educational programs.

- WaterWise Partner Program – a program that recognizes commercial customers that have incorporated efficiency measures into the design of new properties or that have made comprehensive water-efficiency upgrades in the facilities.
- Dowser Dan Show – Targeting kindergarten through fourth grade students, the Dowser Dan show educates children and teachers about water conservation and reaches approximately 18,000 students each year.
- Mobile Classroom – The mobile exhibit is housed inside a 40-foot trailer and utilizes interactive exhibits and hands-on activities, functioning as a mobile science museum.
- Speakers Bureau – Allows area groups to schedule Austin Water staff members to speak on topics including, but not limited to, conservation measures, irrigation, leak detection, and water waste.
- WaterWise Irrigation Professional Seminar – Seminars that include information on water-efficient irrigation systems, water conservation programs, the mandatory watering schedule, electrical troubleshooting, irrigation auditing, and turf grass watering requirements so that licensed professional irrigators in the area can earn credits toward their license renewal.
- Annual Austin Water/LCRA Industrial, Commercial and Institutional Water Conservation Technical Workshop – An annual free water conservation technical workshop on water saving measures, technologies, and rebate programs for industrial, commercial and institutional customers, facility managers and engineers.
- "Controller 101" Workshops – Residential customers may attend a free hands-on workshop to review how irrigation controllers work and find out about hidden features and options that can help save water and money.

- Irrigation System Maintenance for Efficiency – Free workshops to teach basic maintenance skills to maximize performance and efficiency of irrigation systems to manage landscapes and to reduce watering costs.
- Online Information, Electronic Newsletters and Social Networking – Covers conservation related topics via www.WaterWiseAustin.org, Facebook, Twitter, NextDoor, YouTube, and an e-Newsletter that reaches approximately 30,000 customers.

6.4 Candidate Future Water Conservation and Demand Management Strategies Considered

In support of the IWRP, candidate future water conservation and demand management strategies were identified to evaluate their potential to help the city meet their long-term water supply needs. Demand management measures were identified based on input from the Water Forward Task Force members, Austin Water staff, the public, the consulting team, previous task force recommendations, and the Water Conservation Study[8] conducted through the Office of Sustainability.

From a "blue sky" list of 65 options, an initial list of 25 options was developed. Of the initial 25 options, two were re-categorized as supply side options, two were determined to be continuing best management practices, and three were determined to be necessary implementation components to other options. The remaining options were combined or split out into one or more options, thereby reducing the number of options for screening to thirteen. An overview of the demand management screening process is included in **Appendix H**.

Through the options screening process, a list of 10 options were identified to be carried forward to the option characterization process. During the characterization process, the list of ten was further refined into a list of 12 with each of several alternative water options being listed separately. (See **Section 3** for discussion on the screening process). A summary of the 12 resulting options, which were carried forward and used in the portfolio development and evaluation process, is provided in **Table 6-2**.

Table 6-2. Candidate future water conservation and demand management strategies considered

Option Number	Option Name	Annual Community Unit Cost Per AF of Savings
D1	Advanced Metering Infrastructure	$2,800
D2	Water Loss Control Utility Side	$3,690
D3	Commercial, Industrial, and Institutional Ordinances (Cooling Towers and Steam Boilers)	$71
D4	Water Use Benchmarking and Budgeting	$21
D5	Landscape Transformation Ordinance	$23
D6	Landscape Transformation Incentives	$96

[8] Water Conservation Study, September 30, 2015, prepared by Maddaus Water Management, Inc, for City of Austin, Office of Sustainability, and Austin Water Utility. Posted in Austin Integrated Water Resource Planning Community Task Force regular meeting materials from October 6, 2015: http://www.austintexas.gov/edims/document.cfm?id=240290

Option Number	Option Name		Annual Community Unit Cost Per AF of Savings
D7	Irrigation Efficiency Incentives		$202
D8	Alternative Water Ordinances and Incentives	Lot Scale Stormwater Harvesting	$5,510 - $5,062
D9		Lot Scale Rainwater Harvesting	$2,619 - $2,960
D10		Lot Scale Graywater Harvesting	$3,898 - $10,666
D11		Building Scale Wastewater Reuse	$12,692
D12		Air Conditioning Condensate Reuse	$2,702

The following sections provide a short description of the candidate options. A more comprehensive summary for each option providing the conceptualized yield, the overall community cost, and assumptions made in developing each of the final demand management options can be found on the options characterization sheets in **Appendix J**. For information on candidate demand management options that were chosen as recommended strategies, see **Section 9-1**.

6.4.1 Advanced Metering Infrastructure (AMI)

Advanced Metering Infrastructure (AMI), also known as smart meters, record near real-time water use and provide that information to customers through an easy-to-use interface such as a web or a smart phone application. The AMI option targets all customers and sectors. Savings are primarily achieved through identification of customer leaks, behavior modification, and other water-saving opportunities that are realized because of: (1) improving customer meter accuracy, (2) reducing unauthorized consumption, (3) reducing data transfer/archive errors, and (4) reducing data billing errors.

6.4.2 Utility-Side Water Loss Control

This option represents an expansion of Austin's existing water loss program to reduce leaks in the water distribution system. While the target Infrastructure Leakage Index (ILI) for Austin Water is sustaining an ILI at or below 2.7, from fiscal year 2013 to 2015 Austin Water lost an amount of water which equates to an infrastructure leakage index of 3.26. The Water Forward recommendation includes an aggressive leak detection, correction, and prevention program to reduce the ILI to 2.7 by 2020 and further reduce and sustain a 2.0 ILI from 2040 to 2115. The savings analysis for this option focused on four pillars of real water loss control: (1) active leak detection, (2) improving response time to leaks, (3) pressure management, and (4) pipeline and asset management selection, installation, maintenance, renewal, and replacement. This option represents savings from reductions in real losses and has potential synergies with strategies like Advanced Metering Infrastructure (AMI) which may also target apparent losses. Real losses are almost entirely comprised of leaks in the distribution system whereas apparent losses are almost entirely comprised of meter inaccuracies. This option targeted both new and existing development in all sectors.

6.4.3 Commercial, Industrial, and Institutional (CII) Ordinances

There are over 400 cooling towers in Austin which are designed to remove heat from a building or facility for the purposes of heating, ventilation, and air conditioning. In the process of cooling air, some water is evaporated, and the rest is recycled through the cooling tower. The greater the number of cycles that the water is recycled through, also known as cycles of concentration, the more efficient the cooling tower becomes.

This ordinance requires: (1) all existing and new cooling towers to meet same efficiency equipment standards required for new and replacement towers since 2008 (makeup and blowdown submeters, conductivity controller, drift eliminator and overflow alarm) and achieve 5 cycles of concentration; and (2) all steam boilers in new development to have conductivity controllers, makeup meters, steam condensate return systems and blowdown heat exchangers for steam boilers. These code changes have already been approved by City Council in June 2017 and implementation is underway. This ordinance targets existing development HVAC uses in the multi-family residential, commercial, and City of Austin sectors.

6.4.4 Water Use Benchmarking and Budgeting

Water use benchmarking and budgeting uses standards to "benchmark" how much water buildings of a certain size and type would be expected to use. Based on these benchmarks, a "water budget" can be created to track water use in a given building and help users meet their water benchmark. This option would be implemented in two phases.

Phase I

- Potential approaches to implement this requirement for pre-and post-development of multi-family and commercial facilities will be evaluated and include public outreach, review by Boards and Commissions and Council action.
- As part of this program:
  - Developers will provide information about all water-using equipment and fixtures associated with the site (including counts), proposed water sources, irrigated area, landscaped area, and other water-use, site, and building characteristics.
  - City staff will provide water efficiency related code requirements, potential water use efficiency best management practices, alternative water recommendations, water use benchmarking data, and information on available incentive and rebate programs for new and existing development. Implementation of the measure will look for ways to tie into the Service Extension Request, Austin Energy's Green Building program, the city's Energy Conservation Audit and Disclosure program, and AMI customer portals for multi-family and commercial use.

Phase II

- Based on the water use benchmarking data developed through these programs, this strategy will be expanded in the future to include a water use budget for new development constructed after 2025 (compliance mechanism to be determined).

6.4.5 Landscape Transformation Ordinances

Landscape transformation is a process of transitioning from traditional landscaping practices to those that rely on regionally appropriate plants and have reduced supplemental water needs, with an emphasis on landscape function. Note that the current Landscape Ordinance has existing requirements for landscaped areas, plant selection, and irrigation systems for Commercial and Multifamily properties. This option would include development of a new ordinance to require water efficient landscapes be installed with new single-family residential development, thus savings from this option would primarily come from the single-family residential sector. Implementation of this option could include implementing turf grass area, irrigated area, and/or irrigation area limitations. If implemented, more detailed ordinance concepts and language will be developed through subsequent implementation processes with future additional public input opportunities.

6.4.6 Landscape Transformation Incentives

This option focuses on incentives for existing development to encourage reductions in water needs for outdoor irrigation through regionally appropriate landscapes with an emphasis on landscape functionality. The current WaterWise landscape rebate offers $35 for every 100 square feet ($0.35/square feet) converted, with a maximum rebate of $1,750 per property. The current program has traditionally had a low participation rate. Implementation of this option could include increasing WaterWise landscape rebates for single-family residential and multi-family residential and implementing a new WaterWise landscape rebate for commercial beyond City of Austin Land Development Code requirements.

6.4.7 Irrigation Efficiency Incentives

Outdoor water use comprises over 22% of the water currently used by Austin Water customers with most of that water used for landscape watering. Over 89,000 homes and over 5,000 businesses have irrigation and sprinkler systems, which often are programmed to turn on at certain times of the day without regard to weather or plant water needs. This option focuses on expanding existing Austin Water rebate programs to incentivize "smart" irrigation controllers that would improve irrigation system efficiency by responding to leaks, high pressure, and soil moisture and also make flow data accessible.

6.4.8 Alternative Water Ordinance and Incentives

This option would require or incentivize on-site (building-scale) alternative water use of rainwater, stormwater, graywater, blackwater, and/or air conditioning condensate through a mix of ordinances and incentive programs. While these alternative water sources can already be used on-site and related codes and ordinances already exist, this "Alternative Water Ordinance and Incentives" option in Water Forward targets new ordinances and incentives aimed at use of these alternative water supplies. Information for Austin Water customers who are considering collecting rainwater, graywater, stormwater, air conditioning condensate or other non-sewage originated waters on their property (onsite), and reusing them for non-potable applications is available on Austin Water's On-Site Water Use Systems[9] web-page.

This Water Forward option would require development of new ordinances to require or programs to incentivize implementation of these projects. If implemented, more detailed incentive program and ordinance concepts and language will be developed through subsequent implementation processes with future additional public input opportunities. Further information for each of the lot-scale options is provided in the following sections. More detail on the decentralized options is provided in the characterization sheets in **Appendix J** and **Appendix K.**

6.4.8.1 Lot Scale Stormwater Harvesting

Lot scale stormwater harvesting involves the capture and storage of stormwater runoff generated from impervious surfaces (including roof water) within the lot boundary of multi-family residential or commercial development. The collected stormwater is then used to supply a range of onsite demands. Implementing stormwater harvesting in new developments provides an opportunity to plumb the building with internal connections for toilet flushing, clothes washing or to cooling towers. Retrofitting existing buildings with internal connections to a dual supply source can be cost prohibitive and practically difficult. It is assumed for the purposes of this plan that stormwater harvesting at the lot scale for existing development would be

[9] http://www.austintexas.gov/page/onsite-water-reuse-systems

used solely for irrigation/landscaping. Where used for irrigation/landscaping only, it is assumed that there will be filtration. Where used to supply indoor non-potable end-uses, it is assumed UV disinfection is also required. Storage is assumed to be an underground tank/cistern.

Two scenarios were considered for establishing typical yields and costs for this option:

- A proportion of newly constructed multi-family and commercial buildings have an underground stormwater harvesting tank supplying outdoor end uses.
- A proportion of newly constructed multi-family and commercial buildings have an underground stormwater harvesting tank supplying outdoor end uses and indoor (non-potable) end uses via dual pipe network.

6.4.8.2 Lot Scale Rainwater Harvesting

Rainwater in urban areas is often routed to a storm drain pipe network and discharged to streams and flood control channels that lead to the ocean. Typically, this runoff carries with it pollutants and trash that have been picked up along parking lots, streets, and other impervious surfaces. Rainwater harvesting (lot scale) involves the capture and storage of roof water to supply a range of onsite demands at the lot/building scale.

Three scenarios were considered for establishing typical yields and costs for this option. The options include:

- A proportion of newly constructed single family, multi-family and commercial buildings have a rainwater tank supplying outdoor end uses.
- A proportion of newly constructed single family, multi-family and commercial buildings have a rainwater tank supplying outdoor end uses and indoor (non-potable) end uses via dual pipe network.
- A proportion of newly constructed single-family buildings have a rainwater tank supplying all end uses (i.e. potable supply).

6.4.8.3 Lot Scale Graywater Harvesting

Graywater harvesting is defined as the reuse of water from the laundry, shower and bath at the lot/unit scale to meet non-potable demands. There are two main types, graywater diversion devices and graywater treatment systems. Graywater diversion is untreated, and therefore cannot be stored and can only be used to supply sub-surface irrigation. They typically include a surge-tank and may include a filter. The system may be gravity fed or require a pump, depending on the site. Graywater treatment systems include treatment, storage and a pump. The treated graywater can be reused to supply outdoor end use demands as well as non-potable indoor end use demands (toilet flushing and clothes washing).

Two scenarios were considered for establishing typical yields and costs for this option (proportion referring to a portion of the project opportunities/systems identified in the analysis). The options include:

- A proportion of newly constructed single family, multi-family and commercial buildings have a graywater diversion system supplying outdoor end uses.
- A proportion of newly constructed single family, multi-family and commercial buildings have a graywater treatment system supplying outdoor and indoor end uses.

- Both scenarios assume back-up supply from the centralized water distribution system.

6.4.8.4 Lot/Building Scale Wastewater Reuse

Building Scale Wastewater Re-use (or 'Blackwater Treatment Plants') is defined, for the purpose of this project, as involving the onsite capture and treatment of the wastewater stream generated from a building for onsite reuse via a dual (purple) pipe system to supply outdoor demands (irrigation/landscaping) and non-potable indoor demands (toilets and potentially also laundry and cooling towers). Blackwater treatment plants are most commonly installed in commercial buildings and high density, multi-story multi-family residential buildings. Treatment may be one or a combination of membrane bioreactor, moving bed biofilm reactor, passive (e.g. engineered wetlands) or other systems, with microfiltration or ultrafiltration, and ultraviolet disinfection and/or chlorination. Wastes (sludge) from the treatment process are typically discharged back to the wastewater network.

A single scenario was considered for establishing typical yields and costs for this option. The scenario considers that a proportion of newly constructed multi-family and commercial buildings have a blackwater treatment system supplying outdoor and non-potable indoor end uses (proportion referring to a portion of the project opportunities/systems identified in the analysis). Two critical assumptions are made for blackwater systems:

- Blackwater reuse is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone.
- All scenarios assume back-up supply from the centralized water distribution system.

6.4.9 Air Conditioning Condensate Reuse Ordinance

This option, which is already in code, is focused on the collection of air conditioning (AC) condensate water from air handling units (AHUs) from new development with a cooling capacity over 200 tons. The condensate water could be reused for beneficial use for any non-potable application including (but not limited to): cooling tower makeup water, irrigation, and indoor toilet flushing. AW will continue to monitor the success of this ordinance.

6.4.10 Other Options Re-categorized in the Planning Process

Of the initial demand management options, there were several that were identified as continuing best management practices rather than new options, and three were identified as necessary implementation components to other options. These include the following:

- The option to require or incentivize government-recognized energy and water efficiency-labeled residential and commercial fixtures was determined to be a "*continued best management practice*" to be included in demand offsets separately (i.e., off-the-top reduction from the baseline forecast that does not require evaluation through the IWRP process) and reflects Austin Water's longstanding programs to incentivize or require these fixtures. Water saving estimates from this best management practice option and passive water conservation from water efficient fixtures are shown in **Table 6-3** and are incorporated into the Water Forward baseline demand projection.

Table 6-3. Water Savings Estimates from Passive Conservation and Best Management Practices

2020	2040	2070	2115
0	4,033 AFY	15,699 AFY	54,355 AFY

- Three options were determined to be "*implementation components*" of a successful conservation program and were not further evaluated or screened. These measures include water rates and fees to promote water use efficiency while maintaining affordability, customer education enhancements, and use of social media programs and web-based content to promote conservation. While these types of programs are indeed critical to a successful conservation program, they may not necessarily have significant water savings of their own, but rather assure the successful implementation of other programs.

The options described in this subsection are considered options that are being implemented as part of Austin Water's ongoing commitment to implement demand management and conservation measures.

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SECTION 7: WATER SUPPLY STRATEGIES

The Colorado River is Austin's core water supply through a combination of state-granted water rights and firm water supply contracts with LCRA. The Colorado River has a series of reservoirs, known as the Highland Lakes, that are used by LCRA to store water for municipal, industrial, recreational, and agricultural water needs as well as to meet in-stream flow requirements throughout the river down to Matagorda Bay on the Texas gulf coast. The following section describes the current water supply infrastructure associated with Austin's existing Colorado River water supply. The section also describes the candidate future water supply options evaluated and considered as part of the planning process. For information on which candidate supply options were chosen as recommended strategies, see **Section 9-1**.

AT A GLANCE

- *Current Water Supply System*
- *Candidate Future Water Supply Options Considered*

7.1 Current Water Supply System

The following sections describe Austin Water's current surface water and reclaimed water systems. It should be noted that additional future water and wastewater plant expansions along with major collection and distribution system improvements will also be required to provide water and wastewater services through the 100-year planning horizon.

7.1.1 Surface Water System

Utility customers are supplied with drinking water from three surface water treatment plants, which draw water from the Colorado River as the river runs through Lake Travis and Lake Austin. The City's combined water treatment capacity is currently 335 MGD.

As described in **Section 2.2**, Austin's main sources of water supply are its own run-of-river water rights, backed up by a firm water supply contract with the LCRA. In 1999, Austin entered into a long-term firm water supply agreement with LCRA for 325,000 AFY. Austin paid $100 million in prepaid reservation and use fees for 325,000 AFY of firm water supply. Austin's annual municipal diversions were approximately 149,000 AFY in 2017. Additional water payments by Austin to LCRA will be triggered when average annual water diversions for two consecutive years exceeds 201,000 AFY. The current contract runs through the year 2050 with an option for Austin to extend the agreement to 2100. The IWRP assumes that the City will extend its current LCRA contract to 2100 and be able to enter into an agreement with LCRA to renew it at that time.

7.1.2 Reclaimed Water System

Wastewater is treated at two major wastewater treatment plants with a combined capacity of 150 MGD and various small-scale treatment plants. Austin Water operates and manages an expanding reclaimed water system which provides reclaimed water to customers for a variety of non-potable uses. The system currently has approximately 59.3 miles of reclaimed water pipe covering three different service areas and supplies approximately 4,000 AFY of water to 120 metered customers annually. Bulk reclaimed water is also available to customers at three bulk fill stations[10].

7.2 Candidate Future Water Supply Options Considered

In support of the IWRP, future water supply options were identified and evaluated to determine their potential to help the City meet identified water supply goals. A total of 21 water supply options were identified through a collaborative process, involving Austin Water staff, the current Task Force, the 2014 Austin Water Resource Planning Task Force report, and the public. These options were then screened as described in **Section 3** and **Appendix I** to identify a total of 13 supply options for further characterization and use within the portfolio development process. These 13 water supply options are summarized in **Table 7-1** and discussed in more detail in the following section.

Table 7-1. Candidate future water supply options considered

Option Number	Option Name	Option Type	Annual Unit Cost ($/AF)
S1	Aquifer Storage and Recovery	Storage / Surface Water	$1,053
S2	Brackish Groundwater Desalination	Desalination / Groundwater	$2,690
S3	Direct Non-Potable Reuse (Centralized Reclaimed Water System) - Master Plan	Reclaimed Water	$1,229
S3-A	Direct Non-Potable Reuse (Centralized Reclaimed Water System) - Expanded System beyond Master Plan	Reclaimed Water	$6,127
S4	Direct Potable Reuse	Reclaimed Water	$2,204
S5	Indirect Potable Reuse (IPR) through Lady Bird Lake and Capture Local Inflows to Lady Bird Lake	Reclaimed Water and Local Inflows	$605
S6	LCRA Additional Supply	Surface Water	$352
S7	Off Channel Reservoir	Storage / Surface Water	$846
S8	Seawater Desalination	Desalination	$3,032
S9	Distributed Wastewater Reuse	Reclaimed water / Decentralized System	$9,612
S10	Sewer Mining	Reclaimed water / Decentralized System	$3,030 - $6,444
S11	Community Scale Stormwater Harvesting	Decentralized	$1,522 - $3,233
S12	Community Scale Rainwater Harvesting	Decentralized	$9,612
S13	Conventional Groundwater Operated by Austin Water	Groundwater	$1,119

The following section provides a brief summary for each of the candidate options. A comprehensive summary for each option providing the projected yield, cost, and assumptions made in developing each of the final water supply options can be found in **Appendix J**. For information on candidate supply options that were chosen as recommended strategies, see **Section 9-1**.

[10] http://www.austintexas.gov/sites/default/files/files/Water/Water_Reclamation/locationsbulkfill.pdf

7.2.1 Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is a strategy in which water can be stored in an aquifer during wetter periods and recovered at a later date. Storing water underground can improve drought preparedness in the same way storing water in a reservoir does, while eliminating the water loss due to evaporation that occurs in open above-ground reservoirs. Although some losses may occur using ASR through leakage or migration, the losses are much smaller than surface evaporation on an above-ground reservoir of similar size. ASR is currently being used by cities in Texas, such as San Antonio, Kerrville and El Paso. Exploring ASR as a potential water storage option was a recommendation of the 2014 Task Force.

Austin had previously initiated feasibility analyses to better understand the geology and hydrogeology characteristics of the Northern Edwards and Trinity Aquifers to evaluate potential for recharge and extraction. These analyses found that regulatory restrictions would prevent injecting into or transecting the Edwards Aquifer, making it very difficult to proceed with ASR concepts in the Edwards or Trinity Aquifers in Travis County. Also, The Carrizo Wilcox Aquifer has more favorable geologic properties for storage of water that would increase the amount of water that is able to be recovered from the aquifer. In Water Forward, the Aquifer Storage and Recovery concept that was evaluated was located in the Carrizo Wilcox Aquifer. This option includes facilities to pipe treated drinking water from Austin's distribution system to an ASR wellfield for injection and storage in the Carrizo-Wilcox aquifer. Facilities also include a pump station and storage tank to convey recovered water from the ASR wellfield to the city's distribution system.

Aquifer Storage and Recovery facilities would be planned to serve solely a storage function, allowing for maximization of surface water resources during drought periods. This concept is in keeping with the Water Forward guiding principle of maximizing locally available water resources. Site selection will depend on favorable hydrogeology to fulfill the ASR facility's intended storage purpose. In implementing this option, Austin Water would work to develop and test a pilot facility to assess potential site characteristics and ensure that the strategy's objective to store surface water in and recover surface from the aquifer is achievable. The ASR option is in no way intended to be a strategy to develop native groundwater. To be clear, the ASR injection and recovery wells are in no way intended to pump native groundwater from the Carrizo Wilcox Aquifer and convey that water to Austin via a transmission pipeline. Potential implementation issues for ASR include understanding the potential migration of stored water and mixing with the native groundwater, protection of stored surface water from recovery by others, and navigating changing regulatory requirements for ASR.

7.2.2 Brackish Groundwater Desalination

Brackish groundwater is defined as groundwater containing between 1,000 and 10,000 milligrams per liter (mg/L) of total dissolved solids. Desalination is often required to remove dissolved solids from brackish groundwater, or brackish water can be blended with another low-total dissolved solids source water to reduce total dissolved solids levels. The specific process used to desalinate water varies depending upon the total dissolved solids, the temperature, and other physical characteristics of the source water, but always requires disposal of concentrate, called brine, that has a higher total dissolved solids content than the source water. The City of El Paso has been treating 27.5 MGD of brackish groundwater since 2007, while the San Antonio Water System started up a 12 MGD brackish groundwater desalination project in 2016. Exploration of brackish groundwater desalination for the Water Forward process was a recommendation of the 2014 Task Force.

There are several aquifers within Central Texas which could be considered for brackish groundwater, including the Edwards, Trinity, Gulf Coast, and Wilcox Aquifers. Facilities associated with this option include the wellfield, pump station, storage tank, and reverse osmosis treatment facilities. Evaporation ponds were assumed to be used for brine disposal. Potential implementation issues for brackish groundwater desalination include concentrate disposal and blending with current supply sources.

7.2.3 Direct Non-Potable Reuse (Centralized Reclaimed Water System)

Direct non-potable reuse water is also known as recycled water, reuse water, or reclaimed water. This is water that has been treated to Type 1[11] standards as defined by the Texas Commission on Environmental Quality for non-drinking water uses such as irrigation, cooling, manufacturing, and toilet flushing. As described in **Section 7.1.2**, Austin Water has a Water Reclamation Initiative underway, which currently supplies approximately 4,600 AF per year. The direct non-potable reuse option considered as part of the IWRP would expand this program to provide additional non-potable water supply through the centralized reclaimed water network. This expansion was conceptualized to occur in two phases over the 100-year planning horizon.

The first phase would include implementation of the current Reclaimed Water Infrastructure Master Plan (2011) and the program described in the 2016 Lower Colorado Regional Water Plan[12]. Facilities included in this phase consist of a total of nine reclaimed pump stations, ten storage facilities and approximately 110 miles of reclaimed pipeline transmission main. Potential additional facilities may also be required to meet 2040 yield targets.

The second phase would focus on direct non-potable use in anticipated growth areas based on demand model estimates between 2070 and 2115. As part of this high-level analysis, facilities included in this phase would include a total of seven reclaimed pump stations, six storage facilities and approximately 66 miles of reclaimed pipeline transmission main. Future modeling and analysis would be required to develop detailed infrastructure requirements as part of this option. Additional cost was included to reflect community costs associated with dual-plumbing which is required for indoor non-potable water use. Potential implementation issues for non-potable reuse include the need for voluntary customer participation to increase utilization, challenges with public opinion, and the need for public education on water safety.

7.2.4 Direct Potable Reuse

Direct potable reuse represents a relatively new approach to maximizing available water resources that involves advanced treatment of wastewater effluent for the purposes of meeting drinking water needs. Although new, several communities in Texas have implemented direct potable reuse projects to address their water supply needs. A full-scale project was implemented by the Colorado River Municipal Water District for the City of Big Springs in 2013 (2 MGD) and the City of Wichita Falls implemented a temporary project in 2012 (10 MGD) as a drought response strategy.

The option evaluated for this study would directly convey highly treated reclaimed water through a pipe from one treatment train at South Austin Regional WWTP to the Ullrich WTP. The effluent would be treated on-site at Ullrich WTP using a new advanced water treatment train, potentially including microfiltration and reverse osmosis. The treated water would then be blended with raw water prior to being pumped back to the headworks of Ullrich WTP for treatment through the conventional water treatment process to produce potable drinking water. Although direct potable reuse offers benefits such as a climate resilient supply, it presents significant regulatory uncertainty, which can impact when and if direct potable reuse projects can

[11] https://www.tceq.texas.gov/assistance/water/reclaimed_water.html#use

[12] https://www.regionk.org/planning-documents/2016-region-k-water-plan/

be implemented. Potential implementation issues for direct potable reuse include regulatory uncertainty challenges with public opinion, and the need for public education on water safety.

7.2.5 Indirect Potable Reuse with Capture Local Inflows to Lady Bird Lake

7.2.5.1 Indirect Potable Reuse (IPR) through Lady Bird Lake

Indirect potable reuse (IPR) was evaluated in Water Forward as an emergency strategy to be used infrequently during only the most severe drought situations. During deep drought periods, when combined storage of the Highland Lakes is lower than at any point in the historical period of record, IPR would be an emergency supply to meet potable water demands. The term “indirect” in the name of this option means that rather than conveying highly treated reclaimed water directly to a water treatment plant, reclaimed water is conveyed indirectly through a natural buffer like a stream to the point of final treatment to potable drinking water quality. The City of Wichita Falls recently implemented an IPR project in response to drought which sends up to 16 million gallons per day (MGD) of wastewater to Lake Arrowhead, which provides a buffer prior to treatment at the surface water treatment plant.

The representative option evaluated for this plan would convey highly treated reclaimed water from one treatment train at South Austin Regional WWTP to Lady Bird Lake through a reclaimed water transmission main and subsequently divert this water through a new intake pump and piping system downstream of Tom Miller Dam to be conveyed to Ullrich WTP. This concept could utilize a reclaimed main from South Austin Regional WWTP to Lady Bird Lake that is already included in the Reclaimed System Master Plan. This approach would supplement water releases from Lakes Buchanan and Travis to extend water supplies during severe drought only. This option is a drought strategy that would be recommended for implementation only in the event of 400,000 AF of combined storage or less in Lakes Buchanan and Travis, which is after the lakes have dropped below emergency and crisis levels. This option would be utilized for the shortest possible time to meet urgent supply needs. Should this option be required to be utilized in a deep drought emergency, Austin Water would perform outreach to educate and notify the public about the use of the strategy, develop robust standards to guide operations for the period when the strategy is in use, perform monitoring to ensure drinking water quality standards are met, and monitor water quality in Lady Bird Lake. Potential implementation issues for indirect potable reuse include challenging permitting process, challenges with public opinion, and the need for public education on water safety.

7.2.5.2 Capture Local Inflows to Lady Bird Lake (infrastructure also included as part of IPR, above)

As the IPR option would only be used on an infrequent basis during severe drought conditions, the intake and pumping components could be used on a more frequent basis to capture spring flows to Lady Bird Lake when available. Lady Bird Lake inflows would be conveyed to Ullrich WTP for treatment and distribution. The average annual yield for the Capture Local Inflows to Lady Bird Lake strategy is estimated to be approximately 3,000 AFY. Water availability for the Capture Local Inflow to Lady Bird Lake option would be intermittent and seasonal, with availability more likely in the months of November through February when downstream agricultural irrigation operations are offline and environmental flow requirements are the lowest for the year. Potential implementation issues for Capture Local Inflows include that water availability would be intermittent and seasonal.

7.2.6 Additional Supply from Lower Colorado River Authority (LCRA)

Water from the Colorado River through its water rights and firm contract with LCRA is the primary source of all raw water for Austin; this water is treated and used to meet Austin’s demands. This option would involve securing additional supply from the LCRA through a new or amended contract. Currently LCRA has approximately 54,600 acre-feet of water available for contracting (50,000 acre-feet of which is the LCRA Board of Director's reserve amount and is subject to contracting approval by the LCRA Board of Directors). The additional LCRA supply would be accessed using existing and future treatment and transmission infrastructure. There could be additional supply available for contracting over time as LCRA plans to continue to develop additional supplies in the future. Potential implementation issues for contracting more LCRA supply include uncertainties regarding future availability of water.

7.2.7 Off-Channel Storage Reservoir

This strategy would involve the construction of a new off-channel reservoir in the Austin region that Austin Water would own and operate. An off-channel reservoir is constructed away from the main stem river channel and is filled by pumping water in from the main river channel to the reservoir. This type of reservoir requires additional infrastructure, such as impoundment structures and pump stations to move water from the main river channel.

The off-channel reservoir option being considered would likely use source water from the Colorado River during times when water is available. The approximate size of this reservoir would be up to 25,000 AF. An evaporation suppressant could be applied during summer months to reduce water lost through evaporation. The off-channel reservoir could also be used conjunctively with ASR, allowing further storage and evaporation management opportunities. Potential implementation issues for an off-channel storage reservoir include significant land area requirements and that the yield of the reservoir is dependent on the reliability of the source water.

7.2.8 Seawater Desalination

Desalination is the process of removing dissolved solids from seawater or brackish groundwater, often by forcing the source water through membranes under high pressure. The desalination process generates waste product known as brine that has a higher total dissolved solids content than the source water. Disposal of the brine may take the form of an injection well, evaporation beds, or an ocean outfall diffuser. This option would involve sourcing water from the Gulf of Mexico and treating it via a desalination plant where dissolved solids are removed by forcing the source water through membranes at high pressure. This option could be implemented through a regional partnership approach. Potential implementation issues for seawater desalination include challenging permitting and regulatory issues and a high per-unit cost due to the energy intensity.

7.2.9 Community Scale Distributed Wastewater Reuse

Distributed Wastewater Reuse is the collection of effluent from the wastewater system in localized new development areas (completely separate from the centralized wastewater collection system), treatment to Type 1[13] quality at a small wastewater treatment plant, and reuse at the community, or neighborhood, scale via a reclaimed water distribution system that would be separate from the centralized reclaimed water system. This strategy would provide water for non-drinking water demands such as irrigation, landscaping, cooling, toilet, and potentially also clothes washing. Facilities may be located at the site of existing local WWTPs, or at new potential sites. Distributed wastewater treatment plants evaluated for Water Forward were sized to manage peak wet weather flows into the wastewater collection system and also to meet demand for reclaimed that would be produced by the plants. Reuse from this option is not considered for

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[13] https://www.tceq.texas.gov/assistance/water/reclaimed_water.html#use

outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone. Initial implementation steps for this strategy will include additional refinement of geospatial analysis and potential project identification. Later steps will include design and construction of projects. Potential implementation issues for distributed wastewater reuse include challenges with public opinion, the need for public education on water safety, and changing behavior to promote usage of the reuse water.

7.2.10 Community Scale Sewer Mining

Sewer mining (or local wastewater scalping) is defined as the extraction of wastewater from the existing centralized wastewater collection system, treatment to treatment to non-drinking water quality at a small wastewater treatment plant, and reuse at the community scale via a reclaimed water distribution system that would be separate from the centralized reclaimed water system. A sewer mining treatment plant would be situated close to both the demand and to the sewer extraction point, to reduce piping and pumping costs. This option can be located either within existing open space or within a new development. This strategy would provide water for non-drinking water demands such as irrigation, landscaping, cooling, toilet, and potentially also clothes washing. Wastewater treatment plant wastes (sludge) from the treatment process are assumed to be discharged back to the centralized wastewater collection system for subsequent treatment at the downstream WWTPs. Potential implementation issues for sewer mining include challenges with public opinion, the need for public education on water safety, and changing behavior to promote usage of the water.

7.2.11 Community Stormwater Harvesting

For the purpose of this project, stormwater harvesting is defined as the collection of excess stormwater runoff from urban areas (e.g. impervious surfaces including roads, pavement, and roofs), for treatment and reuse for irrigation/landscaping or reuse for dual pipe systems at the community, or neighborhood, scale.

Implementing stormwater harvesting in new developments provides an opportunity to plumb buildings with purple pipe internal connections for toilet flushing, clothes washing or to cooling towers. Retrofitting existing buildings with internal connections to a dual supply source can be cost prohibitive and/or practically difficult, and so it is assumed for the purposes of this study that stormwater harvesting for existing developed areas would be used solely for irrigation/landscaping of public open space. Where used for irrigation/landscaping only, it is assumed that the stormwater will undergo filtration. Where used to supply indoor non-potable end-uses, it is assumed UV disinfection is also required. Storage is assumed to be an underground tank/cistern or more typically open storage such as a wet-pond. Potential implementation issues for community stormwater harvesting include changing behavior to promote usage of the water.

7.2.12 Community Rainwater Harvesting

For the purpose of this project, community or neighborhood-scale rainwater harvesting is defined as the collection of roof water from new development areas from a dedicated (dual) roof water drainage network for storage at a central downstream location, for treatment and reuse via dual pipe systems at new developments at the community scale. This is assumed to require UV disinfection. Storage is assumed to be an underground tank/cistern. Potential implementation issues for community rainwater harvesting include changing behavior to promote usage of the water.

7.2.13 Conventional Groundwater

There are several groundwater aquifers, including the Edwards, Trinity, and Carrizo-Wilcox aquifers in the region. This option would rely on fresh groundwater sourced from the Carrizo-Wilcox to the east of Austin.

This option is considered an imported water supply option and assumes that Austin Water would acquire groundwater permits through the requisite Groundwater Conservation District(s) and develop all source water, treatment and disposal infrastructure. Potential implementation issues for obtaining conventional groundwater supply include challenging permitting and regulatory issues and blending with current supply sources and chemical interaction between waters.

7.2.14 Other Options Re-Categorized in the Planning Process

The following options were originally considered for screening but were later determined to fall outside of the typical option classifications. “Lake Austin Operations” is recommended in this plan as a best management practice option while “Regional Partnerships” is categorized as a potential implementation option.

- **Lake Austin Operations:** Instead of being screened, this option was determined to be a best management practice for drought response. The operational drought strategy involves varying the Lake Austin operation level during non-peak months (Oct-May) and after combined storage in the Highland Lakes falls below 600,000 AF. This strategy would allow local usage to draw the lake down to a maximum of three feet in order to catch runoff from local storm events. This approach would allow for use of this runoff, as opposed to excess runoff spilling over Tom Miller Dam to flow downstream. This strategy was assumed as part of the baseline water supply for the IWRP.

- **Regional Partnerships:** This option was determined to be an implementation strategy of other supply options on the screening list and was not screened individually. Regional partnership strategies could be considered when implementing water supply options.

SECTION 8: PORTFOLIO EVALUATION

In order to meet the goals of the IWRP process, including ensuring long-term resiliency, supply diversification, and sustainability in meeting the identified needs, groupings of options called portfolios were developed and evaluated. Portfolios are different combinations of options aimed at meeting needs. Dozens of potential portfolios can be developed by grouping various options. Thus, a structured evaluation process for defining and evaluating portfolios, described in more detail below, was used.

The portfolio evaluation process began with a method using themes around which options were combined to form initial portfolios, such as "maximizing conservation" or "maximizing local control". Thematic portfolios are often designed so that they push boundaries, as illustrated in **Figure 8-1**, thus allowing trade-offs to be more easily seen as part of evaluation. For example, if an initial portfolio maximized water reliability, what would be the impact on cost or environmental impact? If another initial portfolio maximized local control, what would be the impact on implementation or social benefits? For the IWRP, five initial thematic portfolios were developed centered around maximizing certain objectives that were informed by public feedback to see relative trade-offs.

Figure 8-1. Initial portfolios centered around themes to push boundaries and see trade-offs

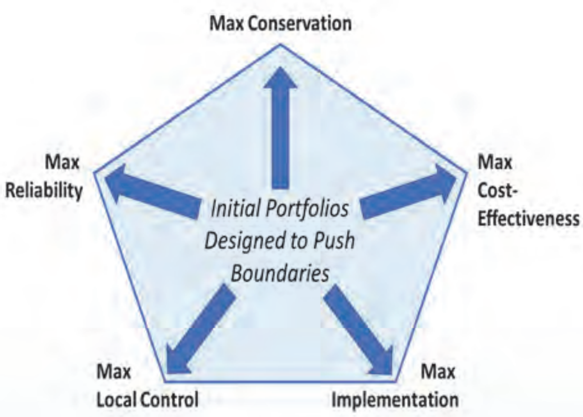
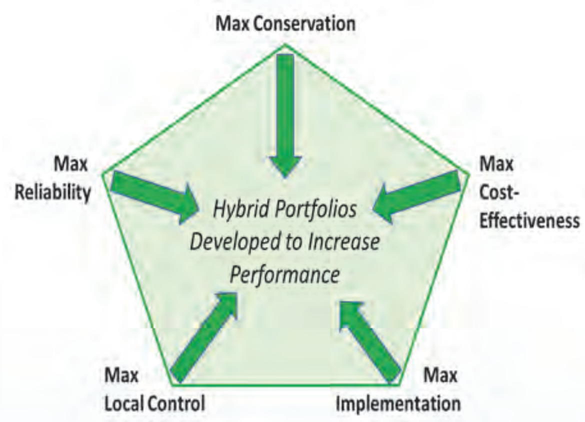


Figure 8-2. Process to develop hybrids



Each of these initial portfolios were comprehensively assessed in terms of how well they provided water supply, environmental, economic, and social benefits. In addition, the portfolios were evaluated in terms of implementation risks and benefits. Based on evaluation of the initial portfolios, two hybrid portfolios were developed (see **Figure 8-2**). The intent of the hybrid portfolios was to extract the best-performing traits from the initial portfolios while minimizing those aspects that were less desirable—thus creating new portfolios with higher performance.

AT A GLANCE

- *Portfolio Definitions*
- *Raw Performance Scorecard*
- *Portfolio Rankings*
- *Summary of Findings*

8.1 Portfolio Definitions

As presented in the intro, five initial portfolios were developed around objective-based themes. The themes were based on public feedback received through the Water Forward outreach process and represent maximizing portfolio performance for certain key objectives without worrying about the performance of another important objective. This approach allowed the initial portfolios to push the boundaries of the plan objectives to see the outcomes of portfolios with a single-objective focus, which allowed for a clearer analysis of trade-offs between objectives. The five initial portfolio themes were developed based on Austin Water, community, and Task Force input. Two hybrid portfolios were then developed which represent a more balanced approach to meeting multiple objectives. Descriptions of the portfolio themes are provided in **Table 8-1.**

Table 8-1. Portfolio themes and descriptions

Portfolio Theme	Description
Maximize Cost-Effectiveness	Options with the lowest unit costs ($/acre-foot/year) were generally selected.
Maximize Local Control	Options which are locally sourced or which Austin Water would have control over the projects and the water supplies in terms of cost, yield, development, and operations were generally selected.
Maximize Implementation	Options that have a higher degree of potential implementation success were generally selected.
Maximize Reliability	Options that provide higher supply reliability and resiliency in terms of climate and hydrology were generally selected.
Maximize Conservation	Options that conserve water and maximize the reuse of treated wastewater and stormwater were generally selected.
Hybrid 1	Built from the initial Maximize Conservation portfolio with the intent of increasing water supply benefits, while not significantly impacting the environmental and social benefits. This was achieved by increasing storage and reuse options.
Hybrid 2	Built from the initial Maximize Reliability portfolio with the intent of increasing environmental and social benefits, while reducing cost and risk. This was achieved by increasing demand management options, scaling back on seawater desalination and eliminating direct potable reuse.

The IWRP process included a key step to quantify projected future identified water needs. Quantifying projected future identified water needs (discussed in more detail in **Appendix F**) was important in that it established the volume of water the plan needed to address through demand management and water supply strategies. In addition to identifying the volume of projected need, the Water Forward process identified the type of projected need—Type 1, Type 2, or Type 3. The different types of need are described in more detail in **Appendix F** and in **Section 5.1** but can briefly be described as needs associated with water restrictions during drought (Type 1), needs associated with regional shortages in deep drought (Type 2), and need associated with water demands above Austin Water's existing water supply contract with LCRA (Type 3). Identifying different "types" of need provided more control when selecting options for portfolios, as certain options were defined as being able to meet certain "types" or need—for example, building-scale wastewater reuse as defined in Water Forward cannot be used to meet Type 2 needs since it does not provide a new potable water source, and Type 2 needs need to be met by options that can provide potable water.

After identifying the volumes and types of needs, goals for portfolio performance related to water supply reliability were developed to assist in grouping options into portfolios. The initial portfolios were developed with the following goals:

1. Meet all identified water needs (Types 1, 2, and 3) reliably for the period of record with historical climate (hydrologic scenario A).
2. Meet most identified water needs (Types 1, 2, and 3) for the period of record with climate change (hydrologic scenario B).
3. Assess how well identified water needs (Types 1, 2, and 3) are met with extended period with climate change (hydrologic scenario D).

The hybrid portfolios were developed with the following goals:

1. Meet all identified water needs (Types 1, 2, and 3) reliably for the period of record with historical climate and with climate change (hydrologic scenario A & B).
2. Meet most identified water needs (Types 1, 2, and 3) with extended period with climate change (hydrologic scenario D).

For reference, **Table 8-2** shows the baseline identified water needs over time, as estimated by Austin Water's WAM for the hydrologic scenario B (period of record hydrology with climate change).

Table 8-2. Baseline 12-month identified water needs (AFY) for the period of record with climate change

Water Need Type	2020	2040	2070	2115
Type 1 - Water need in an amount equal to the estimated savings from City's Stage 4 Drought Contingency Plan implementation [1]	3,000	10,600	15,400	24,800
Type 2 - Fifty percent of the amount of water Austin expects to receive from LCRA supply when combined storage in Lake Travis and Buchanan is extremely low (less than 450,000 acre-feet or about 22% full)[2]	6,000	20,400	77,000	93,600
Type 3 – Amount of water above Austin Water's current LCRA contract of 325,000[1]	0	0	0	170,400
Total Baseline Water Needs	**9,000**	**31,000**	**92,400**	**288,800**

AFY = acre-feet per year
[1]Need can be achieved with new demand management and water supply options.
[2]Need can only be achieved with new water supply options resulting in readily available potable water.

Table 8-3 indicates which demand management and water supply options were included in each portfolio, while **Figure 8-3** shows the maximum annual water yield for portfolio options in the year 2115. Additional detail on the cost and yield of each option is included in **Appendix J**, and overall portfolio cost and yield metrics can be reviewed in **Appendix L**. Note that the options included in each portfolio are in addition to the City's current Colorado River water supplies, current reclaimed water supplies, and current conservation programs. These baseline supplies are the underlying core supplies present in every portfolio.

Table 8-3. Summary of Options Included in Portfolios

Options	Included in Portfolios						
	Max Cost-Effective	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Demand Management Options							
Advanced Metering Infrastructure	X	X	X	X	X	X	X
Water Loss Control Utility Side	X	X	X	X	X	X	X
CII Ordinance for Cooling Towers and Steam Boilers	X	X	X	X	X	X	X
Water Use Benchmarking and Budgeting	X	X	X		X	X	X
Landscape Ordinance	X	X	X		X	X	X
Landscape Incentives	X				X	X	X
Irrigation Efficiency Incentives	X		X		X	X	X
Stormwater Harvesting (Lot)					X	X	X
Rainwater Harvesting (Lot)		X	X		X	X	X
Graywater Harvesting (Lot)		X		X	X	X	X
Building Scale Wastewater Reuse				X	X	X	X
AC Condensate Reuse	X	X	X	X	X	X	X
Water Supply Options							
Aquifer Storage and Recovery	X	X	X		X	X	X
Brackish Groundwater Desal				X	X	X	X
Direct Non-Potable Reuse	X	X	X	X	X	X	X
Direct Potable Reuse				X			
Indirect Potable Reuse with Capture Local Inflows to Lady Brid Lake	X	X	X	X		X	X
Additional Supply from LCRA			X				
Off-Channel Reservoir w/ Lake Evaporation Suppression	X	X	X		X	X	
Imported Option Category - Seawater Desalination				X			X
Imported Option Category – Conventional Groundwater	X						
Distributed Wastewater Reuse	X	X	X	X	X	X	X
Wastewater Scalping (Sewer Mining)		X		X	X	X	X
Community Stormwater Harvesting		X			X	X	X
Community Rainwater Harvesting		X					

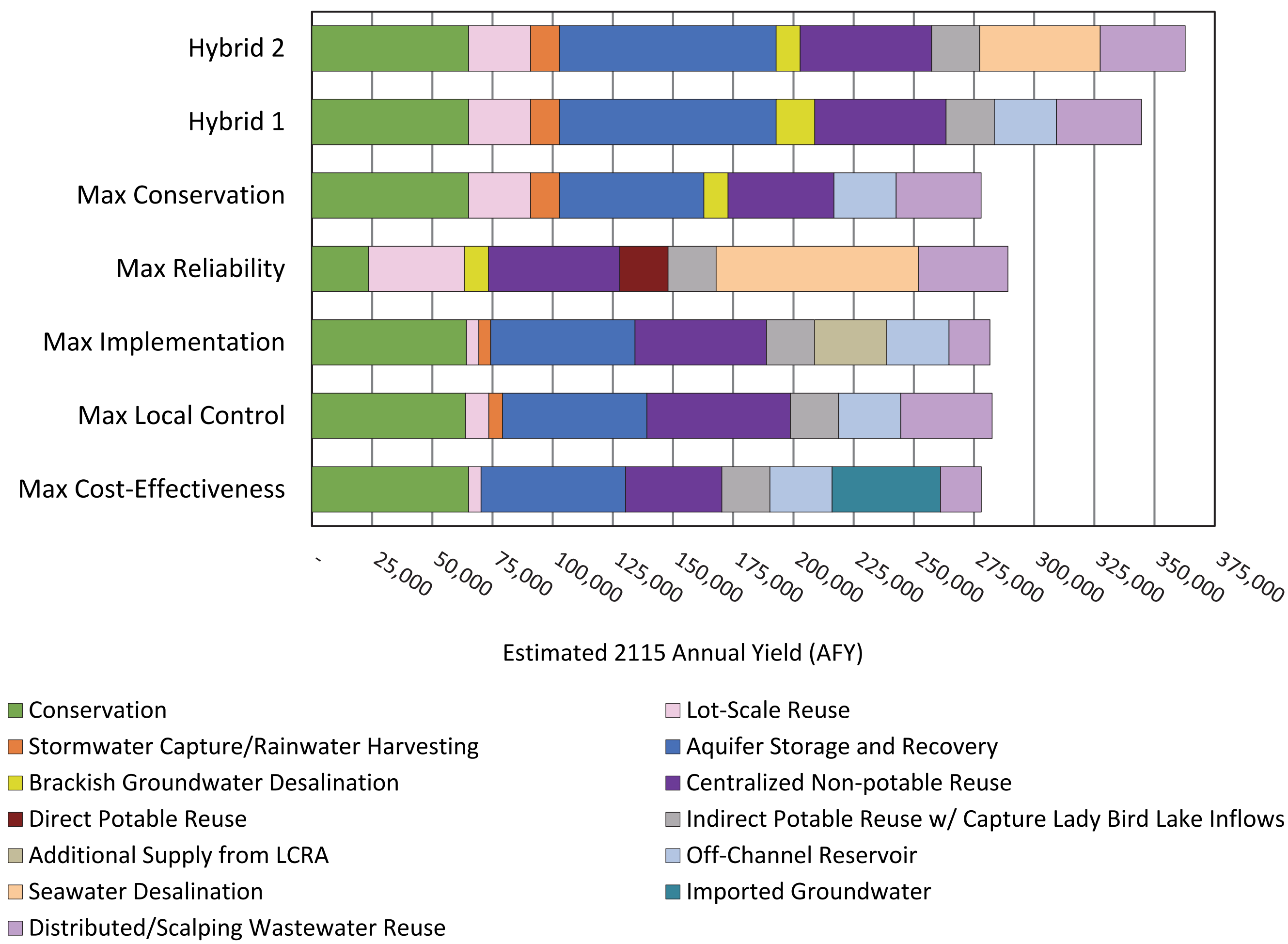


Figure 8-3. Estimated annual water yield (AFY) in 2115 for each portfolio

All portfolios met all identified water needs (Types 1, 2, and 3) for the period of record hydrology with historical climate (hydrologic scenario A). Of the initial themed portfolios, only the Maximum Reliability portfolio came close to meeting all identified needs under period of record with climate change (hydrologic scenario B) and extended period hydrology with climate change (hydrologic scenario D). Both Hybrid 1 and 2 portfolios met all identified water needs under hydrologic scenario B and came close to meeting all identified water needs for hydrologic scenario D.

8.2 Raw Performance Scorecard

As outlined in **Section 3.5**, the IWRP had five major objectives against which the portfolios were evaluated: (1) *Water Supply Benefits*; (2) *Economic Benefits*; (3) *Environmental Benefits*; (4) *Social Benefits*; and (5) *Implementation Benefits*. These five objectives were further defined by sub-objectives. For example, the objective *Water Supply Benefits* had two sub-objectives: *Vulnerability* and *Reliability*. No objective had more than three sub-objectives. Primary weights of relative importance were assigned to each of the five objectives and secondary weights of relative importance were assigned to each of the twelve sub-objectives (see **Table 8-4**).

Table 8-4. Objective and sub-objective weights

Objective	Sub-Objective
Water Supply Benefits – **35%**	Minimize Vulnerability – **80%**
	Maximize Reliability – **20%**
Economic Benefits – **20%**	Maximize Cost-Effectiveness – **75%**
	Maximize External Funding – **25%**
Environmental Benefits – **20%**	Minimize Ecosystem Impacts – **40%**
	Minimize Net Energy Use – **30%**
	Maximize Water Use Efficiency – **30%**
Social Benefits – **13%**	Maximize Multi-Benefit Programs – **38%**
	Maximize Net Benefits to Local Economy – **31%**
	Maximize Social Equity – **31%**
Implementation Benefits – **12%**	Minimize Risk – **60%**
	Maximize Local Control/Local Resource – **40%**

For each sub-objective, performance metrics were established to measure how well the portfolios achieved the sub-objective. Several performance metrics were quantitative and based on modeling or detailed evaluations. The quantitative performance metrics were measured on a continuous scale (e.g., dollars); or in some cases measured on a qualitative scale from one to five, as described in the objective matrix in **Table 3-2**, based on quantitative measurements (referred to as "qualitative based on quantitative"). Other performance metrics were qualitative and measured on a scale from one to five based on expert judgement. For metrics which were not purely quantitative, a score of one indicated poorer performance in that area and a score of five indicated higher performance in that area.

Table 8-5 summarizes the objectives, sub-objectives and performance metrics for the portfolios. A description of how the performance metrics were derived follows. **Appendix L** contains further details about the various metrics used in portfolio evaluation and their values.

Table 8-5. Raw performance scorecard

Objective	Sub-Objective	Performance Metric	Metric Type	Portfolio						
				Max Cost-Effect.	Max Control	Max Implem.	Max Reliable	Max Conserv.	Hybrid 1	Hybrid 2
Water Supply Benefits	Minimize Vulnerability	% of identified needs met during 12-months of worst-case drought[1]	Quantitative (WAM)	81%	77%	77%	95%	76%	89%	92%
	Maximize Reliability	% of months in period of simulation with no identified need shortages[1]	Quantitative (WAM)	93%	97%	97%	98%	97%	100%	100%
Economic Benefits	Maximize Cost-Effectiveness	Lifecycle unit cost ($/AF)[2]	Quantitative (Eng. Estimate)	$1,513	$1,914	$1,540	$3,434	$2,753	$3,150	$3,197
	Maximize External Funding	Grants and developer funding potential (score 1-5)[3]	Qualitative	1.7	2.4	1.8	4.0	3.6	3.6	3.5
Environmental Benefits	Minimize Ecosystem Impacts	Ecosystem impact, net diversions and stormwater capture (score 1-5)[2,3]	Derived from WAM	1.4	2.7	1.7	2.7	4.6	4.0	4.7
	Minimize Net Energy Use	Net change in energy requirement (millions of kWh/yr)[2]	Quantitative (Eng. Estimate)	125	66	48	315	97	144	282
	Maximize Water Use Efficiency	2115 potable water per capita demand (gallons/person/day)[2]	Quantitative (demand model)	79	68	75	73	67	65	65
Social Benefits	Maximize Multi-Benefit Programs	Stormwater capture/harvesting (score 1-5)[2,3]	Derived from Portfolio Mix	3.1	3.7	3.6	1.0	4.7	4.7	4.7
	Maximize Net Benefits to Local Economy	Positive economic impact (score 1-5)[2,3]	Derived from Cost Estimate	1.0	2.1	1.1	5.0	4.4	5.0	4.6
	Maximize Social Equity	Social equity score (score 1-5)[3]	Qualitative	3.1	3.3	3.5	2.9	3.4	3.3	3.3
Implementation Benefits	Minimize Risk	Portion of supply mix considered relatively high in risk (score 1-5)[3]	Qualitative	3.6	4.8	5.0	1.0	4.9	4.4	3.4
	Maximize Local Control/Local Resource	Portion of supply mix within local area and/or within AW's control of operations (score 1-5)[3]	Derived from Portfolio Mix	2.4	3.2	2.8	1.0	2.36	5.0	4.8

[1]Calculated by taking geometric mean of WAM results for hydrologic scenarios B and D; and for years 2040, 2070, and 2115.
[2]Based on period of record with climate change (scenario B).
[3]Score of 1 = lower relative performance, while score of 5 = higher relative performance

8.2.1 Water Supply Benefits

The water supply benefits objective was based on two sub-objectives: supply reliability and vulnerability. Supply reliability was calculated as the percent of months without Type 1, 2, or 3 shortages during the period of simulation, and supply vulnerability was calculated as how much of the Type 1, 2, and 3 water needs are met during the 12-months of worst-case drought. Performance metrics under the water supply benefits objective were calculated using output from Austin Water's Water Forward WAM. For each portfolio, the model was run under hydrologic scenarios B and D (period of record with climate change and extended period with climate change, respectively) for the 2040, 2070 and 2115 planning horizons. Both the vulnerability metric and reliability metric were estimated by taking the geometric mean for hydrologic scenarios B and D, throughout the planning period. **Appendix L** contains more detail on how the water supply benefits sub-objective metrics were calculated.

8.2.2 Economic Benefits

The economic benefits objective was determined based on portfolio performance for two sub-objectives: a portfolio's cost-effectiveness and a portfolio's potential for advantageous external funding. The two sub-objectives were measured by estimating a simplified lifecycle unit cost and a qualitative assessment of advantageous funding, respectively.

The simplified lifecycle unit cost was estimated using a levelized unit cost based on unit costs developed in option characterization (detailed cost assumptions for each option can be found in **Appendix J**) that considered whether the option was modeled to be operating constantly or only when needed. The operation and maintenance (O&M) costs for options that are not operated constantly are lower than those that are, but the tradeoff is the yield of the intermittently operated options is not constant. The levelized unit cost used to measure portfolio cost-effectiveness takes both the cost and yield into account to evaluate trade-offs between options and generate an overall portfolio cost-effectiveness score that accurately represents relative performance.

The maximizing advantageous external funding sub-objective considered two factors: (1) the likelihood that a project projected to be owned and operated by AW could receive outside funding (e.g. loans, grants, or other) and (2) the potential for project implementation and operation costs to be borne by developers. For the external funding component, each option was qualitatively scored on a scale of one to five and then weighted based on the yields of each option. The score for potential developer contribution was based on the total cost of options seen as having potential for developer contribution. The final score for advantageous external funding was then determined as 40% the external funding score and 60% the developer contribution score. See **Appendix L** for more details on how each economic benefits sub-objective score was determined.

8.2.3 Environmental Benefits

The environmental benefits objective was calculated based on three sub-objectives: ecosystem impacts, net energy use, and water use efficiency. **Appendix L** provides more detail on how each of the sub-objectives for the environmental benefits score were calculated, as well as values for the various metrics used.

The ecosystem impact score was based on net diversions outputted from the WAM for hydrologic scenario B (period of record with climate change) and the total volume of stormwater or rainwater harvesting a portfolio contained. When the net diversion results for all portfolios were compared, they did not vary greatly from one portfolio to the next, but to increase relative differentiation in the portfolios and to follow process steps, they were scored on a full one-to-five scale. For the stormwater and rainwater harvesting volume, total yields of the stormwater and rainwater harvesting options in a portfolio were determined and used to assign a scaled one-to-five score. The average of the net diversion and stormwater/rainwater harvesting scores was then calculated to give the raw performance score.

The incremental change in energy use sub-objective considered the additional energy, as compared to today's baseline, needed to operate each option in a portfolio and the energy savings associated with reduced need for potable water treatment due to demand management options. A portfolio's score was the summation of additional energy use or savings from each option in millions of kWh per year. Since the sub-objective is to minimize net energy use, a lower score was better for this performance measure.

The sub-objective to maximize water use efficiency was measured as the potable water use of the portfolio in gallons per capita per day (GPCD) at the 2115 planning horizon. Total 2115 projected Colorado River diversions from the disaggregated demand model (see **Section 4.1** for more detail on the disaggregated demand model) were converted to treated potable water pumpage. The potable water pumpage was then divided by the estimated 2115 population to obtain an estimate for 2115 GPCD. For this performance measure, a lower GPCD is better since it indicates a more efficient use of potable water.

8.2.4 Social Benefits

The social benefits objective was measured by assessing portfolio performance for maximizing multi-benefit infrastructure, benefits to the local economy, and social equity. Options which provided stormwater harvesting, rainwater harvesting, or landscape transformation benefits were used as proxies for options which would increase multi-benefit infrastructure. To score portfolios based on maximizing the multi-benefit infrastructure options they contained, the total volume supplied from the proxies for each portfolio was summed and then assigned a scaled score based on the result. **Appendix L** contains more detail on how this metric and the others discussed in this section were calculated.

The score for maximizing benefits to the local economy was based on options that have the potential to bring economic benefit or work to the local area. While all options characterized for Water Forward would likely contribute some benefit to the local economy, this sub-objective focused on those options with the highest potential to generate local economic activity. This could include options having locally-based construction or options which would promote Austin as a center for innovative water infrastructure. The yield from each of the options seen as benefiting the local economy was multiplied by its unit cost and the totals were summed for each portfolio. These dollar figures were then converted to a scaled score, as outlined in the objective matrix in **Appendix L**.

The social equity sub-objective score is based on an Equity Analysis Worksheet provided by the City of Austin Equity Office. This worksheet is an adaptation of the Equity Assessment Tool, which lays out a process and a set of questions to guide city departments in evaluating policies, practices, budget allocations, and programs and begin addressing their role and impacts on equity. Each option received a total composite score based on evaluation using this worksheet. The total composite scores were then scaled to align with the objective matrix.

8.2.5 Implementation Benefits

The implementation benefits objective was scored through a combination of assessment of overall risk and the amount of local control or local resources a portfolio would have. The risk score was based on the percentage of a portfolio's yield coming from higher-risk options. Higher-risk options were determined by evaluating each option against ten different types of risk (institutional challenges, public/developer opposition, scalability issues after construction, geographic/distribution limitations, permitting/regulatory difficulty, infrastructure failure risks, supply/savings uncertainty, operations and maintenance challenges, siting/land acquisition challenges, and emerging technology/local innovation challenges).

The local control/local resource sub-objective score was based on two metrics: the portfolio yield from options that AW would likely control and the portfolio yield from options located locally. The two yields were summed together, which helped indicate which portfolios had a high degree of both locally-controlled options and locally-sourced options. This combined value for each portfolio was then converted into a scaled score. **Appendix L** contains more detail on how all the implementation benefits metrics were calculated and how each portfolio scored.

8.3 Portfolio Rankings

Using the raw performance scores shown previously in **Table 8-5** and the weights determined for objectives and sub-objectives, the portfolios were evaluated and scored by the decision software Criterium Decision Plus, using the multi-attribute rating method described in more detail in **Section 3.7.3.2**. The portfolios were ranked based on the relative importance of each objective and sub-objective, as defined by the objective matrix, and how they performed within each of those objectives. **Figure 8-4** shows the ranking of portfolios. The figure not only shows which portfolios ranked the highest but also which objectives contributed the most to the scoring. The larger the color bar segment, the better the portfolio does in achieving a particular objective. Further detail on the scoring of each objective and sub-objective is presented in **Appendix L**.

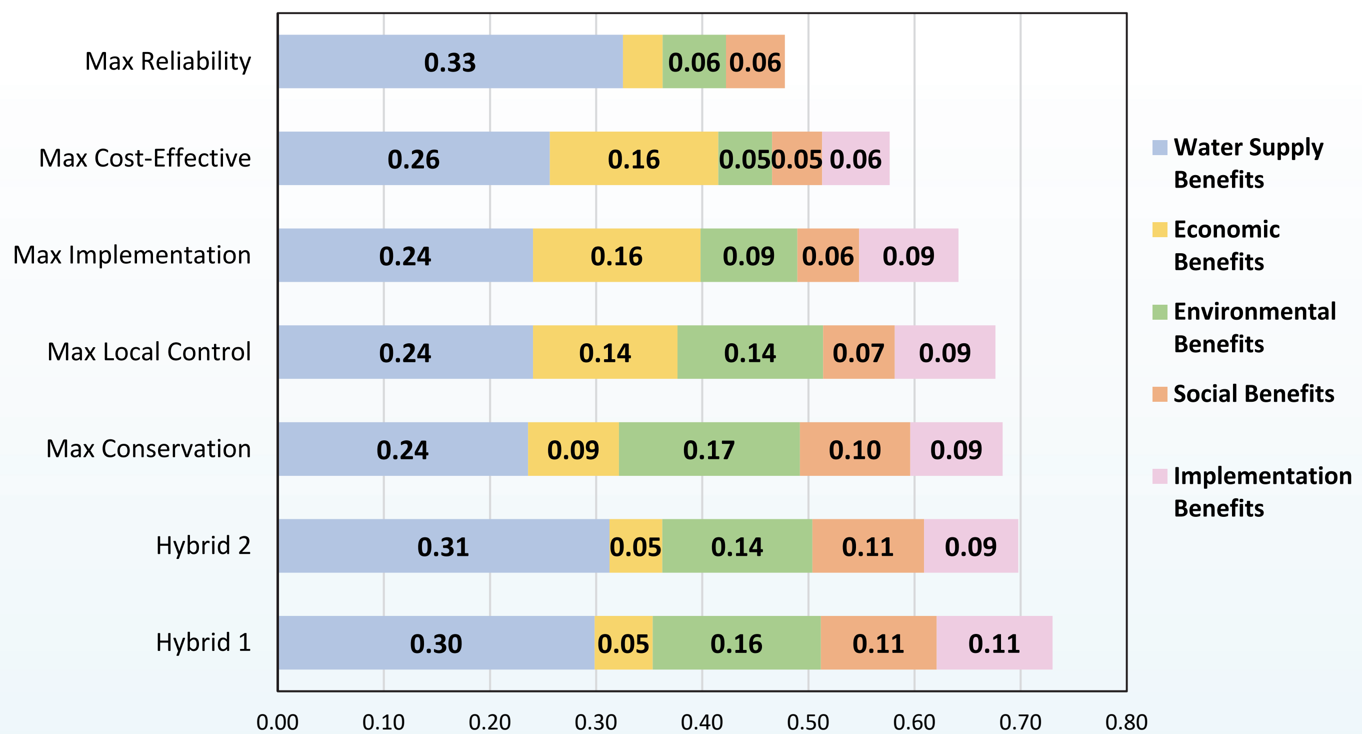


Figure 8-4. Scoring of portfolios using decision software

8.4 Summary of Findings

The results presented in **Figure 8-4** show quite a bit of variability among the portfolios evaluated. The Maximum Reliability portfolio had the best overall score for water supply benefits, but it scored lowest overall due to its higher cost and implementation risk, and lower environmental and social benefits. The Maximum Cost-Effectiveness portfolio scores somewhat higher for economic benefits than the other portfolios and is tied with the Maximum Implementation Ease portfolio for economic benefits.

The figure also shows that the Hybrid 1 portfolio scored highest among all the portfolios evaluated, while the Hybrid 2 portfolio scored second. Of the initial portfolios, the Maximum Conservation portfolio scored third. The fact that the Hybrid 1 and Hybrid 2 portfolios were the highest-scoring aligns with the methodology used, since they were based on improvements made to initial portfolios. Because Hybrid 1 had the highest overall composite score, it was chosen to form the basis for Water Forward plan recommendations. Hybrid 1 represents the best mix of options to meet the city's identified needs and objective. The next section includes the plan recommendations that resulted from the portfolio evaluation and plan development process.

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SECTION 9: RECOMMENDATIONS

The comprehensive evaluation of the five initial and two hybrid portfolios presented in **Section 8** identified the Hybrid 1 Portfolio as the highest ranked overall portfolio. The recommended Hybrid 1 portfolio represents the best mix of strategies in meeting the objectives of the integrated water resource plan. The Hybrid 1 portfolio is the basis for Water Forward recommendations that will be implemented through an adaptive management approach, which allows Austin to prepare for a variety of potential futures. The Water Forward recommendations will strengthen Austin's water supply reliability, increase the city's supply diversity, and will prepare the city to manage the effects of climate change, droughts worse than those we have experienced in the past, and other uncertainties in the future.

AT A GLANCE

- *Plan Recommendations*
- *Water Forward Plan Benefits*
- *Water Forward Implementation and Adaptive Management Plan*

9.1 Plan Recommendations

The Water Forward recommendations include new conservation and supply strategies based on the Hybrid 1 portfolio composition. The plan also recommends implementation of best management practices, development of alternative water ordinances, expansion of centralized reclaimed water ordinances, and a continued commitment to Austin Water's water conservation program, and to our core Colorado River supplies. **Table 9-1** presents a summary of the Water Forward recommendations from the Hybrid 1 portfolio for new demand management and water supply options, along with the projected yields for these recommended strategies. The following subsections provide a narrative overview of the Water Forward plan recommendations. For more detailed information regarding planned action steps and timeframes, see **Appendix M**.

Table 9-1. Water Forward Recommended Strategies with Planning Horizon Yields

Option #/ Type	Recommended Strategies	Average/ Drought	Estimated Yield (Acre Feet per Year)[1]			
			2020	2040	2070	2115
	Demand Management Strategies					
D1	Advanced Metering Infrastructure (AMI)	Both	600	3,880	5,770	9,370
D2	Utility-Side Water Loss Control	Both	3,110	9,330	10,920	13,064
D3	Commercial, Industrial, and Institutional (CII) Ordinances	Both	1,060	1,060	1,060	1,060
D4	Water Use Benchmarking and Budgeting	Both	-	5,950	11,670	25,230
D5	Landscape Transformation Ordinance	Both	-	3,040	7,430	15,050
D6	Landscape Transformation Incentive	Both	-	320	630	930
D7	Irrigation Efficiency Incentive	Both	40	210	430	390
D8	Lot Scale Stormwater Harvesting	Both	-	330	870	2,280
D9	Lot Scale Rainwater Harvesting	Both	-	1,550	4,030	9,250
D10	Lot Scale Graywater Harvesting	Both	-	2,130	5,620	12,670
D11	Lot/Building Scale Wastewater Reuse	Both	-	1,320	3,670	7,880
D12	Air Conditioning (AC) Condensate Reuse	Both	100	1,080	2,710	5,150
	Demand Management Strategies Sub-Total	-	4,910	30,200	54,810	102,320
	Water Supply Strategies					
S1	Aquifer Storage and Recovery	Drought	-	60,000	60,000	90,000
S2	Brackish Groundwater Desalination	Both	-	-	5,000	16,000
S3	Direct Non-Potable Reuse (Centralized Reclaimed Water System)	Both	500	12,000	25,000	54,600
S5a	Indirect Potable Reuse (IPR) through Lady Bird Lake	Drought	-	11,000	20,000	20,000
S5b	Capture Local Inflows to Lady Bird Lake (infrastructure also included as part of IPR, above)	Average	-	3,000	3,000	3,000
S7	Off Channel Reservoir	Both	-	-	25,000	25,000
S9	Distributed Wastewater Reuse	Both	-	3,150	14,470	30,050
S10	Sewer Mining	Both	-	1,000	2,210	5,280
S11	Community Scale Stormwater Harvesting	Both	-	160	240	500
	Drought Supply Strategies	-	-	71,000	80,000	110,000
	Average/Both Supply Strategies	-	500	19,310	74,910	134,440
	Water Supply Strategies Sub-Total	-	500	90,310	154,910	244,440
	Water Forward Recommend Strategies Overall Total		5,410	120,510	209,720	346,750
	Water Forward Recommended Implementation Strategies to Realize Estimated Yields Above					
	Phase 1 and 2: Water Use Benchmarking and Budgeting Ordinance					
	Phase 1 and 2: Alternative Water Ordinance					
	Expansion of Alternative Water Incentive					
	Phase 1 and 2: Dual Plumbing Ordinance Development					
	Ordinance to Expand Existing Centralized Reclaimed Water Connection Requirements					
	Current Supplies and Conservation					
	Colorado River and Highland Lakes Supply	Both	325,000			
	Drought Contingency Plan	Drought	Varies			
	Austin Water Conservation Programs*	Both	54,320			
	Centralized Reclaimed Water System	Both	3,960			

***Note:** Austin Water conservation program savings were estimated based on savings calculated during 2012-2015

9.1.1 *Water Forward Strategies to Conserve Water*

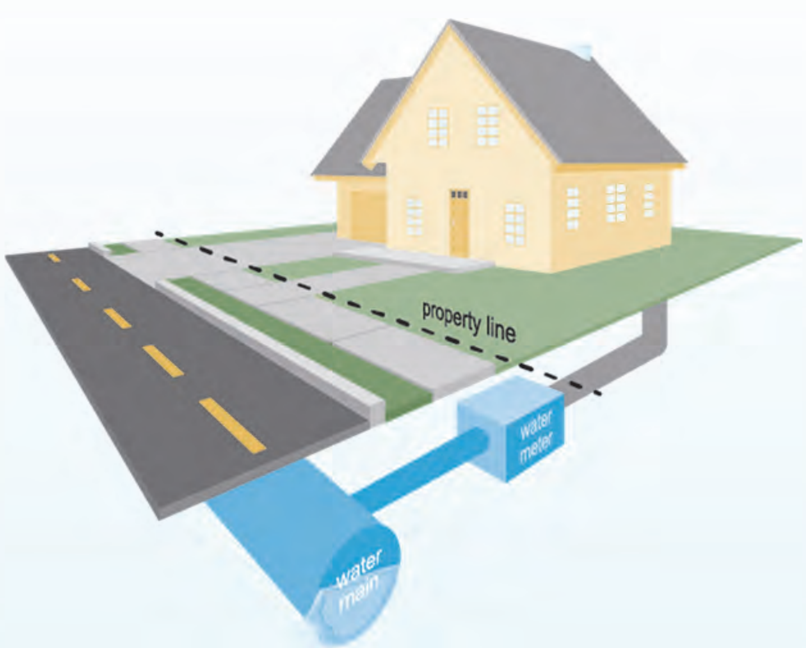
The Water Forward plan includes a robust set of strategies to conserve water, reducing the total volume of water used in Austin, and making our buildings and landscapes more water efficient. These strategies are discussed in the sections below and throughout **Section 9**. For clarity, the name of each strategy is followed by a number and letter (such as D5) or a brief phrase to allow cross-referencing with **Table 9-1**.

9.1.1.1 Advanced Metering Infrastructure (AMI) – D1

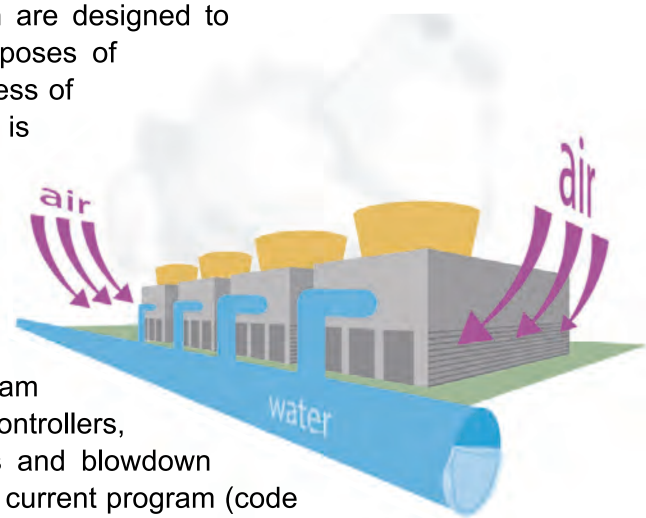
Advanced Metering Infrastructure (AMI), also known as smart meters, record near real-time water use and provide that information to customers through an easy-to-use interface such as a web or a smart phone application. Savings will primarily be achieved through identification of customer leaks, behavior modification, and other water-saving opportunities that are realized because of: (1) improving customer meter accuracy, (2) reducing unauthorized consumption, (3) reducing data transfer/archive errors, and (4) reducing data billing errors. After initial piloting, Austin Water has procured a consultant to assist in scoping the replacement of all retail customer meters with smart meters. Additionally, Austin Water has applied for low-interest loan funding for AMI through the State Water Implementation Fund for Texas. This strategy is targeted to be deployed by 2024, pending Council approval.

9.1.1.2 Utility-Side Water Loss Control – D2

This strategy represents an expansion of Austin's existing water loss program to reduce leaks in the water distribution system. While the target Infrastructure Leakage Index (ILI) for Austin Water is sustaining an ILI at or below 2.7, from fiscal year 2013 to 2015 Austin Water lost an amount of water which equates to an infrastructure leakage index of 3.26. The Water Forward strategy includes an aggressive leak detection, correction, and prevention program to reduce the ILI to 2.7 by 2020 and further reduce and sustain a 2.0 ILI from 2040 to 2115. Strategies to achieve these targets will include enhancements to existing programs focused on active leak detection, improving response time to leaks, pressure management, and pipeline and asset management selection, installation, maintenance, renewal, and replacement. This strategy may have potential synergies with strategies like Advanced Metering Infrastructure (AMI).



9.1.1.3 Commercial, Institutional, and Industrial (CII) Ordinances – D3



There are over 400 cooling towers in Austin which are designed to remove heat from a building or facility for the purposes of heating, ventilation, and air conditioning. In the process of cooling air, some water is evaporated, and the rest is recycled through the cooling tower. This ordinance requires: (1) all existing and new cooling towers to meet the same efficiency equipment standards required for new and replacement towers since 2008 (makeup and blowdown submeters, conductivity controller, drift eliminator and overflow alarm) and achieve five cycles of concentration; and (2) all steam boilers in new development to have conductivity controllers, makeup meters, steam condensate return systems and blowdown heat exchangers for steam boilers. This strategy is a current program (code changes were approved by Council action in June 2017) and was included as a best management practice as part of the Water Forward plan.

9.1.1.4 Water Use Benchmarking and Budgeting – D4

Water use benchmarking and budgeting uses standards to "benchmark" how much water buildings of a certain size and type would be expected to use. Based on these benchmarks, a "water budget" can be created to track water use in a given building and help users meet their water benchmark. This strategy is planned to be implemented in two phases.

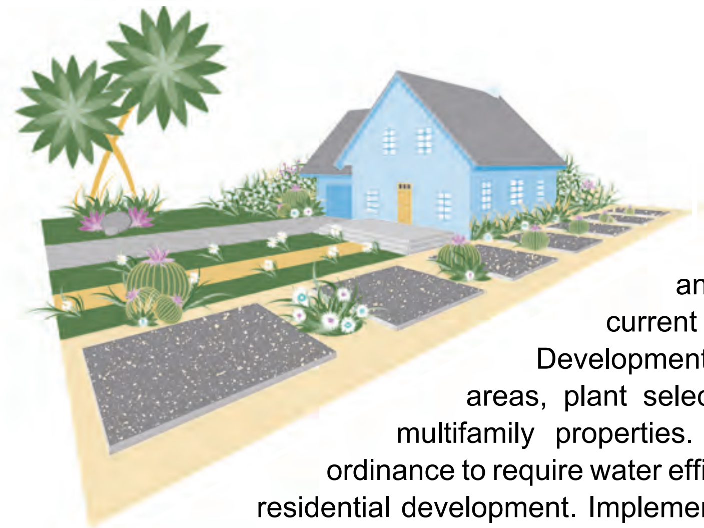
Phase I

Potential approaches to implement this requirement for pre-and post-development of multi-family and commercial facilities will be evaluated and will include public outreach, review by Boards and Commissions and Council action.

As part of this program, developers will provide information about all water-using equipment and fixtures associated with the site (including counts), proposed water sources, irrigated area, landscaped area, and other water-use, site, and building characteristics. City staff will provide information on water efficiency related code requirements, potential water use efficiency best management practices, alternative water recommendations, water use benchmarking data, and available incentive and rebate programs for new and existing development. Implementation of the measure will look for ways to tie into the Service Extension Request process, Austin Energy's Green Building program, the city's Energy Conservation Audit and Disclosure program, and AMI customer portals for multifamily and commercial use.

Phase II

Based on the water use benchmarking data developed through these programs, this strategy will be expanded in the future to include a water use budget for new development constructed after 2025 (compliance mechanism to be determined).



9.1.1.5 Landscape Transformation Ordinance – D5

Landscape transformation is a process of transitioning from traditional landscaping practices to those that rely on regionally appropriate plants that have reduced supplemental water needs, with an emphasis on landscape function. Note that the current Landscape Ordinance in the City of Austin Land Development Code has existing requirements for landscaped areas, plant selection, and irrigation systems for commercial and multifamily properties. This strategy includes development of a new ordinance to require water efficient landscapes be installed with new single-family residential development. Implementation of this strategy could include implementing turf grass area, irrigated area, and/or irrigation area limitations. More detailed ordinance concepts and language will be developed through subsequent implementation processes with future additional public input opportunities.

9.1.1.6 Landscape Transformation Incentive – D6

This strategy focuses on incentives for existing developments to encourage reductions in water needs for outdoor irrigation through regionally appropriate landscapes with an emphasis on landscape functionality. The current WaterWise landscape rebate offers $35 for every 100 square feet ($0.35/square feet) converted, with a maximum rebate of $1,750 per property. The current program has traditionally had a low participation rate. Implementation of this strategy will explore increasing WaterWise landscape rebates for single-family residential and multi-family residential and implementing a new WaterWise landscape rebate for commercial beyond City of Austin Land Development Code requirements.

9.1.1.7 Irrigation Efficiency Incentive – D7

Outdoor water use comprises over 22% of the water currently used by Austin Water customers with most of that water used for landscape watering. Over 89,000 homes and over 5,000 businesses have irrigation and sprinkler systems, which often are programmed to turn on at certain times of the day without regard to weather or plant water needs. This strategy focuses on expanding existing Austin Water rebate programs to incentivize “smart” irrigation controllers that would improve irrigation system efficiency by responding to leaks, high pressure, and soil moisture and also making flow data accessible.

9.1.2 Water Forward Strategies to Make Use of Alternative Water

Water Forward also includes strategies which will help Austin make use of alternative water sources, such as treated rainwater, stormwater, graywater, air conditioning condensate, and highly treated wastewater effluent to meet non-drinking water demands, such as toilet flushing and irrigation. To achieve this, the plan includes implementation of both ordinances requiring and incentives encouraging the use of these alternative waters at various scales, described below:

- Decentralized lot scale reuse – Including onsite generation, treatment, and reuse of alternative waters to include rainwater, stormwater, graywater, air conditioning condensate, and highly treated wastewater effluent.
- Decentralized community scale reuse – Including collection of alternative waters to include stormwater and wastewater effluent from a cluster of homes or businesses, treatment at locally sited stormwater facilities, distributed wastewater treatment plants, or sewer mining facilities, and reuse via a reclaimed water distribution system that would be separate from the centralized reclaimed water system.
- Centralized reclaimed water system – Including collection of wastewater effluent, treatment at a major wastewater treatment plant, and reuse through connection to the City's centralized reclaimed water distribution system.

All alternative water strategies in Water Forward are intended to meet non-drinking water demands and are recommended to be backed up by the City's drinking water distribution system. Both centralized and decentralized reuse strategies will be developed in an integrated manner. As an initial step during the implementation phase, this means using geospatial modeling and analysis to determine the most beneficial alternative source water and most appropriate scale for reuse strategy deployment across the City in a context-sensitive manner.

Increasing the amount of alternative water available to meet non-drinking water demands helps Austin diversify its water supplies and move towards a more resilient system, as illustrated in **Figure 9-1**. Further description of each of the recommended strategies that will help Austin make use of all its sources of water is provided in the sections below.

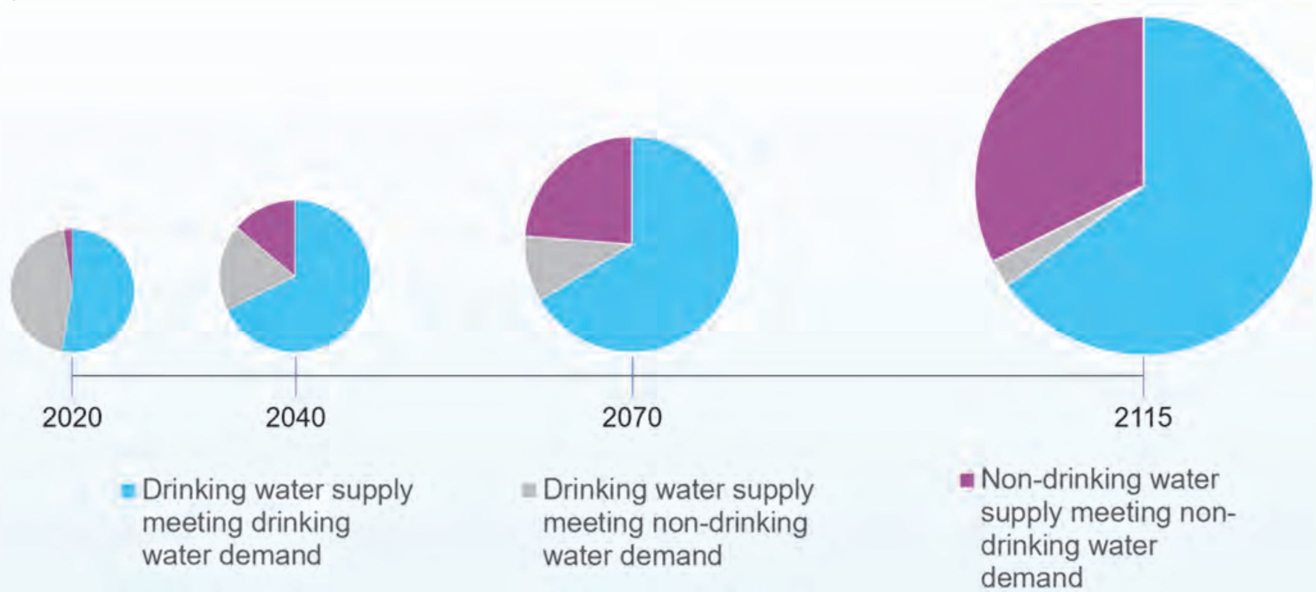


Figure 9-1. Amount of non-drinking water demand being met by non-drinking water sources over time

9.1.2.1 Alternative Water Incentives and Ordinances – D8, D9, D10, D11, S3, S9, S10, S11

Alternative Water Incentive: This strategy will expand existing Austin Water incentive programs to encourage the installation and use of lot scale rainwater harvesting, lot scale stormwater harvesting, lot scale graywater reuse, lot scale blackwater reuse, or community scale stormwater harvesting. Incentive program details will be developed through subsequent implementation processes including interdepartmental coordination.

Alternative Water Ordinance: This strategy includes development of an ordinance to require use of alternative water either generated on-site, such as rainwater, stormwater, graywater, blackwater, air conditioning condensate, or that may be available via the centralized reclaimed and/or decentralized reclaimed systems (decentralized reclaimed includes both distributed wastewater reuse and sewer mining). This strategy is currently planned to be implemented as part of a phased approach.

The initial phase of implementation will explore, through a stakeholder engagement and ordinance development process, requiring use of alternative waters to meet a portion of indoor and outdoor non-potable demands for new large commercial and multifamily buildings (with a potable back-up required). The second phase of implementation will build on the previous phase by exploring, through a stakeholder engagement and ordinance development process, expanding the Phase 1 ordinance's applicability to potentially include mid-size new commercial and multifamily development (with a potable back-up required). See **Table 9-2** for more detail.

Table 9-2. Water Forward recommended alternative water incentives and ordinances initial assumptions related to specific strategies

#	Strategy Name	Targeted Sector and End Use (All New Development)	Initial Assumption: Savings Achieved Via Incentive or Ordinance?	2040 (AF/yr)	2070 (AF/yr)	2115 (AF/yr)
D8	Lot Scale Stormwater Harvesting	MFR Outdoor Irrigation	Incentive 50%, Ordinance 50%	180	496	1,391
		COM Outdoor Irrigation	Incentive 50%, Ordinance 50%	149	373	885
D9	Lot Scale Rainwater Harvesting	SFR Outdoor Irrigation	Incentive	937	2,410	5,088
		MFR Outdoor Irrigation	Incentive 50%, Ordinance 50%	54	151	425
		COM Outdoor Irrigation	Incentive 50%, Ordinance 50%	82	209	498
		MFR Outdoor Irrigation and Toilet Flushing	Ordinance	195	556	1,562
		COM Outdoor Irrigation, Toilet Flushing, and Cooling	Ordinance	281	706	1,678
D10	Lot Scale Gray Water Harvesting	SFR Outdoor Irrigation	Incentive	244	631	1,336
		SFR Outdoor Irrigation, Toilet Flushing, and Clothes Washing	Incentive	571	1,461	2,860
		MFR Outdoor Irrigation, Toilet Flushing, and Clothes Washing	Ordinance	991	2,702	6,832
		COM Outdoor Irrigation and Toilet Flushing	Ordinance	321	823	1,638

#	Strategy Name	Targeted Sector and End Use (All New Development)	Initial Assumption: Savings Achieved Via Incentive or Ordinance?	2040 (AF/yr)	2070 (AF/yr)	2115 (AF/yr)
D11	Lot/Building Scale Wastewater Reuse	MFR Outdoor Irrigation, Toilet Flushing, Clothes Washing, and Cooling	Ordinance	1,323	3,672	7,875
S11	Community Scale Stormwater Harvesting	SFR, MFR, COM, COA Outdoor Irrigation	Incentive	48	48	48
		SFR, MFR, COM, COA Outdoor Irrigation, Toilet Flushing, Clothes Washing, and Cooling	Incentive	109	188	455

9.1.2.2 Air Conditioning Condensate Reuse Ordinance – D12

This strategy, which is already in code, is focused on the collection of air conditioning (AC) condensate water from air handling units (AHUs) from new development with a cooling capacity over 200 tons. The condensate water can be reused for beneficial use for any non-drinking water application including (but not limited to): cooling tower makeup water, irrigation, and indoor toilet flushing. AW will continue to monitor the administration of this ordinance.

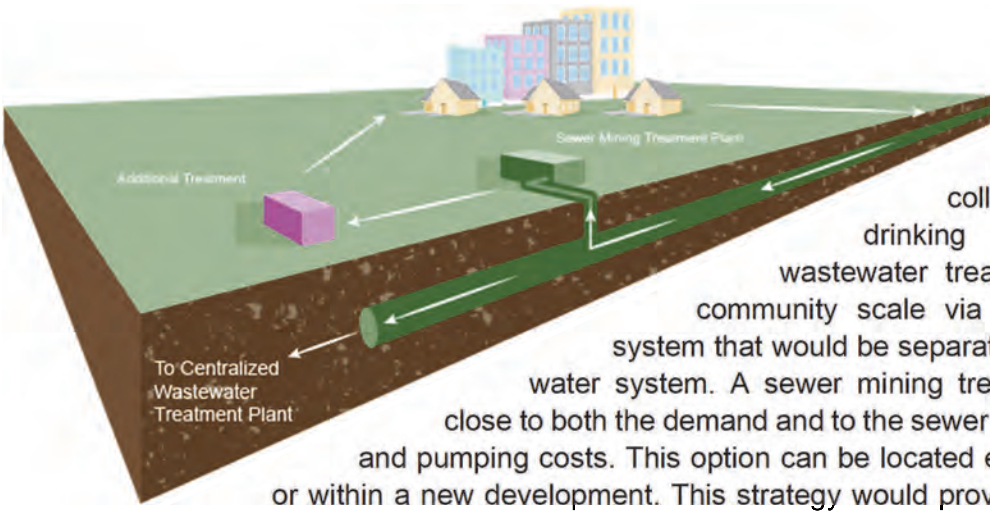
9.1.2.3 Direct Non-Potable Reuse (Centralized Reclaimed Water System) – S3

Through its Water Reclamation Initiative, AW provides highly treated wastewater effluent for non-drinking water uses such as irrigation, cooling, manufacturing, and toilet flushing. As described in **Section 7.1.2**, Austin Water has a Water Reclamation Initiative underway, which currently supplies approximately 4,600 AF per year. The direct non-potable reuse strategy recommended in Water Forward includes expansion of this program to provide additional non-potable water supply through the centralized reclaimed water network. This expansion would occur in two phases over the 100-year planning horizon. The first phase would include implementation of the current Reclaimed Water Infrastructure Master Plan (2011) and the program described in the 2016 Lower Colorado Regional Water Plan, with potential modifications necessary to meet 2040 Water Forward yield targets. The second phase would focus on direct non-potable use in anticipated growth areas based on demand model estimates between 2070 and 2115.

9.1.2.4 Community Scale Distributed Wastewater Reuse – S9

Distributed Wastewater Reuse is the collection of effluent from the wastewater system in localized new development areas (completely separate from the centralized wastewater collection system), treatment to non-drinking water quality at a small wastewater treatment plant, and reuse at the community scale via a reclaimed water distribution system that would be separate from the centralized reclaimed water system. This strategy would provide water for non-drinking water demands such as irrigation, landscaping, cooling, toilet, and potentially also clothes washing. Facilities may be located at the site of existing local WWTPs, or at new potential sites. Distributed wastewater treatment plants evaluated for Water Forward were sized to manage peak wet weather flows into the wastewater collection system and also to meet demand for reclaimed that would be produced by the plants. Reuse from this strategy is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone. Initial implementation steps for this strategy will include additional refinement of geospatial analyses and potential project identification. Later steps will include design and construction of projects.

9.1.2.5 Community Scale Sewer Mining – S10



Sewer mining (or local wastewater scalping) is defined as the extraction of wastewater from the existing centralized wastewater collection system, treatment to non-drinking water quality at a small wastewater treatment plant, and reuse at the community scale via a reclaimed water distribution system that would be separate from the centralized reclaimed water system. A sewer mining treatment plant would be situated close to both the demand and to the sewer extraction point, to reduce piping and pumping costs. This option can be located either within existing open space or within a new development. This strategy would provide water for non-drinking water demands such as irrigation, landscaping, cooling, toilet, and potentially also clothes washing. Wastewater treatment plant wastes (sludge) from the treatment process are assumed to be discharged back to the centralized wastewater collection system for subsequent treatment at the downstream WWTPs. Reuse from this strategy is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone. Initial implementation steps for this strategy will include additional refinement of geospatial analyses and potential project identification. Later steps will include design and construction of projects.

9.1.2.6 Dual Plumbing Ordinance – Implementation Strategy

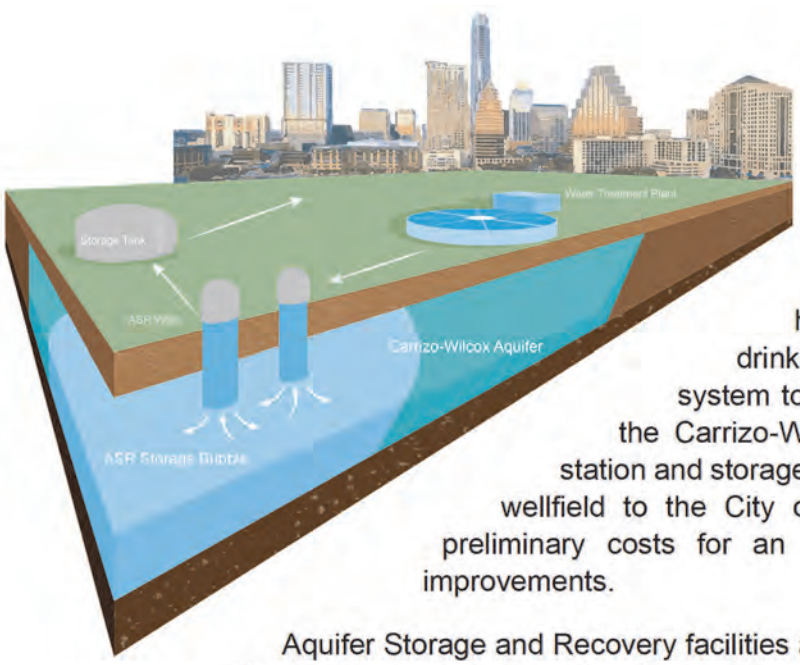
This strategy is currently planned to be implemented as part of a phased approach. In Phase 1, a stakeholder engagement and ordinance development process will explore requiring dual plumbing for new large commercial and multifamily development to facilitate use of alternative water to meet non-drinking water demands (backed up by the City's drinking water distribution system). In Phase 2, a stakeholder engagement and ordinance development process will explore expanding the Phase 1 ordinance's applicability to potentially include mid-size new commercial and multifamily development (backed up by the City's drinking water distribution system). These requirements would consider existing and future indoor centralized reclaimed water use requirements. Implementation of this strategy will include refinement of ordinance scope, applicability, location in code, and enforcement considerations.

9.1.2.7 Expansion of Current Centralized Reclaimed Water System Connection Requirements – Implementation Strategy

This strategy will explore, through a stakeholder engagement and ordinance development process, expanding existing centralized reclaimed water system connection requirements for new commercial and multifamily development. These ordinance changes would assist in achieving the Water Forward Centralized Reclaimed Water System volumetric targets. Implementation of this strategy will include refinement of ordinance scope, applicability, location in code, and enforcement considerations.

9.1.3 Water Forward Strategies to Increase Potable Drinking Water Supplies

Water Forward includes several strategies to increase Austin's access to potable water supplies. The major water supply projects included in the plan are largely to augment Austin's access to water during drought when our core surface water supplies are severely limited. Potable water supplies for the purpose of this plan were defined as sources that could be treated to drinking water quality and provided to Austin Water's customers through the potable drinking water distribution system. The plan includes strategies that will help see Austin through times of deep drought, such as storage and potable reuse options. It also includes strategies that help supplement Austin's water supply at all times, such as brackish groundwater, and the ability to capture additional inflows during wet times.



9.1.3.1 Aquifer Storage and Recovery – S1

Aquifer storage and recovery (ASR) is a strategy in which water (ex: potable drinking water) can be stored in an aquifer during wetter periods and recovered for use during drier periods. The Carrizo-Wilcox ASR strategy included in Water Forward for implementation by the 2040 planning horizon includes facilities to pipe treated drinking water from the City of Austin's distribution system to an ASR wellfield for injection and storage in the Carrizo-Wilcox aquifer. Facilities also include a pump station and storage tank to convey recovered water from the ASR wellfield to the City of Austin distribution system. To date, only preliminary costs for an ASR pilot are include in the AW capital improvements.

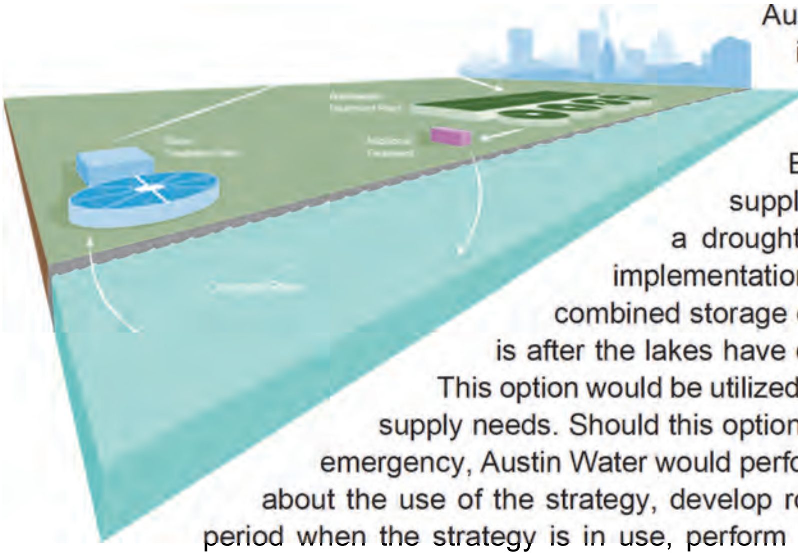
Aquifer Storage and Recovery facilities are planned to serve solely a storage function, allowing for maximization of surface water resources during drought periods. This concept is in keeping with the Water Forward guiding principle of maximizing locally available water resources. Site selection will depend on favorable hydrogeology to fulfill the ASR facility's intended storage purpose. In implementing this option, Austin Water will work to develop and test a pilot facility to assess potential site characteristics and ensure that the strategy's objective to store surface water in and recover surface from the aquifer is achievable. The ASR strategy is in no way intended to be a strategy to develop native groundwater. To be clear, the ASR injection and recovery wells are in no way intended to pump native groundwater from the Carrizo Wilcox Aquifer and convey that water to Austin via a transmission pipeline.

9.1.3.2 Brackish Groundwater Desalination – S2

Brackish groundwater is recommended in Water Forward for the 2070 planning horizon. Brackish groundwater is defined as groundwater containing between 1,000 and 10,000 milligrams per liter (mg/L) of total dissolved solids. Desalination is often required to remove dissolved solids from brackish groundwater. The specific process used to desalinate water varies depending upon the total dissolved solids, the temperature, and other physical characteristics of the source water, but always requires disposal of concentrate, called brine, that has a higher total dissolved solids content than the source water. Evaporation ponds were assumed to be used for brine disposal. Future implementation steps will include further study of potential brackish groundwater opportunities. Exploration of brackish groundwater desalination for the Water Forward process was a recommendation of the 2014 Task Force.

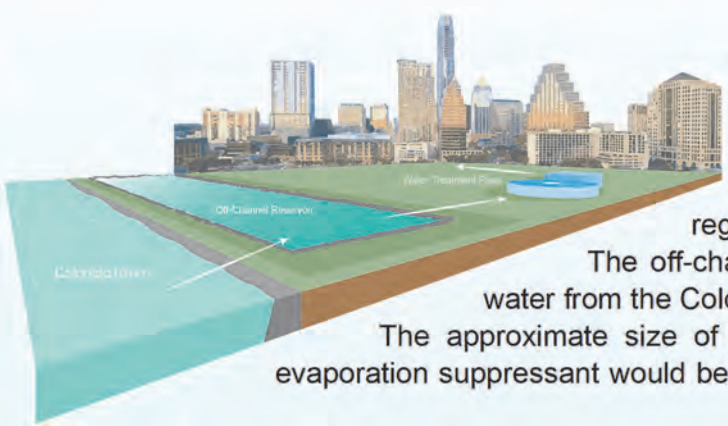
9.1.3.3 Indirect Potable Reuse through Lady Bird Lake – S5(a)

Indirect potable reuse (IPR) is included in Water Forward as an emergency strategy to be used infrequently during only the most severe drought situations. During deep drought periods, when combined storage of the Highland Lakes is lower than at any point in the historical period of record, IPR would be an emergency supply to meet potable water demands. This option will convey highly treated reclaimed water from one treatment train at South Austin Regional WWTP to Lady Bird Lake through a reclaimed water transmission main and subsequently divert this water through a new intake pump and piping system downstream of Tom Miller Dam to be conveyed to Ullrich WTP. This concept could utilize a reclaimed main from South Austin Regional WWTP to Lady Bird Lake that is already included in the Reclaimed System Master Plan. This approach would supplement water releases from Lakes Buchanan and Travis to extend water supplies during severe drought only. This option is a drought strategy that would be recommended for implementation only in the event of 400,000 AF of combined storage or less in Lakes Buchanan and Travis which is after the lakes have dropped below emergency and crisis levels. This option would be utilized for the shortest possible time to meet urgent supply needs. Should this option be required to be utilized in a deep drought emergency, Austin Water would perform outreach to educate and notify the public about the use of the strategy, develop robust standards to guide operations for the period when the strategy is in use, perform monitoring to ensure drinking water quality standards are met, and monitor water quality in Lady Bird Lake.



9.1.3.4 Capture Local Inflows to Lady Bird Lake – S5(b)

As the IPR strategy would only be used on an infrequent basis during severe drought conditions, the intake and pumping components could be used on a more frequent basis to capture spring flows to Lady Bird Lake when available. Lady Bird Lake inflows would be conveyed to Ullrich WTP for treatment and distribution. This strategy would allow for the capture of available spring flows, including flows from Barton Springs that flow into Lady Bird Lake, and other stormwater flows when they are not needed downstream for environmental flow maintenance or for downstream senior water rights. The average annual yield for the Capture Local Inflows to Lady Bird Lake strategy is estimated to be approximately 3,000 AFY. Water availability for the Capture Local Inflow to Lady Bird Lake option would be intermittent and seasonal, with availability more likely in the months of November through February when downstream agricultural irrigation operations are offline and environmental flow requirements are the lowest for the year.



9.1.3.5 New Off-Channel Reservoir with Lake Evaporation Suppression – S7

This strategy is targeted for the 2070 planning horizon. This strategy involves the construction of a new off-channel reservoir in the Austin region that Austin Water would own and operate. The off-channel reservoir strategy would likely use source water from the Colorado River during times when water is available. The approximate size of this reservoir would be about 25,000 AF. An evaporation suppressant would be applied during summer months to reduce water lost through evaporation. The off-channel reservoir could also be used conjunctively with ASR, allowing further storage and evaporation management opportunities.

9.1.4 Water Forward Strategies to Continue Core Colorado River Supplies

The Colorado River and Highland Lakes system will continue to be Austin's core supply in the future. As Austin's core supply, the City will continue to work with its regional partners to protect and enhance the Colorado River and Highland Lakes system supply. Planned actions to enhance supply include:

- Continued participation in the Lower Colorado River Authority/City of Austin Water Partnership
- Continue to engage on potential water supply development in the basin, which may include regional partnerships as a way to implement supply or demand management options
- Continued communication and information sharing with other entities in the basin
- Continued participation in the Lower Colorado River Authority's Water Management Plan update processes
- Continued participation in the Texas Water Development Board-administered Regional Water Planning process
- Continued leadership and participation in Imagine Austin's Sustainably Manage Our Water Resources priority program, co-led by Austin Water and Watershed Protection Department
- Austin Water and Austin's Watershed Protection Department will continue efforts to look for synergistic opportunities
- Broaden our understanding of basin-wide issues, including both upstream and downstream issues. Explore opportunities for Austin Water to proactively protect its water supply watersheds through tools like land conservation and other potential measures.
- Continue involvement in activities, monitoring, and other efforts related to water quality analysis and protection
- Share information and work with others to study potential future climate change impacts
- Continued participation in Water Utility Climate Alliance

9.1.5 Additional Water Forward Strategies

Austin Water will continue to implement best management practices and general implementation components required for the recommended options. These best management practices and option implementation components are summarized in the sidebar on the next page.

9.1.6 Water Forward Task Force Continuation

Water Forward recommends continuing the Water Forward Task Force on a quarterly basis to support the implementation process. Austin Water plans to lead the implementation and adaptive management phase and work with the Task Force during the implementation process. One component of the recommendation to continue the Water Forward Task Force is to have an Austin Water-led review of Ex-Officio membership on the Task Force and make adjustments to enhance the implementation process. Currently, the Ex-Officio members are made up of representatives from various City departments, but membership could include alternate City departments or additional community representatives in the future.

Best Management Practices

- *Require or incentivize government-recognized energy and water efficiency-labeled residential and commercial fixtures (included in baseline in portfolio evaluation)*
- *Incentivize or require toilet, urinal, and bathroom faucet aerator efficiencies (included in baseline in portfolio evaluation)*
- *Implement the "Lake Austin Operations" strategy as defined in the Water Forward screening process. This strategy would be implemented during drought periods.*
- *In alignment with ongoing efforts, add municipal as a potential use to existing City of Austin steam electric water rights*

Implementation Components

- *Use water rates and fees to promote water use efficiency while maintaining affordability*
- *Customer education enhancements*
- *Social media programs and web content to promote conservation*
- *Regional partnerships could be considered when implementing water supply options*

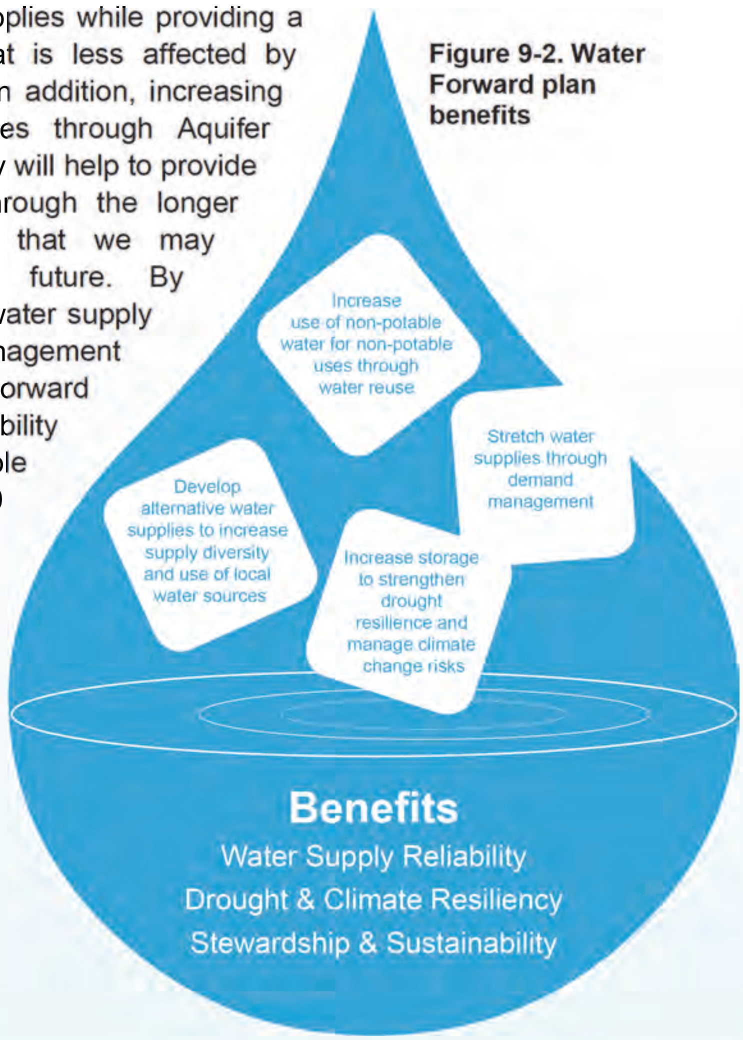
9.1.7 Other Options and Potential Future Strategies

Other options that progressed through screening but were not included in Hybrid 1 could be considered at a future point, as the plan is reevaluated on a five-year cycle. Options include community-scale rainwater harvesting, direct potable reuse, additional LCRA supply, and import options like seawater desalination or conventional groundwater.

9.2 Water Forward Plan Benefits

Implementation of Water Forward strategies will be transformative for the City of Austin and provide many benefits for our community (see **Figure 9-2**). Water Forward's recommended strategies will help Austin stretch existing supplies through water use reductions, more efficient water use, and water reuse. Capturing and reusing water at the point of use increases our community's ability to access all local water sources and adds to supply diversity and resiliency. Expanding reuse supplies, whether at the building scale or from the City's reclaimed water system, allows us to use non-drinking water to meet demands that don't require drinking water quality. This "fit for purpose" approach offsets demand for drinking water supplies while providing a source of supply that is less affected by changes in climate. In addition, increasing water supply reserves through Aquifer Storage and Recovery will help to provide water to the City through the longer periods of drought that we may experience in the future. By diversifying Austin's water supply and demand management portfolio, Water Forward increases the City's ability to maintain a reliable supply for the next 100 years.

Figure 9-2. Water Forward plan benefits



9.3 Water Forward Implementation and Adaptive Management Plan

Austin Water plans to begin the implementation process using an adaptive management approach immediately after City Council approval of the Water Forward plan. The Water Forward adaptive management plan (see **Appendix M**) will guide implementation timelines with the flexibility to change to address possible uncertainties in the future. Additionally, the Water Forward plan will be updated on a five- year cycle, using new data about changing conditions to inform potential adjustments to the planned implementation strategy and to ensure that we are on a path to meeting our goals. During the next five years, Austin Water will work to implement the Water Forward plan by taking the actions described in the sidebar. The current adaptive management plan lays out a timeline that takes into consideration the need to "ramp up" demand management strategies sooner, as they take time to realize their full benefits; time for public outreach and community engagement; time for engineering, field testing, and construction; processes for adjusting strategies should one or more strategies not perform as expected; and the possibility that in the longer-term, strategies not included in the Hybrid 1 Portfolio might become more feasible and beneficial for implementation. The exact timing of implementation will be based on several factors, such as potential uncertainty related to action step duration, the need for sequential actions, and potential resource and budget constraints of the utility, but the Water Forward adaptive management plan will allow implementation adjustments to account for these uncertainties and keep the plan on track.

Figure 9-3. Illustration of going from strategic, planning-level recommendations to implementation of projects, programs, and ordinances

Major Water Forward Implementation Actions in the Next 5 Years

Ordinances (new or changes existing)

- *Alternative water ordinance for new larger commercial and multifamily development*
- *Dual plumbing ordinance for new larger commercial and multifamily development*
- *Expand current reclaimed water system connection requirements*
- *Ordinance to require submittal of water use information for new development*
- *Monitor existing ordinances related to air conditioning condensate reuse and cooling tower and steam boiler efficiency*

Incentives

- *Expand alternative water incentive program*
- *Expand landscape incentive program*
- *Expand irrigation efficiency incentive program*

Projects and Programs

- *Study and begin design, construction, and testing of an Aquifer Storage and Recovery pilot*
- *Implement Advanced Metering Infrastructure*
- *Enhance utility water loss reduction program*
- *Expand the centralized reclaimed water system*
- *Explore community-scale decentralized reclaimed water options*
- *Refinement of Indirect Potable Reuse strategy*
- *Refinement of Capture Lady Bird Lake Inflows strategy*
- *Begin preliminary analyses to support five-year Water Forward plan update*

9.3.1 Costs

The planning-level estimated costs to implement the Water Forward plan through the 2040 planning horizon are presented in **Table 9-3**, and further detail can be found in **Appendix J**. The estimated capital and operations and maintenance (O&M) costs presented reflect community costs, which include costs to be paid by Austin Water and its ratepayers, as well as costs to developers and program participants, with potential cost offsets though utility incentives. **Table 9-3** is organized into three categories, reflecting current utility strategic initiatives in the capital plan, new utility strategies, and developer/program participant-owned strategies with potential cost offsets through utility incentives.

Cost and affordability were key community values communicated to the project team throughout the public input process for Water Forward. To reflect cost and affordability in the development of the plan recommendations, several of the sub-objectives used to evaluate strategies were based on cost-effectiveness and the ability to secure external funding for implementation. The recommended Water Forward plan contains several conservation and reuse strategies, which help in stretching our existing supplies through delaying the cost of paying for water under Austin's current municipal water supply contract or purchasing additional supply that would be needed every year. As our community will need additional supplies during future droughts, planning today allows the utility to leverage advantageous funding mechanisms for projects and pace out infrastructure investment over time to mitigate potential rate impacts.

The cost of implementing the recommended strategies could be funded through, among other methods, Austin Water revenues, low-interest bonds or other outside funding, development costs, or shared community investments. In some cases, Austin Water investments could be combined with investments from the community, as in rebates and other incentive programs. Austin Water will work to determine what funding and resource requirements are most suitable to consider for implementing plan strategies and programs. This will include, among other things, evaluation of the Texas Water Development Board's State Water Implementation Fund for Texas loan program and other financing and funding mechanisms to minimize ratepayer costs.

The Water Forward plan is a high-level strategic plan intended to provide a roadmap to guide development of future programs, projects, and ordinances. More detailed cost estimates and funding approaches for each recommended strategy will be developed in the implementation phase and will be subject to future Council action as required.

Table 9-3. Estimated planning-level community cost summary for Water Forward strategies through 2040 (in current dollars, not escalated)

Water Forward Strategies	2019-2040 Est. Cumulative Capital Cost ($M)	2019-2040 Est. Cumulative O&M Cost ($M)	2020 Yield (AFY)	2040 Yield (AFY)
Strategies that are Currently Strategic Initiatives in AW's Capital Improvement Plan (to 2040 Horizon)				
Advanced Metering Infrastructure (AMI)	$79.9	$21.0	600	3,880
Water Loss Control	$313.6	$38.5	3,110	9,330
Direct Non-Potable Reuse - Centralized Reclaimed Water	$215.4	$46.2	500	12,000
Aquifer Storage and Recovery Pilot	$4.8	$ -	NA	NA
Sub-Total:	$613.6	$105.8	4,200	25,210
Average Annual Cost Through 2040:	$27.9	$4.8		
New Strategies				
Benchmarking	$ -	$5.4	0	5,950
Landscape Transformation Ordinance	$ -	$2.9	0	3,040
Landscape Transformation Incentives*	$ -	$1.6	0	320
Irrigation Efficiency Incentives*	$ -	$1.6	40	210
Full-Scale Aquifer Storage and Recovery	$362.9	$57.2	0	60,000
Brackish Groundwater Desalination	Strategy to be implemented beyond 2040		0	0
Indirect Potable Reuse (IPR) through Lady Bird Lake	$34.9	O&M costs included as part of Capture Local Inflows in LBL (below)	0	11,000
Capture Local Inflows to Lady Bird Lake (LBL)	Capital costs included as part of IPR (above)	$1.9	0	3,000
Off Channel Reservoir	Strategy to be implemented beyond 2040		0	0
Distributed Wastewater Reuse	$18.1	$19.4	0	3,150
Sewer Mining	$13.3	$12.6	0	1,000
Sub-Total*:	$429.1	$102.7	40	87,670
Average Annual Cost Through 2040:	$19.5	$4.7		
Developer/Program Participant-Owned Strategies with Potential Cost Offsets Through Utility Incentives				
CII Ordinances	$4.0	$1.7	1,060	1,060
Lot Scale Stormwater Harvesting	$16.2	$4.8	0	330
Lot Scale Rainwater Harvesting	$31.7	$13.4	0	1,550
Lot Scale Graywater Harvesting	$111.6	$97.6	0	2,130
Lot Scale Wastewater Reuse	$74.5	$80.7	0	1,320
AC Condensate Reuse	$34.4	$ -	100	1,080
Community Stormwater Harvesting	$1.7	$0.7	0	160
Sub-Total:	$274.1	$198.9	1,160	7,630
Average Annual Cost Through 2040:	$12.5	$9.0		
Community Cost Total Through 2040*:	$1,316.8	$407.3		
Average Annual Community Cost Through 2040*:	$59.9	$18.5		

*Cost estimates do not include costs for incentives. Incentive amounts will be determined as part of the implementation phase.

Note: Some option costs may vary from costs presented in Appendix J due to further refinement during portfolio evaluation. These planning-level cost estimates are subject to change pending further study and analysis.

9.3.2 Metrics

Various metrics will likely be used to track Austin Water's progress in implementing the Water Forward plan. Additionally, the Water Forward plan includes a recommendation that the Water Forward Task Force meet on a quarterly basis after plan approval to support and monitor plan implementation efforts. Potential metrics to monitor implementation and the need for plan adjustments are listed below.

- Austin Water Served Population and Employment, Development Trends, and Demands: Are they tracking with the IWRP projections?

Table 9-4. Projections of population, climate adjusted pumpage, and GPCD

Planning Horizon	Served Population	Potable and Non-Potable Pumpage (AFY)	Potable and Non-Potable GPCD	Potable Pumpage (AFY)	Potable GPCD
2020	1,101,600	145,000	117	144,000	117
2040	1,577,800	182,000	103	160,000	91
2070	2,314,800	262,000	101	204,000	79
2115	3,977,400	415,000	93	288,000	65

- Supplies: What is the ratio of supply capacity to demand?
- Project Implementation:
  - Progression of projects and programs compared to estimated project milestones (see **Appendix M** for more detailed information on planned action steps).
  - Estimated savings from implemented demand management options.

Table 9-5. Preliminary estimated savings from demand management strategies (subject to change pending further detailed analysis to be performed in the implementation phase)

Demand Management Strategy	2025 Water Savings Estimate (AF/Year)	2040 Water Yield Estimate (AF/Year)
Advanced Metering Infrastructure (AMI)	600	3,880
Utility-Side Water Loss Control	4,090	9,330
CII Ordinances (existing ordinance)	1,060	1,060
Benchmarking	0	5.950
Landscape Transformation Ordinance	0	3,040
Landscape Transformation Incentive	80	320
Alternative Water Ordinance	210	1,620
Alternative Water Incentive	500	3,860
AC Condensate Reuse (existing ordinance)	350	1,080
Irrigation Efficiency Incentive	80	200

Note: Estimates subject to change dependent on many factors including growth rates, development trends, specific ordinance and program design, regulatory and permitting considerations, etc.

- Estimated yield from implemented supply options.

Table 9-6. Preliminary estimated yield from recommended supply strategies (subject to change pending further detailed analysis to be performed in the implementation phase)

Supply Strategy	2025 Water Yield Estimate (AF/Year)	2040 Water Yield Estimate (AF/Year)
Centralized Reclaimed System (Direct Non-Potable Reuse)	1,110	12,000
Community-Scale Distributed Wastewater Reuse	10	3,150
Community-Scale Sewer Mining	10	1,000
Aquifer Storage and Recovery	0	60,000
Indirect Potable Reuse (IPR) through Lady Bird Lake with Capture Lady Bird Lake Inflows	0	11,000
New Off-Channel Reservoir and Brackish Groundwater Desalination	0	0

Note: Estimates subject to change dependent on many factors including growth rates, development trends, specific ordinance and program design, regulatory and permitting considerations, etc.

With hard work and community support, implementation of Water Forward will create a more sustainable, reliable water supply for Austin for the next 100 years and beyond.

APPENDIX A: PUBLIC OUTREACH AND PARTICIPATION SUMMARY

Public outreach and education efforts for the Integrated Water Resources Plan (IWRP) were performed to gather meaningful public input to develop a plan that is representative of Austin community values.

A.1 IWRP Public Outreach Framework

The Water Forward Public Outreach Framework was designed with the intent of providing a flexible and actionable approach to community engagement as part of the plan development process.

A.1.1 Objectives-Driven Approach

The IWRP Public Outreach Framework was based on an objectives-driven approach. This was defined as "public participation with a purpose," designed to achieve meaningful outcomes for the community and the utility.

- Objectives provide specific, achievable targets that the utility can use to solicit input in multiple formats across diverse groups
- Participants understand what input is needed and how it will be used
- Objectives provide common ground for reporting results back to the public

A.1.2 Key Objectives

At the outset of the plan development process, Austin Water staff worked with the Water Forward Task Force to develop key objectives for public outreach and education efforts undertaken as part of the plan. Three key goals were established that formed a core element of the IWRP Public Outreach Framework.

- Community Values: Identify community values that should be reflected in the IWRP
- Diverse Public Input: Seek input from the community which reflect the diversity of Austin's population and customers.
- Public Education: Inform and educate the community throughout the plan development process.

A.1.3 Targeted Participant Groups

The framework also identified several participant groups to engage as part of the plan development process. This list was not comprehensive, but was meant to serve as a starting point for further identification of groups to target as part of public outreach and education efforts.

- Austin Water customers: to include various sectors such as Single-Family Residential, Multi-Family Residential, and Commercial customers.
- Diverse participant groups

- Underrepresented groups
- Groups with high interest

- Community groups
- Regional agencies
- Policymakers

A.1.4 Potential Public Outreach Strategies

The IWRP framework identified a toolbox of potential public outreach strategies, many of which were utilized during the plan development process.

Existing Initiatives & Outlets	Public Events & Opportunities	Social Media	Print and Digital Media
• Imagine Austin and CodeNext: Sustainably Manage our Water Resources and Green Infrastructure Programs • Water use report software (DropCountr) • City of Austin Community Registry • Coordination with other department and agencies	• Public workshops • Focus groups • Conversation Corps • Neighborhood meetings • Community events • Presentations • Education panels • Festivals	• Twitter (inc. Q and A's) • Facebook • Hashtag • Flickr • Videos (ATXN, YouTube, Vine) • Pinterest • NextDoor • BloomFire	• Flyers • Bill inserts • Reports and fact sheets • Advertising • Community association newsletters • Mailing lists • Austin Water eNewsletters • Austin Water website • Austin Energy Power Plus • COA Environmental Portal Banner • ATXN Slideshow • Surveys • Neighborhood lists

A.1.5 Creating a Public Outreach Plan

The IWRP Public Outreach Framework culminated in a six-step methodology to develop objectives-driven outreach strategies as part of the IWRP Public Outreach Action Plan. The Action Plan was intended to be a living document that could help to guide the selection and implementation of outreach strategies, while remaining flexible enough to adjust based on participant feedback and progress towards achieving outreach goals.

Identify Audiences
- Identify preliminary audiences by building an understanding of the demographic and geographic diversity of Austin Water customers
- Identify underrepresented groups and others with high interest
- Identify barriers to participation and strategies to overcome those barriers

Identify Messages & Questions
- Identify information that should be communicated to the public as part of public education effort
- Identify what type of input is being sought from the community

Develop Strategies
- Develop outreach strategies based on an objectives-driven public outreach approach

Prioritize
- Prioritize outreach strategies based on criteria such as effectiveness, reach, and cost.
- Assign levels of effort and resources to each outreach strategy

Create an Action Plan
- Develop an action plan to implement objectives-driven outreach strategies

Implement & Iterate
- Implement the action plan, allowing for iteration and evolution of the plan based on feedback from participants

The IWRP Public Outreach Framework culminated in a six-step methodology to develop objectives-driven outreach strategies as part of the IWRP Public Outreach Action Plan. The Action Plan was intended to be a living document that could help to guide the selection and implementation of outreach strategies, while remaining flexible enough to adjust based on participant feedback and progress towards achieving outreach goals.

A.2 Task Force Involvement

In 2014, the Austin Water Resource Planning Task Force was convened during the height of the 2008 to 2016 drought and was tasked with analyzing the City's water needs and making recommendations on how to augment the City's future water supply (see Resolution No. 20140410-033). On July 10, 2014, the Austin Water Resources Planning Task Force presented their recommendations to the Austin City Council, which included recommendations on demand management and water supply strategies. This IWRP was a foremost recommendation of the 2014 Austin Water Resource Planning Task Force.

The Austin Integrated Water Resources Planning Community Task Force was created to support the development of this IWRP (see Resolution No. 20141211-119).

The Council-appointed Task Force members are shown below:

Sharlene Leurig (Chair) District 4 - Council Member Casar	Lauren Ross District 5 - Council Member Kitchen
Jennifer Walker (Vice-Chair) District 9 - Mayor Pro Tem Tovo	Todd Bartee District 6 - Council Member Flannigan
Bill Moriarty Mayor Adler	Robert Mace District 7 - Council Member Pool
Clint Dawson District 1 - Council Member Houston	Marianne Dwight District 8 - Council Member Troxclair
Sarah Richards District 2 - Council Member Garza	Diane Kennedy District 10 - Council Member Alter
Perry Lorenz District 3 - Council Member Renteria	

The Task Force also included Ex Officio members from several City of Austin departments:

Austin Water Greg Meszaros, Director	**Office of Innovation** Kerry O'Connor, Chief Innovation Officer
Austin Energy Kathleen Garrett, Director of Environmental Services	**Office of Sustainability** Lucia Athens, Chief Sustainability Officer
Austin Resource Recovery Sam Angoori, Director	**Parks and Recreation** Sara Hensley, Interim Assistant City Manager
Neighborhood Housing and Community Development Josh Rudow, Planner Senior	**Watershed Protection** Chris Herrington, Supervising Engineer

The Task Force played an instrumental role in shaping the development of the Water Forward Process, providing input along the way to shape the planning process and recommendations that are included in the plan. Task Force meetings were held on a roughly monthly basis from May 2015 through October 2018. To view agendas, approved minutes and supporting documents, please visit: http://austintexas.gov/cityclerk/boards_commissions/meetings/132_1.htm.

A.3 Public Workshops and Meetings

Austin Water gathered meaningful public input throughout the process in order to develop a plan that is representative of the community's values. Input was gathered from community members and representatives from partner organizations through:

- Austin Integrated Water Resource Planning Community Task Force
- Targeted Stakeholder Meetings
- Water Forward Public Workshops
- Summer Series
- Community Events
- Information Sharing
- Community Group Meetings
- Seminars/Professional Events
- District Town Halls

Since 2016, Austin Water has collected input through nearly 80 outreach events including five Water Forward Workshops, four Targeted Stakeholder Meetings, ten Summer Series events (one in each City Council district), and has delivered presentations and/or outreach materials to a total of 60 community events, information sharing sessions, community group meetings, seminars/professional events, and district town halls (see **Table A-1**). The input received has been incorporated into the Draft Water Forward Plan Recommendations.

A.3.1 Outreach and Publicity

All public workshops were publicized by Austin Water as described in **Table A-1**.

Table A-1. Types of outreach and publicity used for Water Forward

Newsletter Lists Emailed	Groups Receiving Targeted Invitations Included	Additional Efforts
• Water Forward (495 people) • WaterWise Residential List (~15,000 people) • WaterWise Commercial List (206 people)	• Neighborhood Associations • Businesses, Developers & Professional Organizations • Environmental Advocates • Civic Leaders • Faith-Based Organizations • Education Representatives	• Outreach to City Council members • Engagement with the Water Forward Task Force • Emails were sent to staff liaisons for the following commissions: o Water Wastewater Commission o Resources Management Commission o Environmental Commission • Social Media included: o Nextdoor o Facebook o Twitter o Water Forward website

[1] Newsletter lists as of March 2018

A.3.2 Outreach Highlights

Highlights from Water Forward public outreach are included below. For a list summarizing outreach activities for Water Forward as of May 2018, please see **Table A-2**.

A.3.2.1 Imagine Austin Speaker Series: Water Forward – Planning for the Next 100 Years

As part of the Imagine Austin Speaker Series, on August 3, 2016, Austin Water Director Greg Meszaros and Austin Integrated Water Resource Plan Community Task Force Chair Sharlene Leurig shared insights on the process and importance of creating a long-term plan that will help secure Austin's water supply for future generations, shown in **Figure A-1**. 62 members of the community attended.

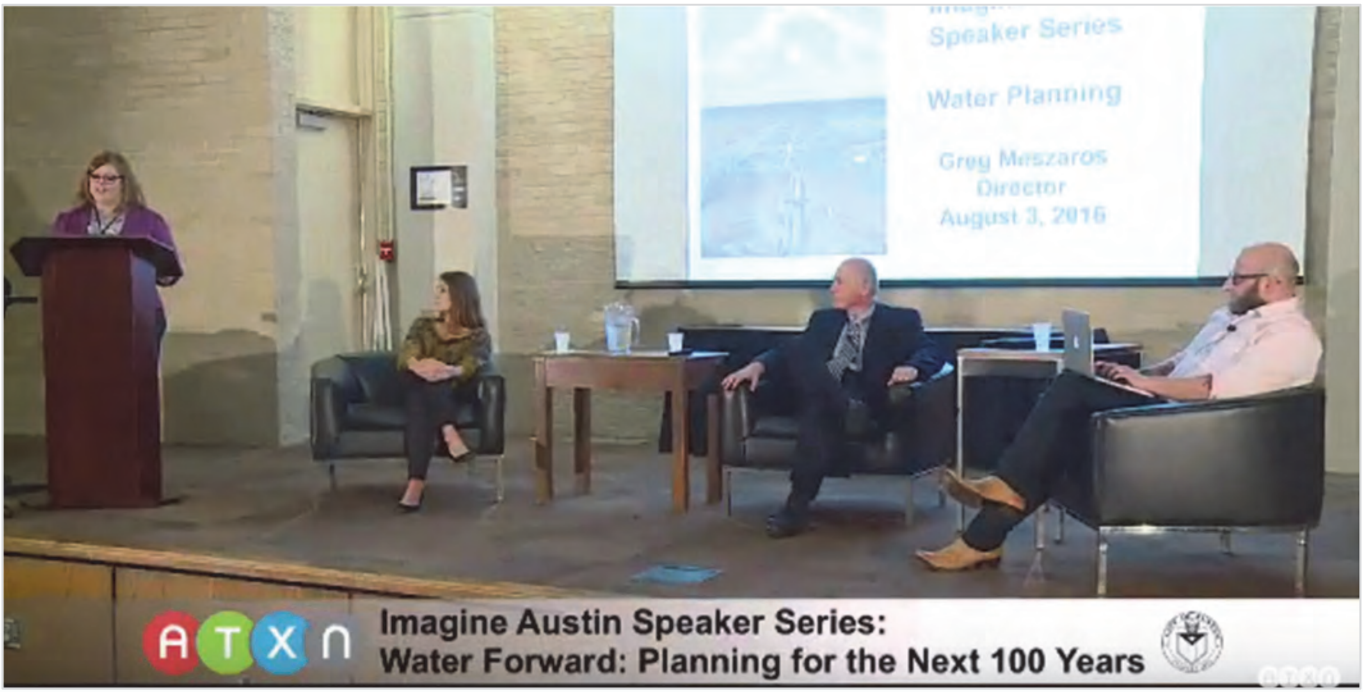


Figure A-1. Photo from the Imagine Austin Speaker Series

A.3.2.2 Austin Water IWRP Public Workshop #1

On September 7, 2016, Austin Water hosted the first of five public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). The workshop gave community members an overview of the IWRP, explained why a water plan is needed, and outlined some of the elements of a potential plan. Participants were then given a chance to offer input on the portfolio evaluation criteria for the IWRP. The workshop was held at the Waller Creek Center, located at 625 E 10th Street, Austin TX from 6:00 p.m. - 8:30 p.m. 24 members of the community attended.

A.3.2.3 Targeted Stakeholder Meetings

Austin Water invited a wide range of participants from various industries to three Targeted Stakeholder Meetings held on January 19th, 24th and 26th in 2017.

Targeted Stakeholder Meetings were aimed at gathering input on specifically identified options from the project team's draft list of 25 demand management options. Participants from various industries were invited to attend one or all of these meetings based on the topics most important to them.

All meetings took place at the Waller Creek Center located at 625 E. 10th St, Austin, TX 78701 from 6:00 p.m. – 8:00 p.m.

Invitees included landscape and irrigation professionals, representatives of environmental interest groups, chambers of commerce, industry representatives, business leaders, and industry professionals.

All meetings began with a presentation from Austin Water to introduce the 100-year plan to participants and explain the disaggregated demand model at a very high level. The presentation included information about public outreach and charts showing consumption by sector and end uses.

Following the Austin Water presentations, full group discussions were led regarding the following meeting topics:

- Targeted Stakeholder Meeting #1: Landscape Transformation and Irrigation Efficiency Ordinances and Incentives
- Targeted Stakeholder Meeting #2: Alternative Ordinances and Incentives (i.e. rainwater, graywater, and AC condensate)
- Targeted Stakeholder Meeting #3: Development-Focused Water Use Estimates & Benchmarking; Commercial, Industrial & Institutional & Non-Residential Ordinances; Plumbing Codes & Ordinances & Fixture Incentives; Reclaimed Water (Centralized Purple Pipe System) Ordinances & Incentives

Conversations and input gathering continued in smaller, facilitated group discussions. Austin Water staff were on hand to answer questions and offer clarifications. Participants discussed how current programs and ordinances affected them, whether they use current rebates and incentives, what barriers they run up against, and how various current programs and ordinances could be improved. Participants were also asked about new technologies being used in the field.

A.3.2.4 Austin Water IWRP Public Workshop #2

On February 8, 2017, Austin Water hosted the second of five public workshops in order to collect public input for the Integrated Water Resource Plan. The workshop featured presentations from the project team about the plan development process, public outreach, and supply and demand modeling. After the presentation, participants were asked to give feedback on supply and demand-management options in a brief exercise. The workshop was held at the Austin Independent School District Performing Arts Center multipurpose room, 1500 Barbara Jordan Boulevard, Austin TX from 6:00 p.m. to 8:30 p.m. 30 members of the community attended.

A.3.2.5 Austin Water IWRP Workshop #3

On April 4, 2017, Austin Water hosted the third of four public workshops in order to collect public input for the Integrated Water Resource Plan. The workshop featured presentations from the project team about the plan development process, public outreach, and supply and demand modeling. After the presentation, participants were asked to give feedback on supply and demand-management options in a brief exercise. The workshop was held at One Texas Center, 505 Barton Springs Road, Room 325, Austin, TX 78704, from 6:00 p.m. to 8:30p.m. 22 members of the community attended.

A.3.2.6 Summer Series

During the months of July and August 2017, Austin Water held a series of ten public meetings. These meetings were held at diverse times of the day and week and hosted at public libraries in each Council district. Meetings were advertised as child friendly and snacks were provided. The meetings focused on discussing emerging themes from stakeholder feedback, for the purpose of portfolio development. The Summer Series were designed as a lead up to Public Workshop #4.

The meetings featured a presentation from staff about the plan development process with a focus on the portfolio development process. The presentation included information about stakeholder outreach events and the themes that had emerged from ongoing outreach efforts, including the Community Values Survey. Participant's questions were answered during the presentation. A group discussion followed the presentation, where input was gathered on the emerging themes.

A.3.2.7 Austin Water IWRP Workshop #4

On August 16, 2017, Austin Water hosted the fourth of five public workshops in order to collect public input for the Integrated Water Resource Plan. The workshop featured presentations from the project team about the plan development process including key process steps completed, public outreach conducted to date including emerging themes from public feedback, supply and demand options, and portfolio development and evaluation. After these presentations, participants were invited to participate in two Question and Answer sessions followed by facilitated small group discussions. The workshop was held at the Canyon View Events Center (Austin Board of Realtors Building) located at 4800 Spicewood Springs Road, Austin, TX from 6:00 p.m. to 8:00 p.m. 25 members of the community attended.

A.3.2.8 Targeted Stakeholder Meeting #4: Update on Plan Process & Initial Portfolio Compositions

Austin Water hosted a targeted stakeholder meeting on Wednesday, November 15th, 2017 from 6:00 to 8:00 pm at the Waller Creek Center, 625 E. 10th St, Austin, TX 78701. After successful targeted stakeholder meetings in January of 2017 that focused on getting input on the demand management and supply side options, the same group of participants were invited for this meeting to update them on the project.

A.3.2.9 Austin Water Integrated Water Resources Plan Workshop #5

On March 21, 2018, Austin Water hosted the fifth of five public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). The workshop featured presentations from the project team including a recap of the plan development process, themes from public feedback, portfolio development and evaluation, and draft plan recommendations and benefits. After presentations, participants were invited to participate in two Question and Answer sessions followed by an Open House where participants were invited to view draft plan recommendation benefits and get their questions answered by project team members.

The workshop was held at the Dawson Elementary School Cafeteria located at 3001 S 1st St, Austin, TX 78704 from 6:00 p.m. to 8:00 p.m. 29 members of the community attended (24 participants attended in person and five participants attended via webinar).

A.4 Summary of Outreach Activities

Table A-2. Summary of outreach activities as of October 2, 2018

Date	Event Name	Event Category / Description	Number of Attendees (as available)
8/3/16	Imagine Austin Speaker Series: Water Forward - Planning for the Next 100 Years	Community Event	62
9/7/16	Public Workshop #1	Water Forward Event	24
9/11/16	Planning & Zoning N. Burnet Rd. Better Block Event	Community Event	
9/14/16	AustinCorps High School Program	Community Event	
9/17/16	Carver Library Tabling	Community Event	
9/28/16	Austin Hotel & Lodging Expo	Seminar/Professional Event	
9/28/16	Commercial Programs Technical Workshop	Seminar/Professional Event	
10/1/16	National Night Out Kickoff Party	Community Event	300
10/3/16	South River City Citizen's Meeting	Community Group Meeting	
10/8/16	Southeast Branch Library	Community Event	
10/22/16	25th Annual Austin Arbor Day	Community Event	12
10/27/16	Talk Green to Me - A Gray Water Overview	Community Event	7
10/27/16	UT Campus Sustainability Week Local Impact Day	Community Event	35
10/29/16	AE Community Connection Resource Fair	Community Event	1,000
11/5/16	Northwest Austin Neighborhood Association	Community Group Meeting	10
11/19/16	Grow Green Homeowner's Training	Community Event	25
11/26/16	Chuy's Children Giving to Children Parade	Community Event	
12/9/16	Gilbert Elementary College and Career Fair	Community Event	125
12/10/16	Frost Bank Home Improvement Mini-Expo	Community Event	37
12/17/16	Pleasant Valley Market	Community Event	10
1/19/17	Targeted Stakeholder Meeting #1	Water Forward Event - Demand Management Options with focus on Landscape Transformation and Irrigation Efficiency Ordinances and Incentives	23
1/24/17	Targeted Stakeholder Meeting #2	Water Forward Event - Demand Management Options with focus on Alternative Water Ordinances and Incentives that may include rainwater, gray water, and A/C condensate	15
1/26/17	Targeted Stakeholder Meeting #3	Water Forward Event - Demand Management Options with focus on Development-focused Water Use Estimates and Benchmarking; Commercial, Industrial, and Institutional and Non-residential Ordinances; Plumbing Codes and Ordinances and	12

Date	Event Name	Event Category / Description	Number of Attendees (as available)
		Fixture Incentives; and Reclaimed Water (centralized purple pipe system) Ordinances and Incentives	
1/31/17	Youth Career Fest 2017	Community Event	90
2/2/17	Central Texas Water Efficiency Network Symposium	Seminar/Professional Event	100
2/7/17	African American Heritage Network- Black History Luncheon	Community Event	150
2/8/17	Public Workshop #2	Water Forward Event - Future Water Supply Needs and Strategies to Meet Them	30
2/21/17	WaterWise Irrigation Professionals Seminar	Seminar/Professional Event	252
2/27/17	UT Graduate Class, Energy and Earth Resources program	Seminar/Professional Event	25
3/25/17	Zilker Garden Festival	Community Event	350
3/26/17	Interfaith Dialogue Event	Community Event	~50
3/26/17	Zilker Garden Festival	Community Event	250
4/4/17	Public Workshop #3	Water Forward Event - Future Water Supply Needs and Strategies to Meet Them	22
4/6/17	University of Texas City Forum	Seminar/Professional Event	~25
4/12/17	Texas Water Conference	Community Event	
4/18/17	IBM Earth Day	Community Event	125
4/20/17	TX Parks and Wildlife Earth Day Event	Community Event	75
4/20/17	IBM Earth Day	Community Event	80
4/21/17	Arboretum Plaza Earth Day	Community Event	
4/22/17	Earth Day ATX	Community Event	400
4/23/17	Sun Radio Earth Day	Community Event	100
5/4/17	Apartment Association Trade Show	Community Event	
5/5/17	Save Barton Creek Association Meeting	Community Group Meeting	~12
5/13/17	District 7 Town Hall	District Town Hall	40
5/22/17	Northwest Austin Coalition Meeting - District 6 Town Hall	District Town Hall	~15
5/25/17	El Concilio - A Coalition of Mexican American Neighborhoods	Community Group Meeting	~12
5/30/17	Montopolis Neighborhood Association Meeting	Community Group Meeting	~12
6/11/17	Cool House Tour	Community Event	
6/13/17	Austin Neighborhoods Council - East	Community Group Meeting	15
6/13/17	District 5 Town Hall	District Town Hall	40
6/19/17	District 10 Town Hall	District Town Hall - Tabling	~125
6/21/17	350.org	Community Group Meeting	5
6/22/17	UT Facilities	Information Sharing	~18

Date	Event Name	Event Category / Description	Number of Attendees (as available)
7/8/17	Summer Series - District 2	Water Forward Event - Emerging Themes from Public Input	1
7/12/17	Water and Wastewater Commission	Information Sharing	
7/14/17	NXP	Information Sharing	
7/15/17	Summer Series - District 7	Water Forward Event - Emerging Themes from Public Input	3
7/17/17	Summer Series - District 6	Water Forward Event - Emerging Themes from Public Input	3
7/19/17	Summer Series - District 9	Water Forward Event - Emerging Themes from Public Input	7
7/22/17	Summer Series - District 4	Water Forward Event - Emerging Themes from Public Input	4
7/29/17	Summer Series - District 3	Water Forward Event - Emerging Themes from Public Input	4
7/31/17	Summer Series - District 10	Water Forward Event - Emerging Themes from Public Input	6
8/5/17	Summer Series - District 8	Water Forward Event - Emerging Themes from Public Input	6
8/8/17	Summer Series - District 5	Water Forward Event - Emerging Themes from Public Input	7
8/12/17	Summer Series - District 1	Water Forward Event - Emerging Themes from Public Input	8
8/16/17	Public Workshop #4	Water Forward Event - Emerging Themes from Public Input	25
9/19/17	East Riverside Oltorf Neighborhood Association Meeting	Community Group Meeting	~20
9/28/17	Austin Board of Realtors	Community Group Meeting	6
10/4/17	AARO Energy and Water Committee		
10/19/17	L.B.J. Neighborhood Association	Community Group Meeting	7
10/19/17	TWCA	Seminar/Professional Event	
10/25/17	Friends of Riverside Neighborhood Association	Community Group Meeting	9
10/28/17	Hopefest	Community Event	100
11/15/17	Targeted Stakeholder Meeting	Water Forward Event - Update on plan process, screened option, characterized information and initial portfolio compositions	5
11/15/17	Water Utility Climate Alliance	Seminar/Professional Event	
11/27/17	Colony Park Neighborhood Association	Community Group Meeting	20
1/27/18	Georgian Acres Neighborhood Association	Community Group Meeting	12
3/12/18	Save Barton Creek Association Meeting	Community Group Meeting	7
3/21/18	Public Workshop #5	Water Forward Event – Draft Water Forward Plan Recommendations	29
3/26/18	Leader Track Focus Group #1	Community Group Event	7
3/27/18	Leader Track Focus Group #2	Community Group Event	5
4/6/18	ASCE Continuing Education Conference - Designing a more Resilient Central Texas	Seminar/Professional Event	50-60

Date	Event Name	Event Category / Description	Number of Attendees (as available)
4/22/18	Earth Day ATX	Community Event	~200
5/16/18	One Water For Texas	Seminar/Professional Event	6
6/1/18	Austin Board of Realtors	Community Group Event	~20
7/17/18	Resource Management Commission	Commission Meeting	
7/25/18	Joint Sustainability Commission	Commission Meeting	
8/1/18	Environmental Commission	Commission Meeting	
8/8/18	Water and Wastewater Commission	Commission Meeting	
8/14/18	Planning Commission	Commission Meeting	
8/22/18	AWRA webinar	Seminar/Professional Event	
8/23/18	Central Texas Water Efficiency Network	Community Group Event	~20
8/30/18	Water Forward Stakeholder Meeting	Water Forward Event	9
9/10/18	Save Barton Creek Association Meeting	Community Group Event	
9/11/18	Sierra Club Meeting	Community Group Event	
9/13/18	Water Forward Open House - North	Water Forward Event	7
9/18/18	Water Forward Open House - South	Water Forward Event	5
10/2/18	African American Resource Advisory Commission	Commission Meeting	

A.5 Demographic Summary

The charts and maps included in this section are a summary of self-reported demographic information from participants of the five public workshops, four targeted stakeholder meetings, ten summer series events, and surveys including community value survey, strategies to meet Austin's future water needs survey and demand management options feedback form survey. These do not include demographic information of participants that chose to share their input verbally, or chose to not share their demographic information.

- Total number of responses received: 783
- Number of online responses: 345
- Number of paper responses: 438

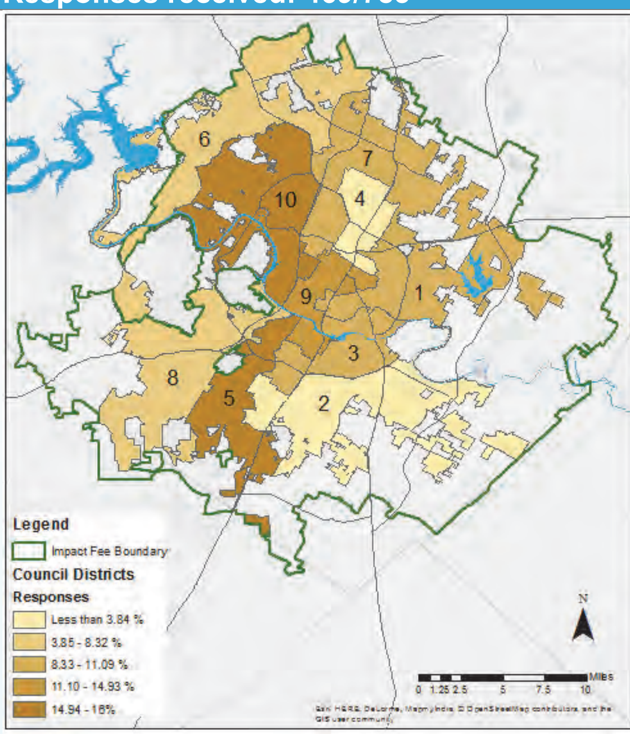
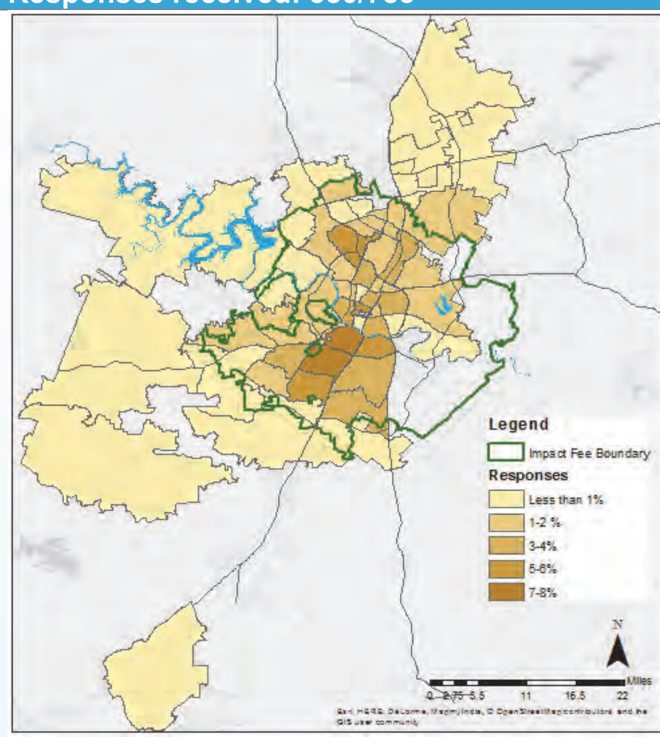
Table A-3. Comparing demographics of Water Forward respondents to demographics of Austin

		Water Forward	Austin
Gender[1]	Male	50.6%	50.3%
	Female	49.4%	49.7%
Age[1]	Under 18	5.4%	21.9%
	18-29	16.7%	48.6%
	30-44	29.1%	
	45-64	33.1%	21.9%

		Water Forward	Austin
	65 and over	15.7%	7.6%
Race/ Ethnicity[2]	Anglo	72.4%	47.1%
	African-American	3.2%	7.0%
	Asian-American	4.9%	6.8%
	Hispanic/Latino	14.4%	36.5%
	Other	5.2%	2.6%
Household Income[1]	Less than $24,999	11.0%	21.0%
	$25,000-$49,999	16.4%	24.1%
	$50,000-$74,999	20.9%	18.3%
	$75,000-$149,999	34.8%	25.5%
	More than $150,000	16.9%	11.1%
Type of Residence[3]	Single-family Home	79.1%	51.8%
	Duplex or Triplex	6.0%	46.70%
	Multi-family	11.8%	
	Other	3.1%	1.60%

Note: Austin city level demographics are summarized from the following sources
1. http://www.austintexas.gov/sites/default/files/files/Planning/Demographics/CoA_ACS_Profile_2013.pdf
2. http://www.austintexas.gov/sites/default/files/files/Planning/Demographics/COA_Travis_MSA_2014_Race_and_Ethnicity_estimates.pdf
3. American Community Survey 2016: Table DP04

Table A-4. Comparison of responses by Council district and zip code

Distribution of responses across Austin when Council District was specified Responses received: 469/783	Distribution of responses across Austin when zip code was specified Responses received: 380/783
	

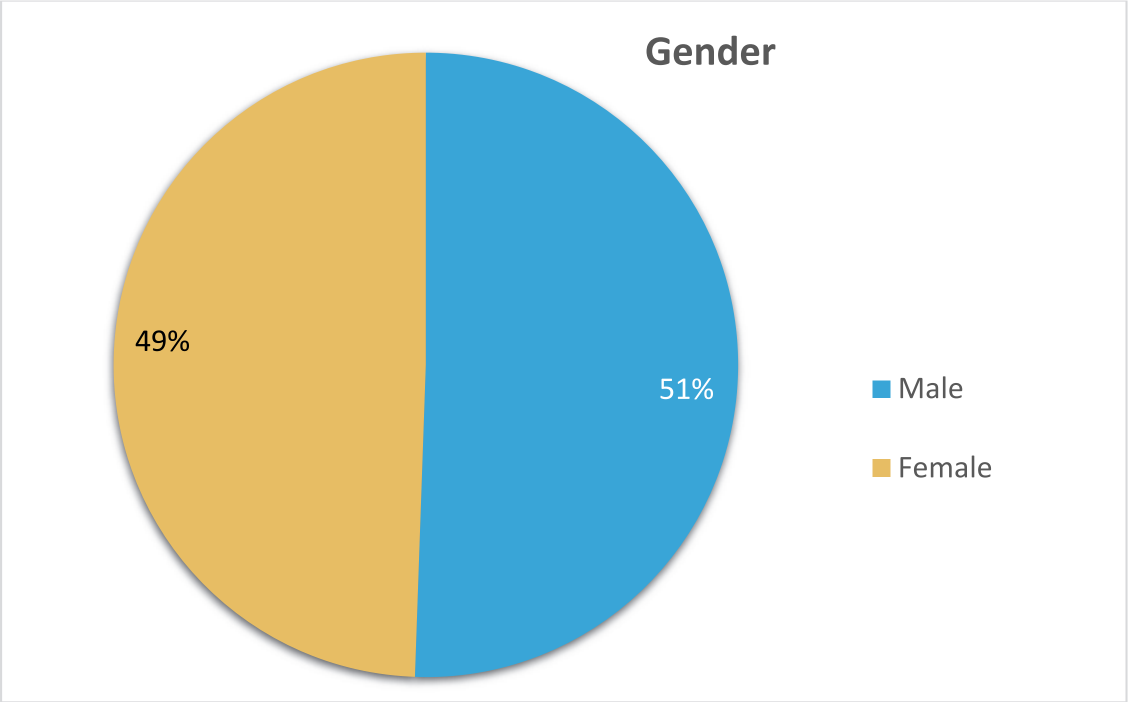


Figure A-2. Distribution of responses across gender. Responses received: 718/783

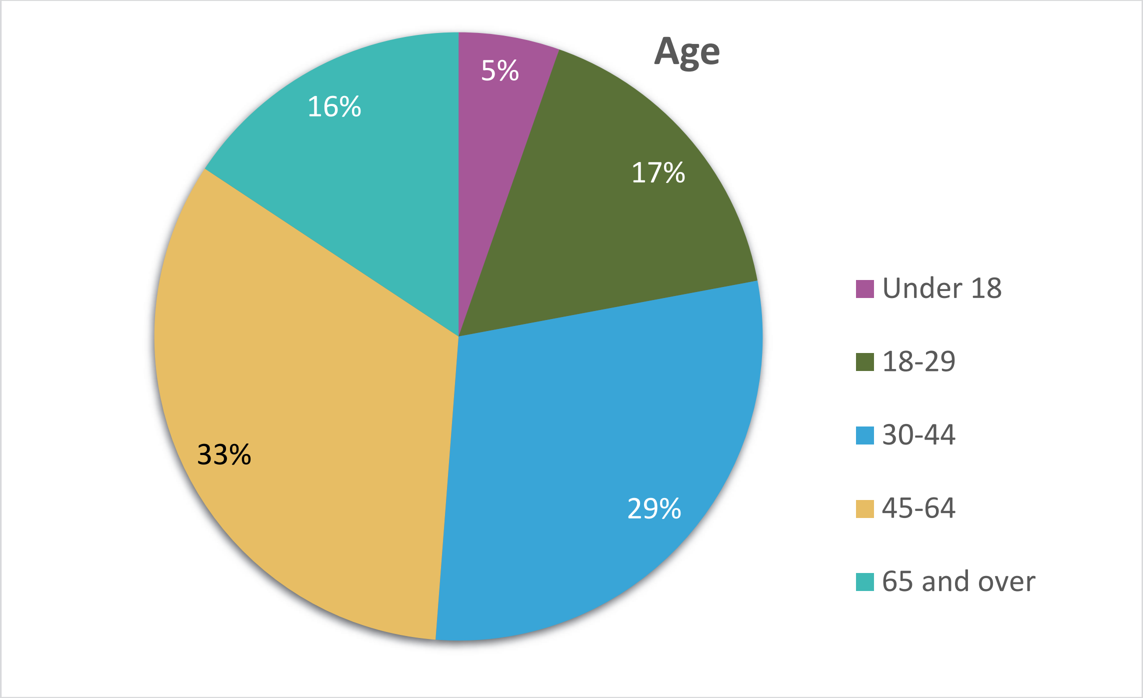


Figure A-3. Distribution of responses across age groups. Responses received: 707/783

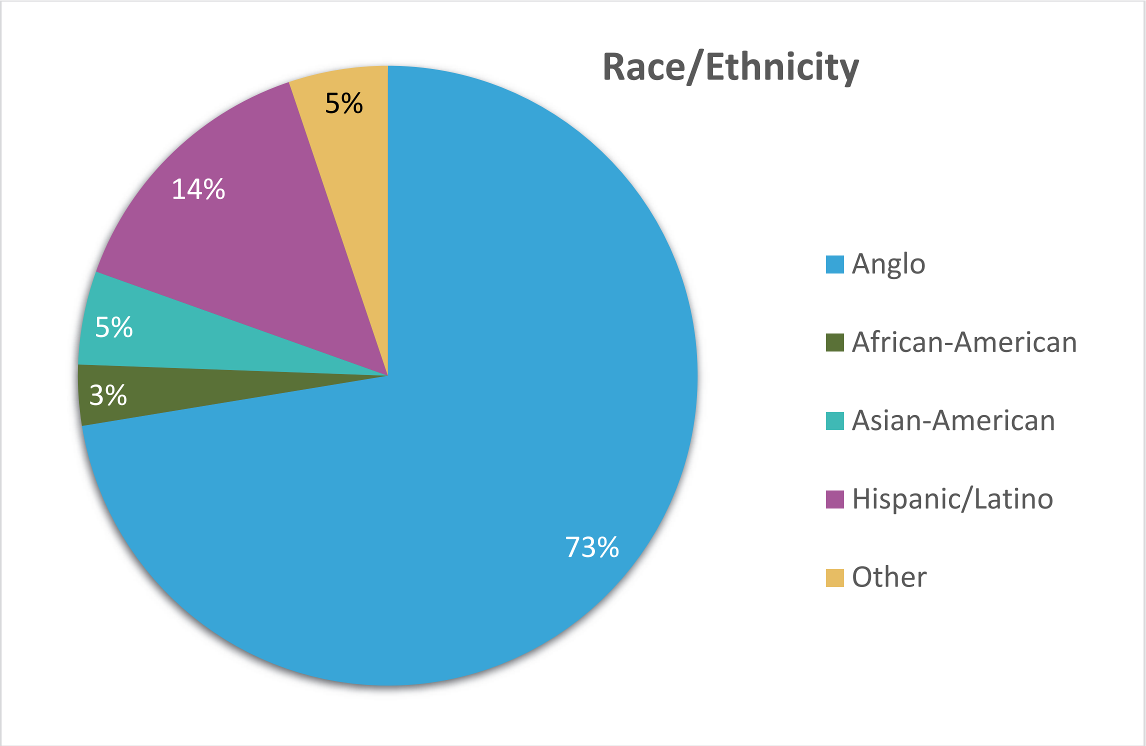


Figure A-4. Distribution of responses across race. Responses received: 696/783

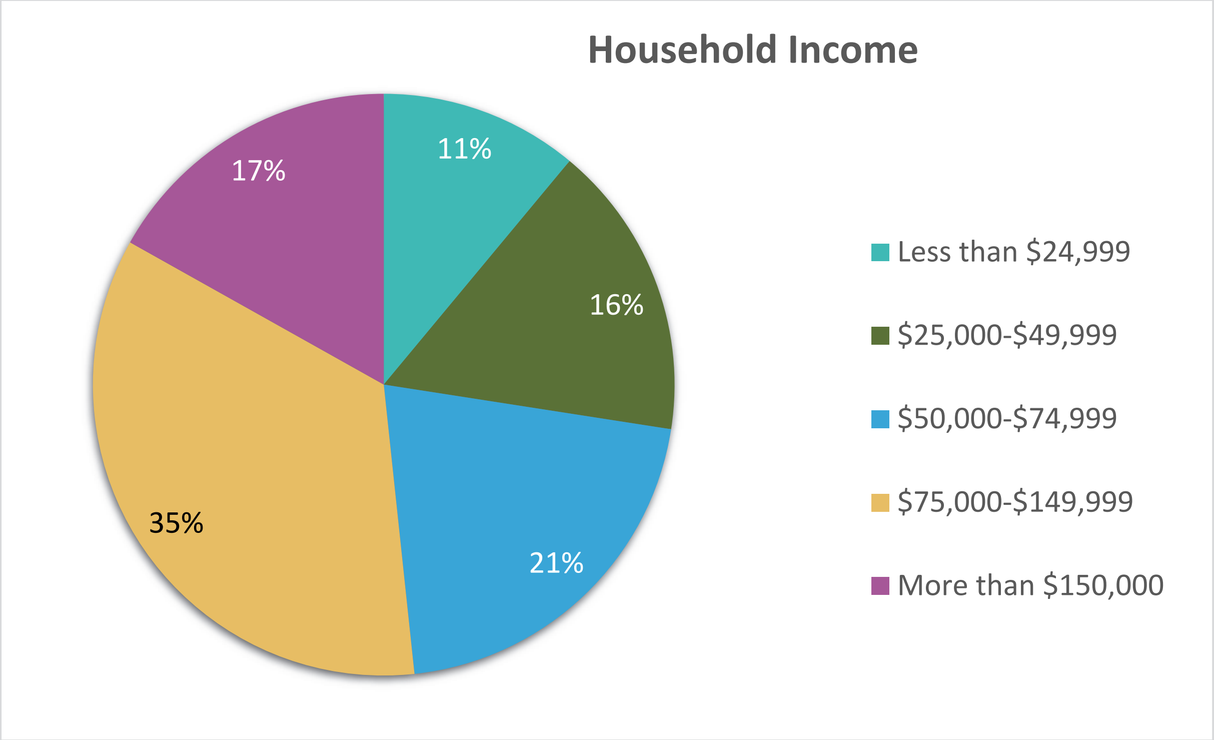


Figure A-5 Distribution of responses across household income. Responses received: 652/783

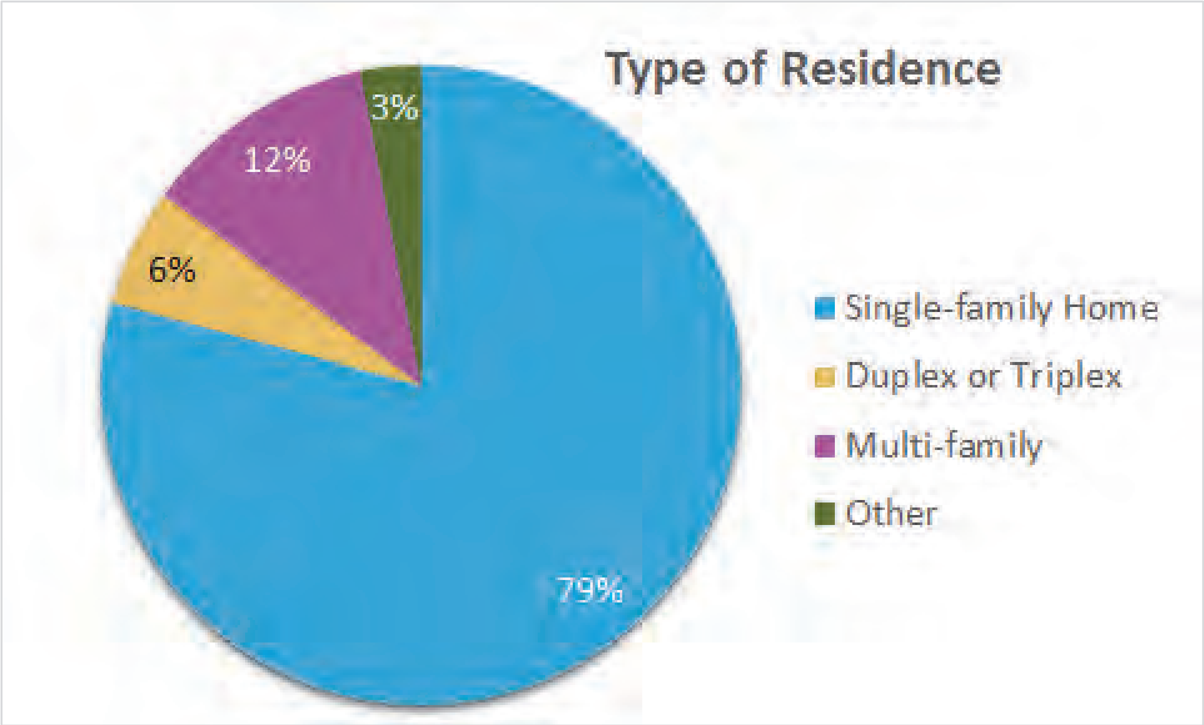


Figure A-6. Distribution of responses across types of residence. Responses received: 719/783

Memorandum

To: *Teresa Lutes, Austin Water*

From: *Megan Klein, Rifeline*

Copied: *Marisa Flores Gonzalez, Austin Water*

Date: *September 22, 2016*

Subject: *Austin Water Integrated Water Resources Plan Workshop 1 Summary Report*
Task 1 – Public Outreach
CDM P/N: 0590-114879

On September 7, 2016, Austin Water hosted the first of four public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). This 100-year water plan will evaluate mid- to long-term water supply and demand management options for the City of Austin. The IWRP planning process will provide a holistic and inclusive approach to water resource planning.

The workshop gave stakeholders an overview of the IWRP, explained why a water plan is needed and outlined some of the elements of a potential plan. Stakeholders were then given a chance to offer input on the portfolio evaluation criteria for the IWRP. The workshop was held at the Waller Creek Center, located at 625 E 10th Street, Austin TX from 6:00 pm to 8:30 pm. Twenty-four members of the community attended and signed in (see sign in sheet in appendix).

Outreach and Publicity

The event was publicized by Austin Water in the following ways:

- Austin Water emailed the following eNewsletter lists a notice about the workshop (see appendix for invitation):
  - Water Forward (225 stakeholders)
  - WaterWise Residential List (16,792)
  - WaterWise Commercial List (145)
- Austin Water emailed invitations to groups and individuals on the Water Forward stakeholder list, including:
  - Neighborhood associations
  - Businesses, developers, and professional organizations

- Environmental advocates
- Civic Leaders
- Faith-based organizations
- Education representatives

- Austin Water reached out to City Council members and engaged the IWRP Task Force.
- Austin Water emailed the staff liaisons for the Water Wastewater Commission, Resource Management Commission (RMC), and the Environmental Commission.
- Posted information to Next Door and Facebook and Twitter (see Appendix).
- Posted information to the Water Forward website, http://austintexas.gov/waterforward.

Presentation

Austin Water staff provided an overview of the background of Austin Water, the Integrated Water Resource Plan and the planning process, as well as future public outreach activities. The presentation highlighted:

- Austin Water's demand and population
- History, purpose and goals of the plan
- IWRP development process and public outreach opportunities

The Consultant team outlined the guiding principles of the planning process and discussed the Objectives, Purpose and Desired Outcomes of the plan on which the stakeholders would give feedback. A copy of the full PowerPoint presentation is available in the Appendix.

Stakeholder Feedback

Stakeholders were asked to give their feedback at five stations, one for each of five Objectives including: water supply benefits; economic benefits; societal benefits; implementation benefits; and environmental benefits. At each station, a member of the project team facilitated a discussion to discover what stakeholders liked about the Objectives, Purpose and Desired Outcomes, what the stakeholders didn't like about the sub-objectives, and if they thought anything needed to be added. A scribe captured their comments on flipcharts and the compiled comments for each Objective are included in the appendix (see appendix). Stakeholders were also given a survey that they could use to write comments that were specific to each Objective and Purpose and Desired Outcomes (see scans of surveys received in the appendix as well as a scan of one comment form received). The following sections provide a summary of the feedback received, categorized by Objective.

Objective: Water Supply Benefits

Purpose: Sustain Austin's water supply reliability, providing resiliency for future population growth and climate change

Desired Outcomes:

- Minimize the number, duration and size of water shortages
- Maximize the certainty that the water supply will be available to Austin when needed
- With emphasis on local sources, enhance the diversification of water supply

Feedback summary:
The drought of the last several years was a major topic of discussion with regard to water supply. Discussion ranged from defining local sources to how we put a monetary value on water. The main recurring theme was the desire to plan for future shortages now. Stakeholders value infrastructure investment with an eye on conservation, safety, and water quality.

Other key feedback themes for this Objective include:

- Need for clarity of technical language (e.g., how do you define a shortage and over what period; what is meant by diversification)
- Climate change should be explicitly addressed
- Need for adaptability to address planning uncertainties like climate change

Objective: Economic Benefits

Purpose: Develop water reliability solutions that are cost-effective for the Austin community

Desired Outcomes:

- Seek cost-effective solutions for improving water supply reliability
- Maximize advantageous external funding for recommended projects/programs

Feedback summary:
The majority of the discussion groups' feedback centered around two themes: affordability and how to plan for a 100-year time period. Affordability concerns included making sure rates stay affordable for families over time, with emphasis on low-income families. Stakeholders highlighted that cost-effectiveness can be viewed from multiple perspectives, including from the perspective of the ratepayer and the perspective of the utility, and costs should be communicated in a way that acknowledges this distinction. In terms of planning 100 years out, stakeholders suggested addressing cost uncertainties by incorporating future evaluations for re-assessing cost-effectiveness. During the discussion on all objectives, stakeholders mentioned maintaining flexibility, as technology and circumstances are expected to change over the 100-year time frame.

Other key feedback themes for this Objective include:

- Clarity around how cost-effectiveness is defined (over what time period, etc.) and how our community values water
- Interest in partnerships and potential funding sources
- Considering regional impacts and benefits upstream and downstream
- Clarity around the plan in general (what's the end product, how concrete will the plan be)

Objective: Environmental Benefits

Purpose: Protect and sustain the local environment for the benefit of the Austin community

Desired Outcome:

- Sustain local watersheds and ecosystem health
- Seek lower energy-intensive solutions for improving water supply reliability
- Increase water use efficiency to reduce demands on potable water supplies

Feedback summary:
There were a few terms stakeholders agreed needed to be defined more clearly - "watershed" and "ecosystem health." Several stakeholders mentioned the idea of conservation and that in order for a plan to be successful, everyone in the community needs to know how they can conserve and how water use and energy go hand in hand. There were also quite a few ideas about how water can be conserved, such as using native landscaping; capturing air conditioning condensate for reuse; expanding grey water use; and changes to irrigation systems.

Other key feedback themes for this Objective include:

- Taking a regional view (consider downstream impacts, good neighbor policy)
- Evaluation of net environmental impacts (including water consumption and waste generation impacts on base flow, aquifers, aquatic plant and animal health, etc.)

Objective: Societal Benefits

Purpose: Provide societal benefits from improving water supply reliability for the Austin community

Desired Outcomes:

- Enhance livability and recreation through multi-beneficial water infrastructure/programs
- Protect and improve local economic vitality
- Seek social equity and environmental justice, with emphasis on underserved communities

Feedback summary:
Clarity and prioritizing environmental justice were recurring themes at the Societal Benefits table. For many stakeholders, the language was too vague or too technical. Some said the concepts of local economic vitality and underserved communities should be defined, for example. In addition, stakeholders noted the social benefits of the project should be more specific.

Other key feedback themes for this Objective include:

- Water quality should be included as a social benefit
- Societal impacts should stand alone from economic impacts
- Public health and safety are social benefits

Objective: Implementation Benefits

Purpose: Reduce potential implementation challenges thereby increasing likelihood of success for projects/programs

Desired Outcomes:

- Achieve public acceptance and permitting/regulatory success, and reduce potential legal/institutional barriers
- Emphasize the scalability of projects/programs to better meet needs over time
- Seek projects/programs that have proven or tested technologies

Feedback summary:
Stakeholders agreed that the implementation of the project should be innovative and raise the bar for other cities. Stakeholders felt the project should account for and embrace emerging technologies, especially in light of uncertainties inherent in planning a century in advance. Outreach and education were seen as key to the process of implementation.

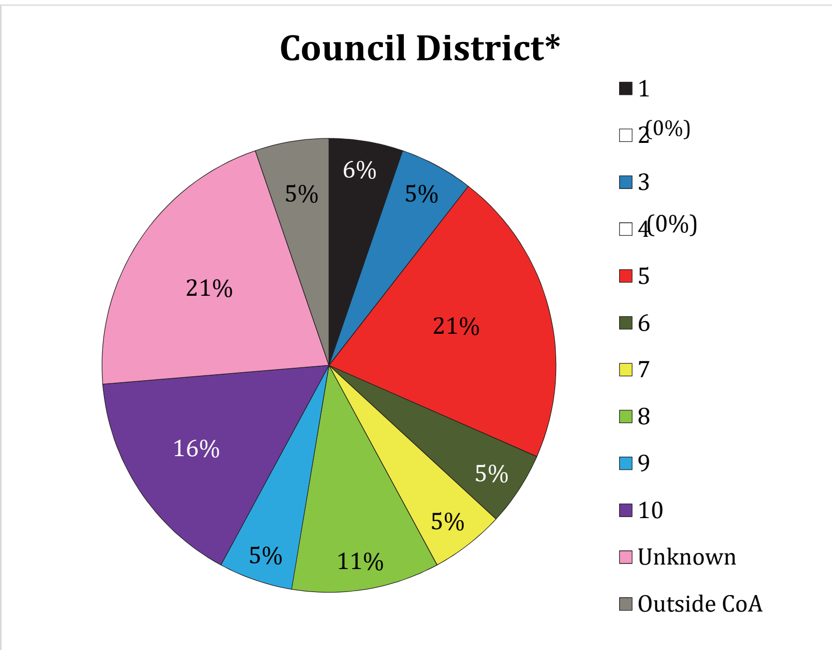
Other key feedback themes for this Objective include:

- Clarify impacts and benefits to surrounding communities

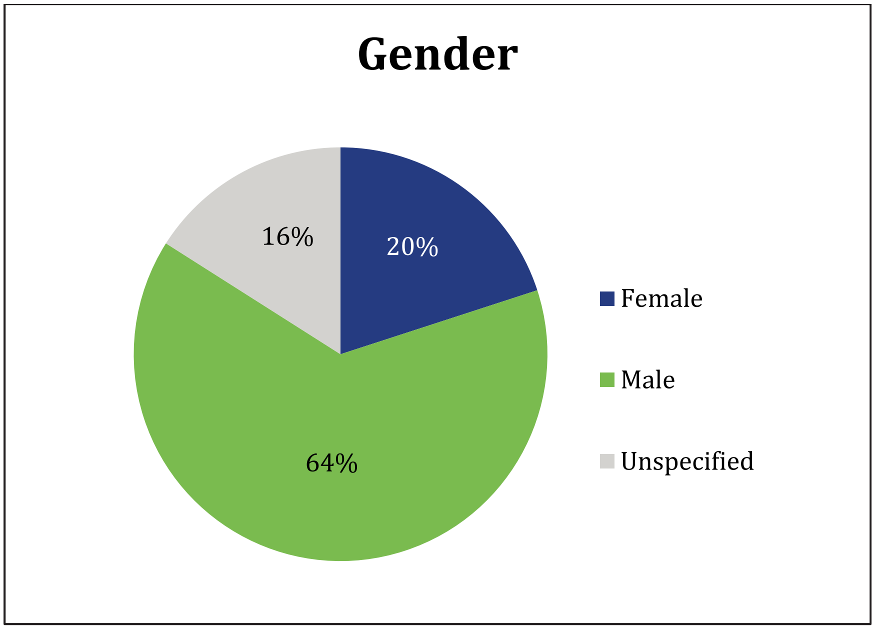
- Minimizing public and private property impacts
- Recognize that regulatory and institutional frameworks have the potential to change over the 100-year planning horizon
- Transparency

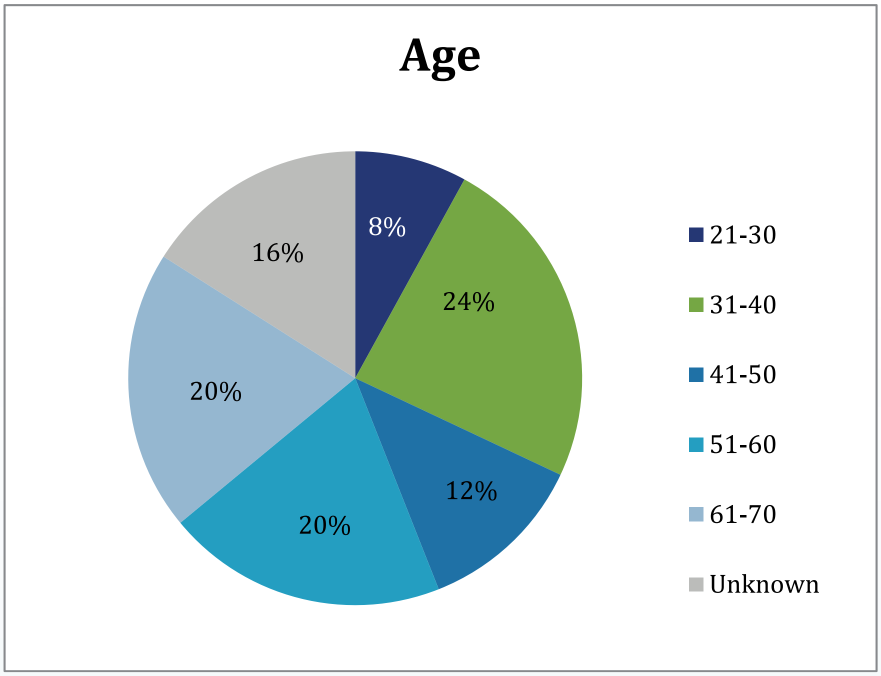
Demographic Breakdown

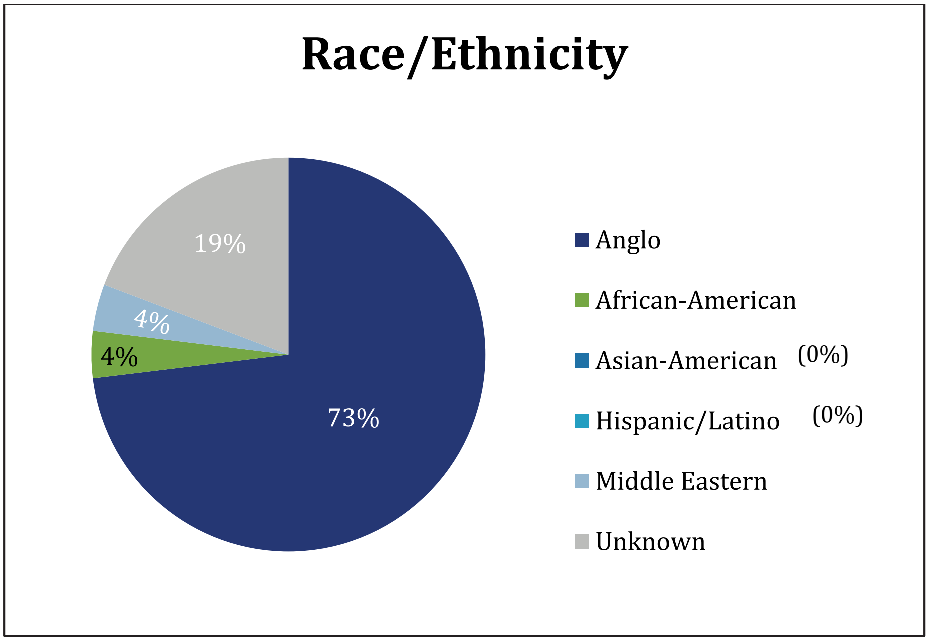
Of the 25 surveys collected, the following demographic information was self-reported (note that demographic information was not provided on all 25 surveys submitted – see survey forms in appendix):

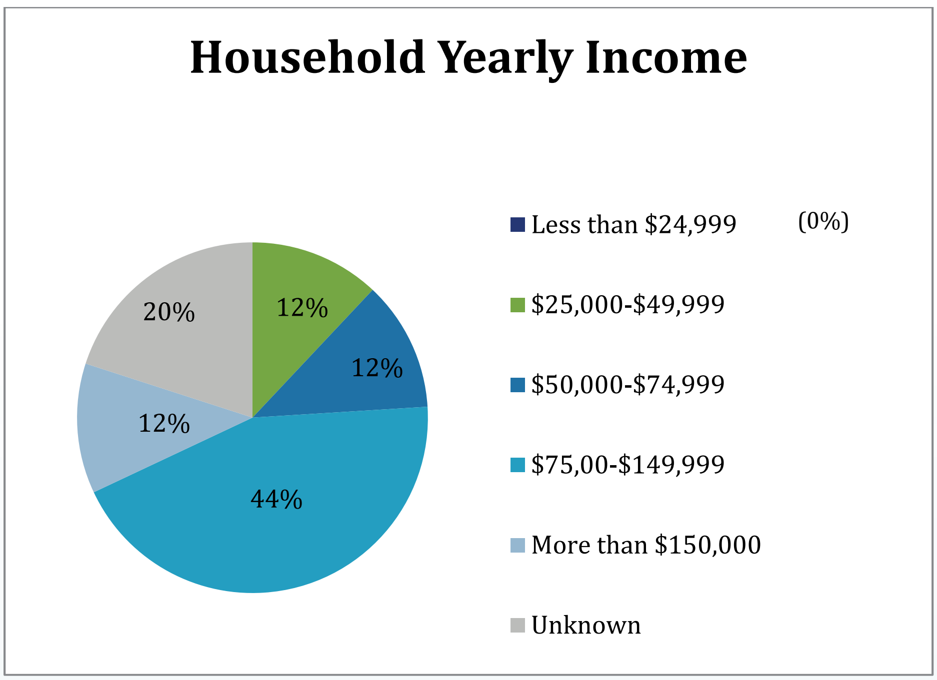


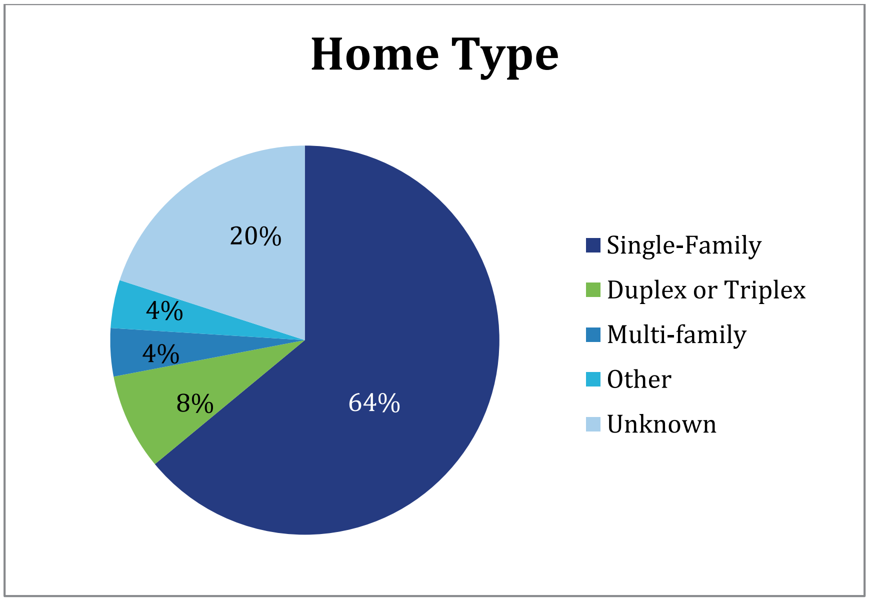
- * Five respondents did not know their district and so provided the list of ZIP codes below:
  - 78702 (1)
  - 78744 (1)
  - 78751 (1)
  - 78757 (1)
  - 78759 (2)

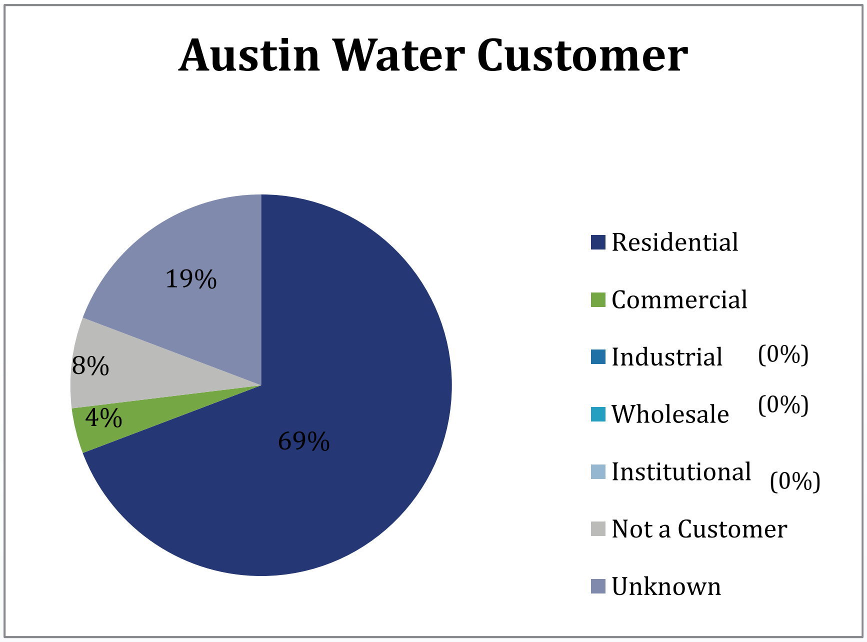

Gender
16%
20%
64%
Female
Male
Unspecified


Age
8%
24%
12%
20%
20%
16%
21-30
31-40
41-50
51-60
61-70
Unknown


Race/Ethnicity
19%
4%
4%
73%
Anglo
African-American
Asian-American (0%)
Hispanic/Latino (0%)
Middle Eastern
Unknown


Household Yearly Income
20%
12%
12%
12%
44%
Less than $24,999 (0%)
$25,000-$49,999
$50,000-$74,999
$75,00-$149,999
More than $150,000
Unknown





Next Steps

The next Workshop is tentatively set for February of 2017. In the meantime, Austin Water and the project team will strive to incorporate stakeholder feedback and find more avenues to collect feedback.

Appendix

Due to the large number of additional pages, the appendix section is available upon request from Austin Water.

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Memorandum

To: *Marisa Flores Gonzalez, Austin Water*
Teresa Lutes, Austin Water

From: *Megan Klein, Rifeline*

Copied: *Tina Petersen, CDM Smith*
Dan Rodrigo, CDM Smith
Linda Rife, Rifeline

Date: *February 9, 2017*

Subject: *Austin Water Integrated Water Resources Plan Workshop 2 Summary Report*
Task 1 - Public Outreach
CDM P/N: 0590-114879

On February 8, 2017, Austin Water hosted the second of four public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). This 100-year water plan will evaluate mid- to long-term water supply and demand management options for the City of Austin. The IWRP planning process will provide a holistic and inclusive approach to water resource planning.

The workshop featured presentations from the project team about the plan development process, stakeholder outreach, and supply and demand modeling. After the presentations, stakeholders were asked to give feedback on supply- and demand-management options in a brief exercise. The workshop was held at the Austin Independent School District Performing Arts Center multipurpose room, 1500 Barbara Jordan Boulevard, Austin, Texas from 6:00 pm to 8:30 pm. approximately 30 members of the community attended. Copies of sign in sheets are attached in Appendix.

Outreach and Publicity

Austin Water publicized the event in the following ways:

- Austin Water emailed a notice about the workshop to the following eNewsletter lists (see Appendix for a copy of the invitation):
  - Water Forward (339 stakeholders)
  - WaterWise Residential List (Mailing list of 15,738 people)
  - WaterWise Commercial List (Mailing list of 128 people)
- Austin Water emailed invitations to groups and individuals on the Water Forward stakeholder list, including:

- Neighborhood associations
- Businesses, developers, and professional organizations
- Environmental advocates
- Civic Leaders
- Faith-based organizations
- Education representatives

- Austin Water distributed 562 invitation flyers in English and Spanish in the Mountain Ranch (City Council District 3), Village at Collinwood (District 1) and Santoras Villas (District 3) apartment complexes. Emails were sent to an additional 2,709 residents through the apartment management associations. One complex without the ability to email residents posted a flyer on a bulletin board in the common area.
- Austin Water reached out to City Council members and engaged the Water Forward Task Force.
- Austin Water emailed the staff liaisons for the Water Wastewater Commission, Resource Management Commission (RMC), and the Environmental Commission. Due to scheduling limitations, the Water Forward Workshop #2 occurred on the same evening as the February Water and Wastewater Commission Meeting.
- Austin Water invited attendees of past stakeholder outreach meetings.
- Austin Water posted information to Next Door, Facebook and Twitter.
- Austin Water posted information to the Water Forward website, http://austintexas.gov/waterforward.
- Notice of the Workshop was distributed through various local media outlets and was published in the Austin American Statesman and The Monitor.

Presentation

Austin Water staff provided an overview of the background of Austin Water, the Integrated Water Resource Plan and the planning process, as well as past and future public outreach activities. The presentation highlighted:

- Austin Water's demand and population
- History, drivers, objectives and goals of the plan
- IWRP plan development process and public outreach activities

The Consultant team outlined past stakeholder activities including workshop #1 and three targeted stakeholder meetings with industry experts. The presentation highlighted some of the feedback stakeholders have given and how public input will be incorporated in the plan.

Austin Water presented an overview of the water demand forecast. The presentation highlighted:

- Historical and future population figures
- Water use types
- Forecast assumptions
- Impact of weather
- Historical and future demand

Austin Water presented the results of the preliminary water needs analysis and projected supply and demand at several planning horizons. A copy of the full PowerPoint presentation is available in Appendix.

The project team held a brief question and answer session following the first set of presentations. Question and comments included:

- Current and Future Water Supply
  - Does the supply include the Edwards Aquifer?
    - *No, Austin's water supply comes from the Colorado River system. The Colorado River System Water Availability Model (WAM) does not directly take into account water from the Edwards Aquifer.*
  - How many aquifers along Colorado River are fed by the Colorado River and have you measured those effects on supply?
    - *Interaction effects between the river and aquifers are not specifically modeled. However, the Water Availability Model (WAM), used in the river system analyses, includes inflows of water to the river and lakes system based on measured flows through the basin's streams and rivers so in that way the model takes interaction effects into account to the extent of the historical interactions.*
  - We're asked to ration water. Who is monitoring demand to meet supply? Why keep letting people move here if we already don't have enough water?
    - *Through the recent drought Austin water customers did an excellent job in responding to calls to conserve water to help manage demand for water during the dry times. This strong community commitment to water conservation continues through on-going efforts to conserve water resources and prepare for future droughts. We can see future droughts being even worse than the most recent drought and our city continuing to grow. Through*

this Water Forward planning process, we are looking ahead and seeing what possible water options and strategies Austin will need for the future.

- There's a possibility of drought with climate change. Is there more variability of water availability too? Could we store floodwater?
    - *In a climate study performed by Dr. Katherine Hayhoe for the Austin region, long term projections indicate that there could be longer periods of drought interspersed with more extreme rain events. Strategies aimed at capturing additional water from rain events could be evaluated as part of the planning process.*

- Conservation
    - We're being asked to conserve, but there's lots of new development. We call 311 and nothing happens to those who are in violation.
        - *Austin Water appreciates the efforts and works to follow-up on reported water waste and watering schedule violations.*
    - Single-family homes are the largest water user, based on the chart you showed. What is the City doing to support conservation, especially existing homes?
        - *The watering schedule updates approved by City Council in May 2016 includes this water use sector. There are a wide-range of water conservation programs for the single-family residential sector. Information about many of these program was provided at an information table at the workshop. In recent years, conservation efforts have contributed to a significant reduction in residential gallons used per person per day, from 103 gallons in 2006 to 71 gallons in 2016.*
- Innovation and New Technology or Ideas
    - Water is also rare in other parts of the world. Are you reaching out and looking into what is being done internationally?
        - *One of our project team members, GHD, is a firm from Australia. We are incorporating cutting edge global best practices into our plan.*
    - How transportable is water throughout the country? There are rainy areas like the Pacific Northwest, could other areas use their water?
        - *It's feasible, but very expensive. You need major facilities and equipment like pipes, pumps, reservoirs and moving water long distances expends a lot of energy.*
- Coordination
    - South Austin combined neighborhood plan showed that City departments may not be coordinating as well as we would think.

  - *Imagine Austin has led to increased coordination between departments like Austin Water, Watershed Protection, Austin Energy, and Office of Sustainability on a wide-range of water and sustainability related matters.*

- Are you considering suburbs like Round Rock? Do you coordinate with them?
  - *There's some coordination with some surrounding municipalities like Cedar Park, Buda and Round Rock, but we generally are planning for Austin's water planning area. Round Rock manages its own supplies.*

▪ Current Water Use

- What is the percentage of total volume of graywater use in Austin now, what will it be 50 years out?
  - *Right now, it's a very small percentage, but we anticipate it will be an option in the future. It will be included in our modeling if it is chosen as an option to move forward.*
- What is the per capita water use now?
  - *122 gallons/person/day right now. In the future, we're predicting using similar numbers as a baseline.*
- What has been the highest per capita water use recently?
  - *In 2006, it was 190 gallons/person/day, overall. We've seen that number trend down because of conservation measures such as the Stage 2 water restrictions that lasted for five years during the drought.*

▪ Other questions and comments included:

- A question from a board member of the Las Calinas Condos Homeowners Association off 2222 and Mopac: They've saved 1.5 million gallons of water and are paying more rates and fees because condos are treated as commercial property. Why is that? Why are there increases in rates and fees?
  - *Austin Water explained this group may not be able to answer that specific question but asked this citizen to write down the question so we can respond on follow-up. .*
- What models are you taking these numbers from, especially regarding climate change? Are they modeling severe climate change?
  - *The climate change adjusted hydrology projections are based on an assemblage of global climate model results which use the Representative Concentration Pathway (RCP) 8.5 greenhouse gas concentration scenario. This is the higher of the two emission scenarios for which projections were developed: RCP 8.5 and RCP 4.5. (Note that RCP 8.5 is more consistent with recent trends than RCP 4.5.)*

- Without water you can't live. Does modeling have a quota that each person is guaranteed? How does it take the homeless into account?
  - *Demand models are based on current use trends and population and employment projections. The water demand projections at this stage of the plan development process are baseline demands that do not include potential additional future water conservation options that may be recommended as part of the plan. Population projections come from the City demographer. Austin's homeless populations are probably accounted for in those projections of population and water demand.*
- What does purple signify on the gap graph?
  - *Purple is the gap between supply and demand that over time needs to be made up through a combination of options to increase water supply and decrease demand.*

Following the question and answer session, the Consultant team presented the preliminary water supply- and demand management options that are being considered, followed by a brief question and answer session. Questions and comments included:

- Coordination
  - Concern that this process seems hyper-local. Is there regional or statewide coordination happening?
    - *Austin and a wide-range of interests throughout the basin participate in a TWDB administered regional planning process that results in the adoption of a regional water plan every 5-years. The Water Forward plan is to be updated on a 5-year cycle and can help inform next planning round updates to the Region K plan. The City of Austin meets regularly with the Lower Colorado River Authority to discuss water planning from a basin perspective. The recent drought lead to a lot of coordination and programs like SWIFT that provide access to low-interest loans from the Texas Water Development Board (TWDB) to help manage costs of options like Advanced Metering Infrastructure (AMI) and reclaimed water system improvements. Innovation at the government level usually happens at a smaller scale like a city level. Others in the state may look to Austin as a model on this planning process.*
- Code and Ordinance Questions
  - Will new buildings have ordinances imposed on them?
    - *We haven't decided anything yet, but ordinances do come into play for some of the demand strategies, although the final strategy recommendations haven't been developed yet.*
  - Does this dovetail with CodeNext?
    - *We've been working to track with CodeNext process. Some recommendations out of this process may affect the code, but that will come into play later in the process after recommendations are developed and implementation approaches are developed.*

- Clarifications and Requests for Information

  - Can you tell me more about indirect potable reuse?
    - *Indirect potable reuse is a water supply method of putting highly treated wastewater from a treatment plant into a river, reservoir, or alluvial aquifer for withdrawal and treatment at a water treatment plant for potable purposes.*
  - Cost effectiveness is important. I would like to see detailed breakdown of cost and return on investment (ROI).
    - *Right now we have 25 demand management strategies and over 20 supply side strategies. We don't have the time or budget to do a detailed study of all of the strategies at that level. Right now we're doing a high level screening that will reduce the number of options for analysis and evaluation down to 10 water supply options and 10 demand management options.*
  - Austin Energy uses a lot of water. Did you talk to them about different technologies they could use to use less water?
    - *We're also coordinating with Austin Energy (AE) on things like converting to using reclaimed water. AE uses reclaimed water at their Sand Hill Energy Center. AE has been looking at various generation plan options including options that use less water.*
  - For the indirect potable reuse strategy: What if that stream goes dry and you can't use it to help dilute and clean water that is discharged into it?
    - *These types of strategies require thorough analysis and Texas Commission on Environmental Quality (TCEQ) permitting.*
  - San Antonio uses an aquifer to store water now, but the Edwards Aquifer constantly moves around. Is there an aquifer in this area we could use for storage?
    - *Aquifer Storage and Recovery (ASR) is an option that we have been exploring. There are two aquifers in the area that we have looked at thus far, the Trinity Aquifer and the Northern Edwards Aquifer, for which there may be some possibilities.*
  - Do we lose control if it's outside of our region?
    - *Legislation passed during the last legislative session resulted in a number of rule changes that addressed various aspects of Aquifer Storage and Recovery (ASR). For the option to be effective it is important to be able to "control the bubble" of water that is stored underground.*
  - Are you also looking at water rights issues like rule of capture and surface water priority dates (first in time, first in right)?
    - *Yes, we are aware that there are a wide-range of water rights-related aspects to many of the options being considered. We're looking into various aspects, like permitting,*

availability of water rights, etc., since they can effect option feasibility and implementation.

- One strategy mentions renegotiating the amount of water you buy from LCRA. Do they have more available water?
  - *We're looking into it and need to find out the answer to that. LCRA has indicated that they have some water for sale and this amount may change based on various factors, such as development of new resources, commitments made and changes in hydrology.*

Stakeholder Feedback

Dot Exercise

Stakeholders were given 20 sticky dots and were asked give feedback on supply- and demand-side option categories by placing a dot on a grid for each option category indicating 'like it', 'don't like it,' 'okay with it,' or 'need more info.' Stakeholders could also write comments on a post it note and stick it to the board. The results are below.

Preliminary Demand Management Option Categories	Like it	Don't like it	Okay with it	Need more info
Water Loss Control – reducing water losses in AW's water distribution system through strategies like leak detection, reducing main break response time, and performing water main replacements	21			
Automated Metering Infrastructure (AMI) – New meters that provide real time information on customer water use to help encourage efficient water use and identify possible home leaks or other high uses of water that can be corrected by the homeowner	20		2	1
Landscape Transformation – ordinances and/or incentives to encourage changing turf to more water efficient landscaping or limit the amount of turf on properties.	19	1	1	
Irrigation Efficiency – ordinances and/or incentives to encourage the use of water efficient landscape irrigation systems	17	1	1	1
Commercial/Institutional/Industrial Conservation – ordinances and/or incentives to encourage more efficient water use for cooling towers/boiler feeds, AC condensate recovery, swimming pools/decorative fountains, as well as disclosure of inefficient water use fixtures at point of sale	17	2	2	
Plumbing Fixture Efficiency – ordinances and/or incentives to encourage use of Energy Star and WaterSense labeled equipment, and for replacement of non-water efficient plumbing fixtures	14	1	4	3
Onsite Reuse of Water for Non-Potable Uses – ordinances and/or incentives to encourage onsite rainwater harvesting, greywater systems, and dual plumbing (for new developments) in order to reduce the use of drinking water for landscape irrigation and toilet flushing	20	1	1	
Water Use Benchmarking – programs to encourage water efficiency benchmarking for new developments and reporting of water use for large building owners	20		1	
Customer Education/Outreach – programs that continue to educate AW water customers on the conservation and value of water	18		1	
Water Rates/Water Fees– explore how changes in water rates and water fees may further encourage water use efficiency while maintaining affordability	14		6	2

Post it Notes on Demand Management Option Categories Boards:

- Post it placed by "Like it" Column for Water Use Benchmarking: with results visible to public by building, by company, by department, etc. for the + psychological benefit driving uptake on process.
- Post it placed by "Like it" Column for Water Use Benchmarking: Developers should pay for this in their "PUDs" – Developers should have to live in PUDs they build.
- Post it placed by "Like it" Column for Water Rates and Fees: More steeply tiered (progressive) pricing offers best opportunity to pay for needed infrastructure while keeping affordability for low-income residents
- Post it placed by "Like it" Column for Irrigation Efficiency: More than encouragement is needed – ordinance with benchmarks for acceptable water use

Preliminary Supply Side Option Categories	Like it	Don't like it	Okay with it	Need more info
Expanded Reclaimed Water System – expansion of AW's "purple-pipe" reclaimed water system for non-potable uses like irrigation, cooling towers, and toilet flushing	17		3	
Decentralized Options for Wastewater Reuse – use of neighborhood satellite wastewater plants or onsite (building-scale) wastewater treatment for non-potable uses like toilet flushing, cooling towers, and landscape irrigation	19		1	1
Indirect Potable Reuse – various strategies to transport highly treated reclaimed water via natural systems like surface water reservoirs or alluvial aquifers for purification to drinking water quality at an existing water treatment plant	5	4	6	7
Direct Potable Reuse – Purifying highly treated reclaimed water using advanced treatment (similar to desalination treatment) to supplement drinking water supply	4	2	5	8
Rainwater and Stormwater Capture – capture and storage of rainwater and stormwater for various uses like irrigation and toilet flushing (neighborhood-scale)	22		2	
Aquifer Storage and Recovery – storing excess surface water during wet years in underground aquifers for later use during dry years	14	1	2	5
Additional LCRA supply/Enhanced Lake Operations/Capture of Stormwater Inflows – additional LCRA supply and various strategies at Lake Austin and Lady Bird Lake to increase ability to draw water from reservoir storage and minimize lake evaporation during dry years	10	3	1	5
Enhanced Off-Channel Storage at Walter E. Long Lake – if Decker Power Station is taken off line, Decker Lake could be used for additional storage that could provide additional water during dry years	15		4	2
Groundwater– to include brackish groundwater desalination (would require removing salts from brackish groundwater using advanced water treatment for new water supply) and conventional groundwater options	2	2	9	7
Seawater Desalination - removing salts from ocean water using advanced water treatment for new water supply	1	10	2	8

Post it Notes on Supply-Side Option Categories Boards:

- Post it placed in "Don't Like it" Column for Indirect Potable Reuse: Bad idea - will effect the environment - see Dripping Springs POW fight

See Appendix for a photo of one of the boards, as an example.

Comment Forms

Stakeholders were very interested in conservation, rewarding customers for using less water, and enforcing current restrictions to decrease violations. One stakeholder asked for more information about rainwater harvesting and water conservation. One stakeholder suggested using "seeing eye" that shut off automatically in homes to save water. Another stakeholder commented that her

Homeowners Association had taken steps to drastically decrease water use by 1.5 million gallons per year in 2016, but stated the condominiums were subject to commercial rates. Stakeholders also had comments about taking a regional approach, coordinating with other City departments and possibly establishing a state water resource management structure.

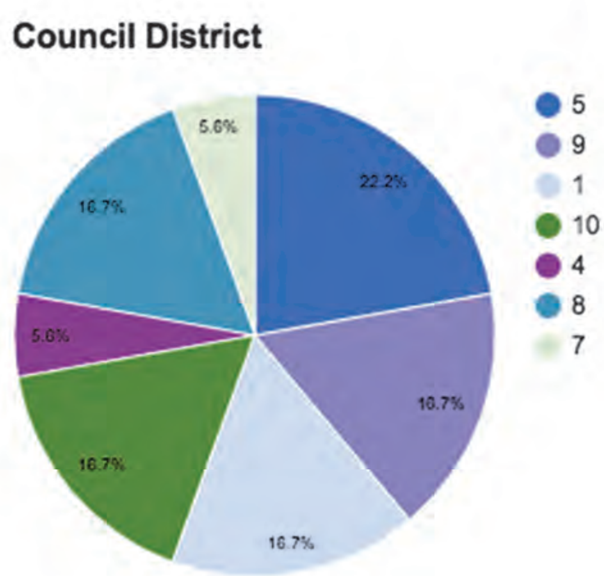
Other feedback included:

- State rules for groundwater rights and where changes may be needed for storage and withdrawal in groundwater aquifers
- Suggestion to eliminate steam boilers for newer technology
- Maintaining flexibility over the 100+ year time frame

Copies of the comment forms and note cards are included in the Appendix.

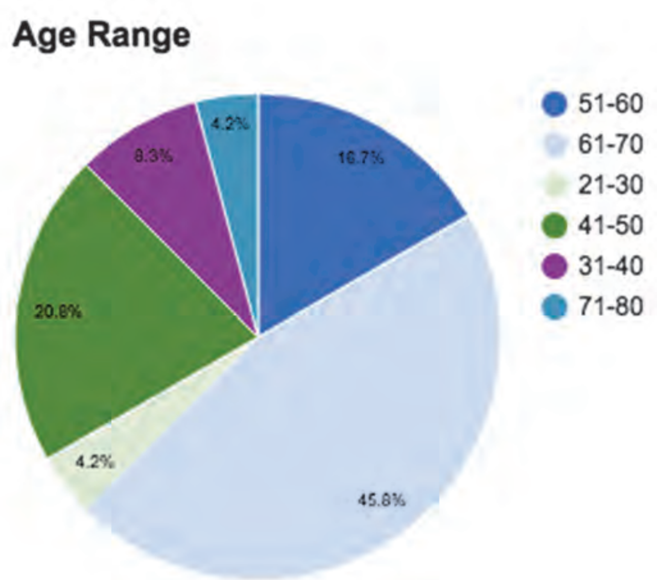
Demographic Breakdown

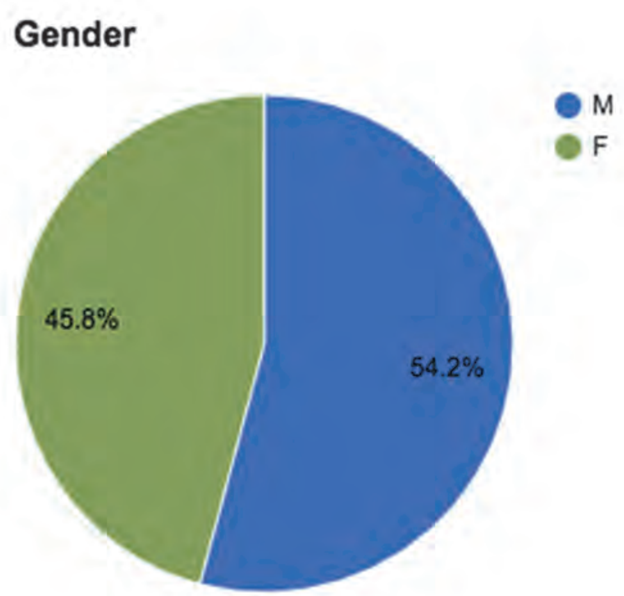
Of the 24 surveys collected, the following demographic information was self-reported (see copies in the Appendix):

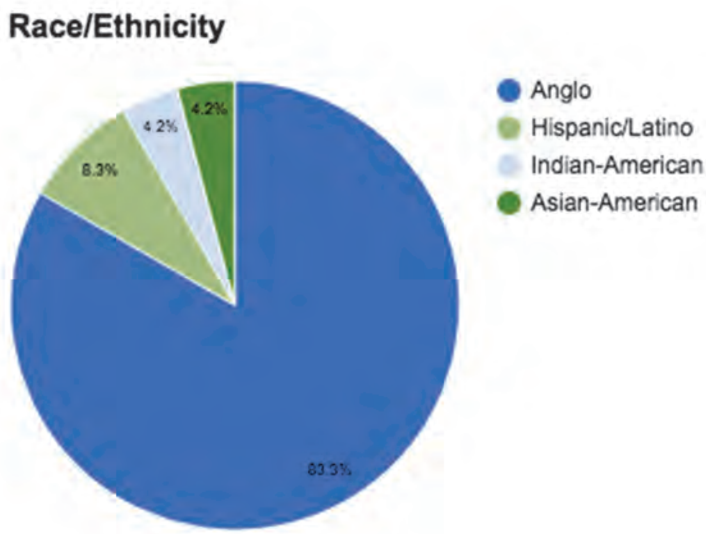


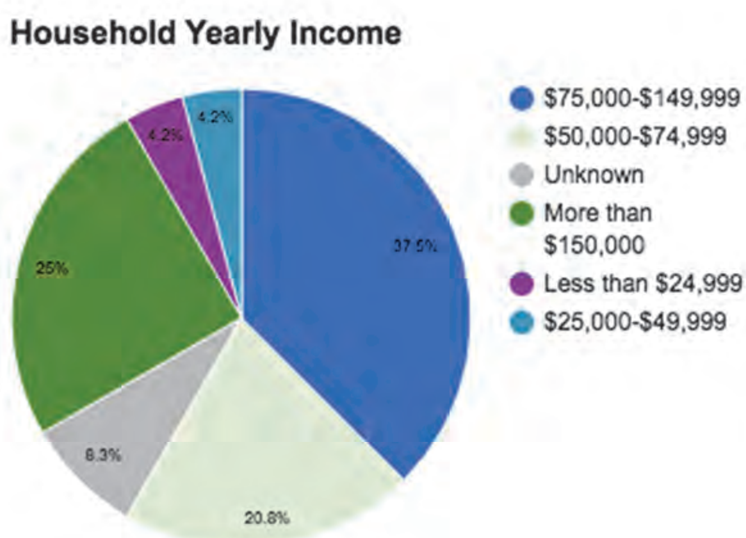
- Six respondents provided their ZIP code instead of their Council District - see below:
    - 78702
    - 78759

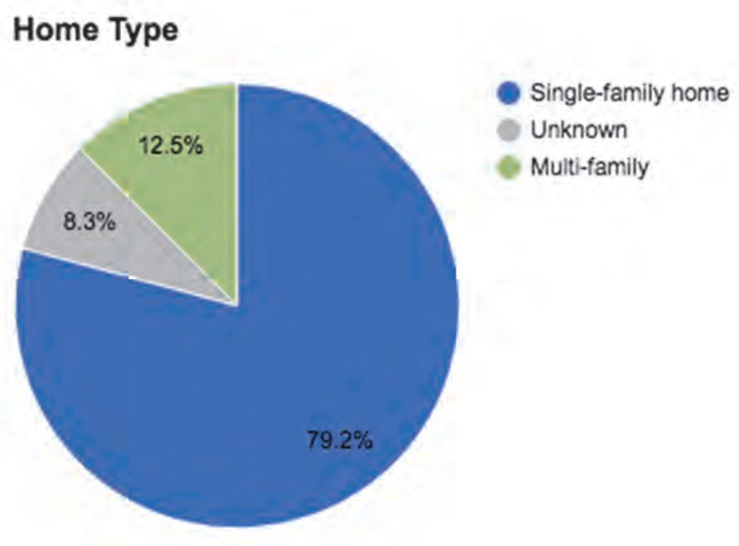
- 78736
- 78745
- 78754
- 78749






Race/Ethnicity
Anglo
Hispanic/Latino
Indian-American
Asian-American
4.2%
4.2%
8.3%
83.3%


Household Yearly Income
$75,000-$149,999
$50,000-$74,999
Unknown
More than $150,000
Less than $24,999
$25,000-$49,999
4.2%
4.2%
37.5%
25%
8.3%
20.8%



Next Steps

A new workshop has been added to gather additional public input with a focus on future Water Supply Options being considered in the Water Forward planning process. This newly planned Workshop #3 will be held on April 4, 2017. Following Workshop #3, the next Workshop is tentatively set for August of 2017. Additionally, Austin Water and the project team will also be seeking input through other avenues including community events and other public forums.

Appendix

Due to the large number of additional pages, the appendix section is available upon request from Austin Water.

Memorandum

To: *Teresa Lutes, Austin Water*
Marisa Flores Gonzalez, Austin Water

From: *Megan Klein, Rifeline*

Copied: Tina Petersen, CDM Smith
Dan Rodrigo, CDM Smith
Linda Rife, Rifeline

Date: *April 4, 2017*

Subject: *Austin Water Integrated Water Resources Plan Workshop 3 Summary Report*
Task 1 – Public Outreach
CDM P/N: 0590-114879

On April 4, 2017, Austin Water hosted the third of five public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). This 100-year water plan will evaluate mid- to long-term water supply and demand management options for the City of Austin. The IWRP planning process provides a holistic and inclusive approach to water resource planning.

The workshop featured presentations from the project team about the plan development process, stakeholder outreach, and supply and demand modeling. After the presentations, stakeholders were asked to give feedback on water supply options in a brief dot exercise. The workshop was held at One Texas Center, Conference Room 325, 505 Barton Springs Road, Austin, Texas 78704, from 6:00 pm to 8:30 pm. Twenty two members of the community attended.

Outreach and Publicity

Austin Water publicized the event in the following ways:

- Austin Water emailed the following eNewsletter lists a notice about the workshop (see Appendix A for invitation):
  - Water Forward (438 stakeholders)
  - WaterWise Residential List (Mailing list of 15,029 people)
  - WaterWise Commercial List (Mailing list of 205 people)
- Austin Water emailed invitations to groups and individuals on the Water Forward stakeholder list, including:

   - Neighborhood associations
   - Businesses, developers, and professional organizations
   - Environmental advocates
   - Civic Leaders
   - Faith-based organizations
   - Education representatives
- Austin Water reached out to City Council members and engaged the IWRP Task Force.
- Austin Water emailed the staff liaisons for the Water Wastewater Commission, Resource Management Commission (RMC), and the Environmental Commission.
- Austin Water invited attendees of past stakeholder outreach meetings.
- Posted information to Next Door, Facebook and Twitter.
- Posted information to the Water Forward website, http://austintexas.gov/waterforward.

Copies of the sign in sheets are available in the Appendix B

Presentation

Austin Water staff provided an overview of the background of Austin Water, the Integrated Water Resource Plan and the planning process, as well as past and future public outreach activities. The presentation highlighted:

- Austin Water's demand and population
- History, drivers, objectives and goals of the plan
- IWRP plan development process and public outreach activities

Austin Water outlined past stakeholder activities including workshops one and two, as well as three targeted stakeholder meetings with industry experts. The presentation highlighted some of the feedback stakeholders have given, how it has influenced the plan so far, and how it will be incorporated moving forward.

Austin Water presented an overview of the water demand forecast. The presentation highlighted:

- Historical and future projected population figures
- Water use types
- Forecast assumptions

- Impact of weather
- Historical and future demand

Austin Water presented the preliminary water needs analysis and projected supply and demand at several planning horizons. A copy of the full PowerPoint presentation is available in the Appendix C.

The project team then held a brief question and answer session following the first set of presentations. Question and comments included:

What is outdoor water use?

- *It generally means irrigation for lawns and landscapes and other uses of water outdoors such as car washing and maintaining water levels in swimming pools.*

Is the State of Texas involved or connected with what's being looked at in Austin?

- *To some extent, yes, because we're part of the state's regional water planning process which is updated on a 5-year cycle. This particular Water Forward effort is a City of Austin effort. Many of the things we're looking at locally are also part of the Region K water plan, as part of the State water planning process, and vice versa. The modeling we're using is a state-wide model (TCEQ WAM, or water availability model) so we're looking at our supply in a statewide context.*

For the water availability model (WAM), did it anticipate the multiple months where there were zero inflows?

- *Yes, the historical inflows, including the unprecedentedly low inflows in year 2011 have been added into the modeling.*

Given that the period of record is all post-industrial era and already within an altered climate period, by applying an additional climate change factor, isn't climate change being over-emphasized?

- *Not from our point of view – it can be thought of in a context of modeling a projected additional difference in the region's hydrology due to additional climate change. We have flows that we know of from the past that our modeling is based on. We're essentially modeling additional change that is projected to occur beyond what is already seen in the historical record.*

The intergovernmental global consortium on climate change predicts things will get much worse in SW US. I'm glad you're looking at this. When you say climate change, I'm assuming you're talking about CO2, greenhouse gases. In the current political climate, do you have an issue selling this idea to the current government, given that some don't acknowledge climate change?

- *From feedback we have received, we believe the community is supportive of us looking at climate change. Some of these things may change over time, and folks may become more accepting of these ideas.*

The stakeholder mentioned that we may need to think about how these ideas are funded given the political climate.

Who buys water wholesale?

- *Small cities, MUDs, water control and improvement districts. There are about 17 wholesale customers. The overall percentage of water use they make up is about 7%.*

Can you explain why 600,000 AF is the emergency trigger level?

- *The Lower Colorado River Authority (LCRA) has a water management plan for lakes Travis and Buchanan, and they work with stakeholders and update the LCRA Water Management Plan (WMP) on a periodic basis. The 600,000 AF combined lakes Travis and Buchanan emergency storage volume trigger is the emergency trigger level in the prior WMP, and that number is in the current WMP. The emergency trigger level relates how much water would need to be available in the reservoirs for supplying needs until drought breaks. The number may need to change upward in the future, from 600,000 AF, as circumstances change. [Note: LCRA set this number in 1992 as part of the three criteria for when a drought worse than a drought of record is triggered and the City incorporates this storage trigger into its drought contingency plans as a trigger for a stage of drought action.]*

We heard reliability is important as is the diversification of water supply – it still seems like the Colorado River is the main supply moving forward. Is there another plan?

- *The Colorado River is currently and is planned to be Austin's core water supply throughout the 100 year planning horizon. When we look at the portfolios of options, we have various metrics that will weight supply diversity and other approaches to assess this aspect of supply reliability. At that point, we'll be able to see which portfolios are the most reliable, balanced against other consideration factors such as cost, feasibility, etc. The supply options you'll see tonight are categories, which include supply augmentation options that are not Colorado River system-based.*

Following the question and answer session, the Austin Water team talked through the IWRP development process and explained the portfolio development process. They also presented the preliminary water supply options that are being considered, including some strategies that have been added by Water Forward Task Force members between Workshops #2 and #3, followed by a brief question and answer session.

Questions and comments included:

Given what we heard in the beginning, it sounded like sustainability and conservation are important to the community. How do you square that with the options you presented?

- *Not included in this presentation are the objectives and sub-objectives that these portfolios will be evaluated against. Sustainability and conservation are included in the Environmental objective, so scoring of how well portfolios of options do with regard to these factors will be included in the process. All of the objectives and sub-objectives were created with input from the community.*

I'm concerned about brackish water desalination. What is the plan for disposal of the minerals and salts that are left?

- *We're at an early stage in the planning process, so specifics on that aspect of that option have not been determined at this stage. Through the plan development additional information will be developed for each option as the process proceeds. We will note this concern. In this process it is important to consider factors like desalination brine disposal.*

In the places these strategies are being used now, how do they do it?

- *Evaporation brine disposal (evaporation ponds) – this is mostly done in West Texas now. In some places desalination brine is disposed of through deep well injection.*

What is the aquifer storage and recovery process, which involves putting water into an aquifer?

- *Aquifer storage and recovery (ASR) involves drilling wells to inject water into an aquifer in wet times for storage. After water is stored up over a period of time, the stored water could be accessed during drought times to supplement supply. ASR is being used in San Antonio, Kerrville, El Paso and Florida now.*

In Florida, they use it because the everglades are depleting so quickly. Where would we put it?

- *We've taken some preliminary looks at the Northern Edwards and Trinity aquifers. Additional aquifers may also be considered including the Carrizo-Wilcox aquifer.*

Would these be aquifers that would be owned by the city, or how would it affect private wells?

- *The general concept is you look for a place you can generally control surface access to the water stored in the underground aquifer. City-owned land or a place the aquifer isn't easily accessible by private well owners could be considered.*

How can we become more informed to what the options are?

- *The 21 options being considered in this screening process are posted on the City of Austin's Boards and Commissions website for the Austin Integrated Water Resource Planning Community Task Force (Water Forward Task Force). There's a link to this site on the Austin Water website. We combined the options into categories to make this process more efficient. You're also welcome to attend upcoming Task Force meetings to learn more about the options as the process continues and more information is developed.*

Interbasin transfer is very limited in Texas and would require changes at the legislature, what makes this option different?

- *The interbasin transfer option was added to the list of options for consideration based on input from the public and Task Force members. The idea is to leave no stone unturned and see if it may be a viable option. We don't have specifics at this time however, more information would need to be developed should this option move through the screening process. Regulatory hurdles would need to be taken into account further into the process.*

Given that water is a commodity that relates to survival, what prevents a higher authority from coming in and tapping our reservoir, and what is our ability to deny wholesale entities the access to water?

- *[In Texas, surface water in a watercourse is owned by the state. LCRA holds the state permits to distribute water from Lakes Travis and Buchanan, which is a vested right protected by law.] Austin has a contract with LCRA and we have a partnership with them. We have an ongoing interest in making sure we have the supply we've contracted for and that it's protected. One of the needs we've identified is continuing to work with our regional partners to make sure our core water supply stays reliable. This IWRP process highlights the need for regional coordination and working with our partners to make sure we have the supply we'll need in the future. [With regard to new contracts for supply from Travis and Buchanan, the decision is made by LCRA which takes into consideration existing commitments. Note that the City of Austin is also a wholesale water supplier, by contract, to a number of entities in the Austin area. These wholesale customers generally follow the City's drought contingency plans in implementing use reductions during drought conditions and other emergencies.]*

You're apparently not allowed to consider at all the shape of your population growth curve. Thirty or 40 years ago, that population growth was due to students staying here. Later it was a general economic growth climate. Now it's high tech and government incentives to attract people here, ignoring water as a resource. At some point, people will want to stop moving here or will choose to leave because it's no longer a nice place to live. Is anyone looking at sociological factors for population growth?

- *The City of Austin is continually looking at population growth in Austin and the region as plans are developed for the future in our community. The current plan development effort is based on current City Demographer projections, however, we plan to update this plan every five years, so we can account for population changes along the way. It's not a one size fits all strategy, it's a dynamic process.*

Stakeholder Feedback

Dot Exercise

Stakeholders were given 15 sticky dots and were asked give feedback on supply-side options by placing a dot on a grid for each option category indicating 'like it', 'don't like it,' 'OK with it,' or 'need more info.' Stakeholders could also write comments on a post it note and stick it to the board. The results are below.

Preliminary Supply Side Option Categories	Like it	Don't like it	Okay with it	Need more info
Expanded Reclaimed Water System – expansion of AW's "purple-pipe" reclaimed water system for non-potable uses like irrigation, cooling towers, and toilet flushing	14		4	
Decentralized Options for Wastewater Reuse – use of neighborhood satellite wastewater plants or onsite (building-scale) wastewater treatment for non-potable uses like toilet flushing, cooling towers, and landscape irrigation	18		1	

Indirect Potable Reuse – various strategies to transport highly treated reclaimed water via natural systems like surface water reservoirs or alluvial aquifers for purification to drinking water quality at an existing water treatment plant	6	6	1	3
Direct Potable Reuse – Purifying highly treated reclaimed water using advanced treatment (similar to desalination treatment) to supplement drinking water supply	13	1	2	3
Rainwater and Stormwater Capture – capture and storage of rainwater and stormwater for various uses like irrigation and toilet flushing (neighborhood-scale)	21			
Aquifer Storage & Recovery – storing excess surface water during wet years in underground aquifers for later use during dry years	4	1	8	4
Additional LCRA supply/Enhanced Lake Operations/Capture of Stormwater Inflows – additional LCRA supply and various strategies at Lake Austin and Lady Bird Lake to increase ability to draw water from reservoir storage and minimize lake evaporation during dry years	6		2	8
New Off-Channel Reservoir - Development of a new off channel reservoir within the Austin vicinity that could be used for additional storage to provide additional water during dry years	5	3	2	5
Groundwater– to include brackish groundwater desalination (would require removing salts from brackish groundwater using advanced water treatment for new water supply) and conventional groundwater options	5	5		5
Seawater Desalination - removing salts from ocean water using advanced water treatment for new water supply	4	9	1	3
Inter-Basin Transfers – Transfer and conveyance of water from available surface water supplies in other river basins	1	9	2	5
Partnership Approaches – Explore partnership approaches with other entities on regional strategies which could include aquifer storage and recovery, purchase of available water supply, or other partnerships	6	5		5

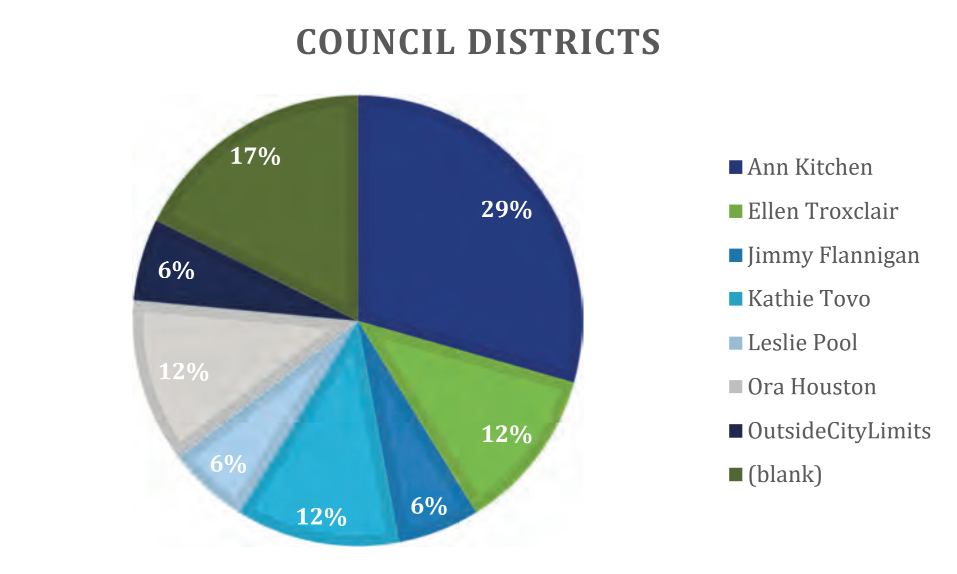
See Appendix D for a photo of one of the boards, as an example.

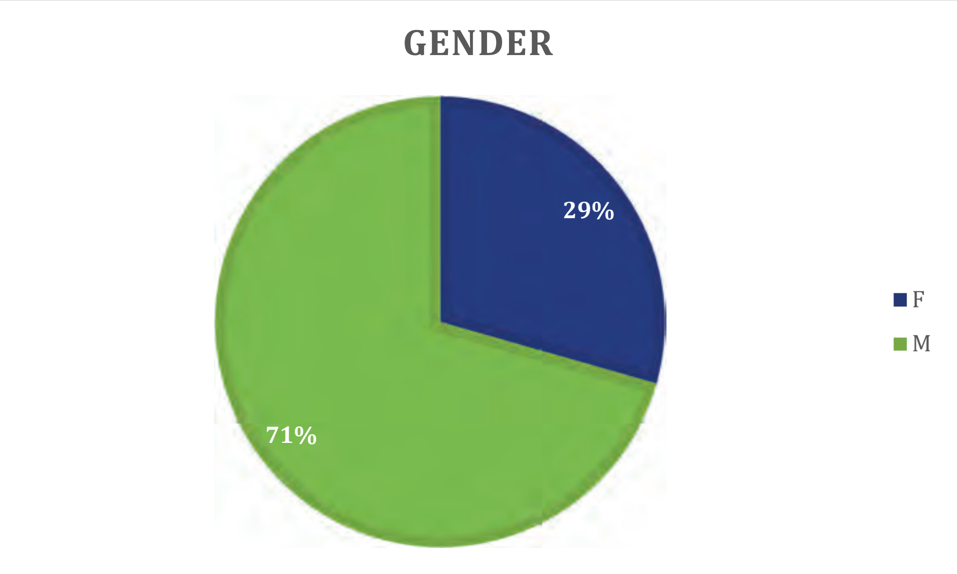
Comment Forms

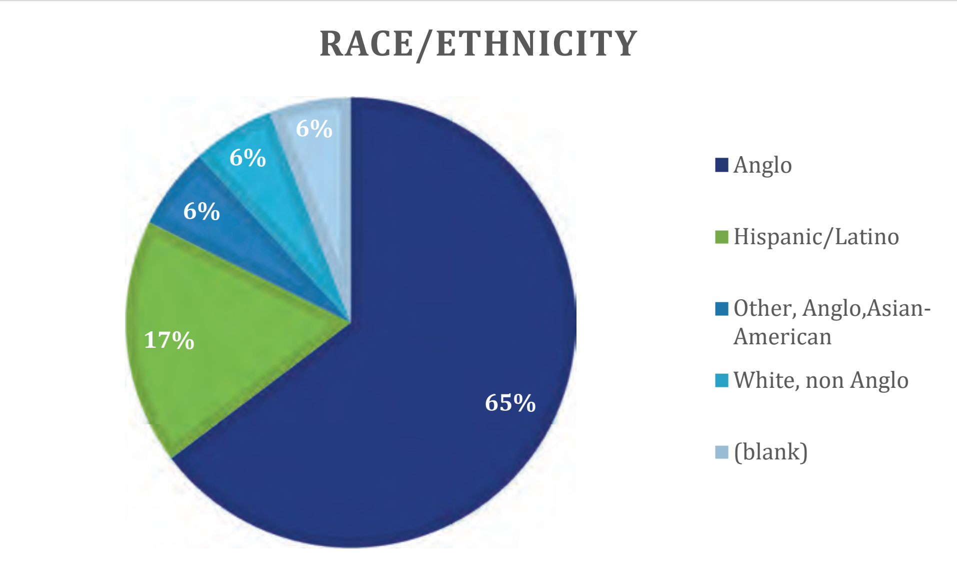
Copies of the comment forms and note cards are included in the Appendix E.

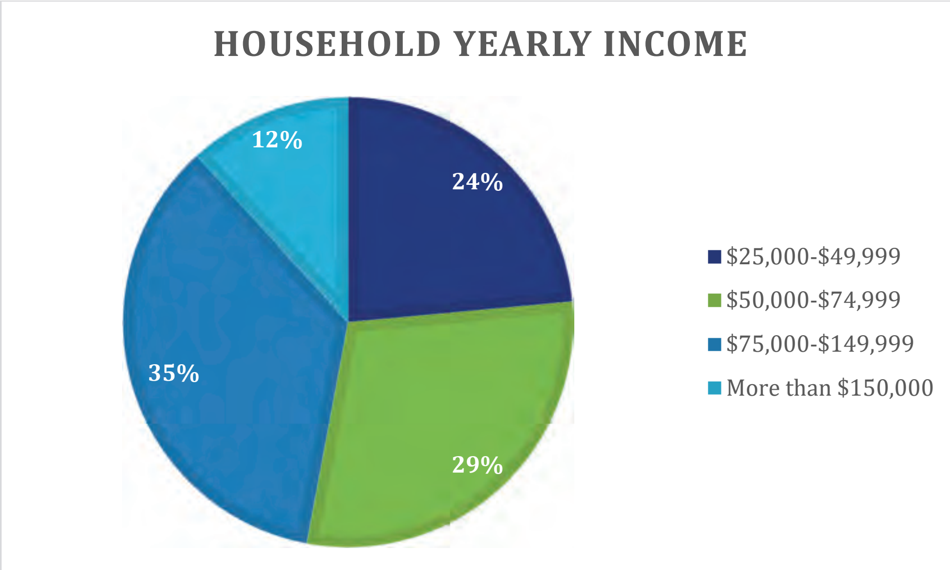
Demographic Breakdown

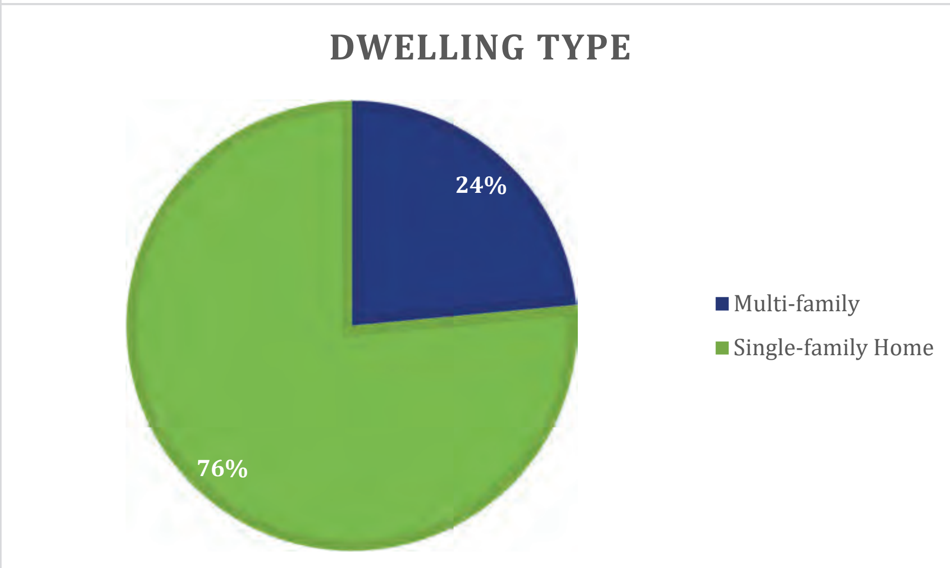
Of the 17 surveys collected, the following demographic information was self-reported (see copies in Appendix F):

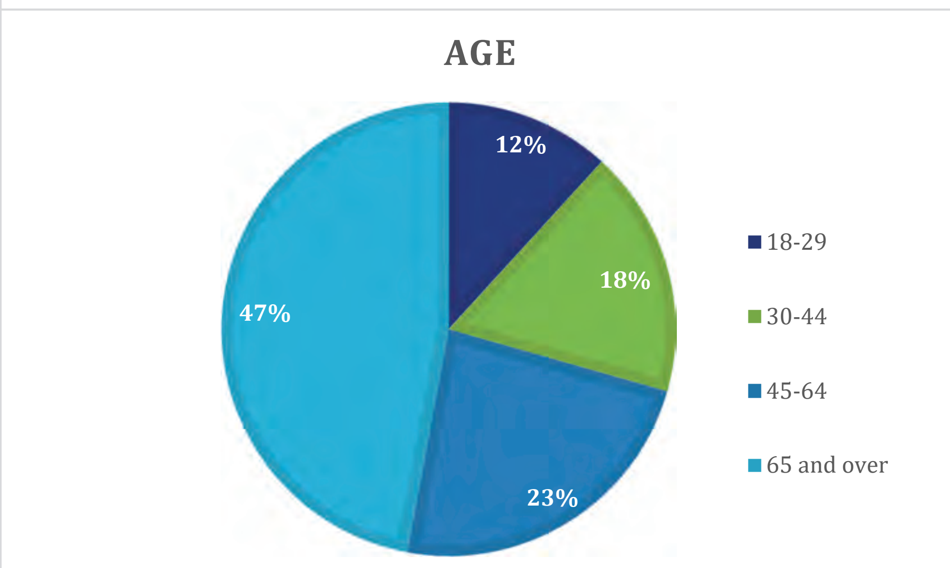

COUNCIL DISTRICTS
17%
29%
6%
12%
12%
6%
12%
6%
Ann Kitchen
Ellen Troxclair
Jimmy Flannigan
Kathie Tovo
Leslie Pool
Ora Houston
OutsideCityLimits
(blank)


GENDER
29%
71%
F
M


RACE/ETHNICITY
6%
6%
6%
17%
65%
Anglo
Hispanic/Latino
Other, Anglo,Asian-American
White, non Anglo
(blank)


HOUSEHOLD YEARLY INCOME
12%
24%
35%
29%
$25,000-$49,999
$50,000-$74,999
$75,000-$149,999
More than $150,000


DWELLING TYPE
24%
76%
Multi-family
Single-family Home


AGE
12%
18%
47%
23%
18-29
30-44
45-64
65 and over

- Three respondents did not know their district and one respondent was from outside of city limits and so provided the following ZIP codes:
  - 78759
  - 78749
  - 78731
  - 78620

Next Steps

The next Workshop is tentatively planned for August 2017. In the meantime, Austin Water and the project team will strive to collect additional public feedback, incorporate stakeholder feedback, and provide additional public engagement opportunities.

Appendix

Due to the large number of additional pages, the appendix section is available upon request from Austin Water.

Memorandum

To: *Marisa Flores Gonzalez, Austin Water*
Teresa Lutes, Austin Water

From: *Lyndsi Lambert and Laura Atlas, Rifeline*

Copied: *Tina Petersen, CDM Smith*
Dan Rodrigo, CDM Smith
Lynda Rife, Rifeline

Date: *August 28, 2017*

Subject: *Austin Water Integrated Water Resources Plan Workshop 4 Summary Report*
Task 1 - Conduct Public Outreach and Participation
CDM P/N: 0590-114879

On August 16, 2017, Austin Water hosted the fourth of five public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). This 100-year water plan will evaluate mid- to long-term water supply and demand management options for the City of Austin. The IWRP planning process provides a holistic and inclusive approach to water resource planning.

The workshop featured presentations from the project team about the plan development process including key process steps completed, stakeholder outreach conducted to date including emerging themes from stakeholder feedback, supply and demand options as well as portfolio development and evaluation. After presentations, stakeholders were invited to participate in two Question and Answer sessions followed by facilitated small group discussions.

The workshop was held at the Canyon View Events Center (Austin Board of Realtors Building) located at 4800 Spicewood Springs Road, Austin, TX from 6:00 pm to 8:00pm. 24 members of the community attended (18 participants attended in person and 6 participants attended via webinar).

Outreach and Publicity

Austin Water publicized the event in the following ways:

- Austin Water emailed the following eNewsletter lists a notice about the workshop (see Appendix A for invitation):
    - Water Forward (Mailing list of 440 people)
    - WaterWise Residential List (Mailing list of 15,026 people)

- WaterWise Commercial List (Mailing list of 206 people)

- Austin Water emailed invitations to groups and individuals on the Water Forward stakeholder list, including:
  - Neighborhood associations
  - Businesses, developers, and professional organizations
  - Environmental advocates
  - Civic Leaders
  - Faith-based organizations
  - Education representatives
- Austin Water reached out to City Council members and engaged the IWRP Task Force.
- Austin Water emailed the staff liaisons for the Water Wastewater Commission, Resource Management Commission (RMC), and the Environmental Commission.
- Austin Water invited attendees of past stakeholder outreach meetings.
- Posted information to Next Door, Facebook and Twitter.
- Posted information to the Water Forward website, http://austintexas.gov/waterforward.

Copies of the , invitations (Appendix A), and sign in sheets (Appendix B)are available in the Appendix Section.

Presentation

Lynda Rife of Rifeline provided a summary of the workshop agenda and explained that there was a webinar option available. The agenda for the workshop included:

- Welcome
- Where We Are in the Process
- What We Have Heard to Date
- Options Characterization
- Q&A
- Portfolio Development Process and Themes
- Q&A

- Facilitated Discussion on Themes:
  - Water supply reliability
  - Cost and affordability
  - Conservation of resources

A copy of the presentation is provided in Appendix C.

Marisa Flores Gonzalez, Austin Water's Water Forward Project Manager, provided an overview of the Integrated Water Resource Plan (IWRP), goals for a resilient water future and the planning process. The presentation highlighted:

- Introduction to Integrated Water Resources Plan (IWRP)
- Drivers for Austin's IWRP
- Development process
- Key process steps completed

Geneva Guerrero, Community Engagement Specialist, Austin Water, provided information on past and future stakeholder activities including public workshops and the Summer Series held at libraries in each City Council district. The presentation highlighted:

- Stakeholder feedback at public workshops and Summer Series
- Emerging themes
- How public input will be incorporated

Tina Petersen, Project Principal with CDM Smith (the main Consultant team for the Water Forward effort), provided information on the process of selecting and characterizing water supply and demand management options. The presentation highlighted:

- The options characterization process including demand management options, decentralized options, and supply options

Examples of characterized options including demand management options, decentralized options and supply options with information on project yield, costs, and climate resiliency of the options

The project team then presented the first of two-scheduled question and answer sessions, facilitated by Lynda Rife of Rifeline. Questions and answers included:

- Demand Management Options, Decentralized Options, and Supply Options
  - Did you look at additional supply options? For example, how can we improve the water flow at the headwaters of the Colorado River to improve or enhance water down river?
    - *We didn't look at that option specifically, but in general other options can be considered in the future. In an overall sense, there is a need for continued regional collaboration.*
  - Did you determine the size for the decentralized options?
    - *With decentralized options, we looked at average-sized homes or lots and cost drivers were based on spatial differences and whether water would be used for indoor and/or outdoor needs.*
  - Does the city have direct aquifer access?
    - *We are evaluating this. Aquifer Storage and Recovery (ASR) in the Carrizo-Wilcox Aquifer is an option being evaluated in the Water Forward process.*
  - Are the options targeting new development only?
    - *Some of the options are targeting only new development projected to occur over the planning horizon, however, some options are targeting both existing and new construction/development.*
  - We built our home to harvest rainwater, but because there was no incentive from the city, we stopped using it. Would there be an incentive for this in the future?
    - *One of the options included in the evaluation process is lot-scale rainwater harvesting. Should this option be selected for inclusion in the plan recommendations, one of the implementation pathways could be incentive-based. In addition to incentive implementation, ordinance-based implementation approaches may also be considered.*
  - [One written question received via comment card] What are cost drivers for lot size rainwater harvesting and stormwater harvesting?
    - *The key cost drivers for lot-scale rainwater and stormwater harvesting include how and where the water will be used (indoors/outdoors), the sizing of the storage tank, and sizing of equipment and other facilities, including pumps.*
- Dan Rodrigo of CDM Smith presented information on the process of developing and evaluating integrated water resource plan portfolios. The objectives for strong portfolios include water supply benefits, economic benefits, societal benefits, implementation benefits, and environmental benefits. Each of the five objectives are tied to the three key factors of sustainability: economic, social, and environmental. Highlights of the presentation included:
  - The Water Forward Task Force gave input to the process of applying weighed values to the five objectives.

- A needs assessment was conducted to look at supplies and identified needs and map them into the future.
- Portfolios were created to meet identified needs.
- Using an adaptive management approach, the IWRP will be updated on a 5-year cycle.
- The goal is to evaluate the portfolios on different objectives, and stakeholder feedback is an important part of the process.

- The presenters then held a brief question and answer session following the presentation on portfolio development and evaluation. Questions and answers included:
  - Do you look at the years gone by when water was needed in a hurry because people moved in quickly? When big bumps happen we're behind the curve. Can we look at what has happened historically?
    - *We work to forecast what the future growth might be. We have methods to track demand and growth in order to be able to bring on additional options as needed. For example, for some options we may have the opportunity to lay the groundwork by doing studies and engineering design, and time construction in sync with the timing of need.*
  - The Texas legislature requires a vote on annexation. Can the city of Austin restrict growth?
    - *Newly approved legislation regarding annexation is a recent development. Potential impacts to long-range service area planning will need to be looked at and could potentially be incorporated in future plan updates, as appropriate.*
  - We have years of surplus that we need to manage. I'm surprised by options like desalination. Why don't we build a reservoir to save water?
    - *We are looking at storage options for Austin like San Antonio has done. San Antonio has a Carrizo-Wilcox Aquifer Storage and Recovery (ASR) facility. A Carrizo-Wilcox ASR project is an option we are considering with Water Forward. We have experienced times of drought and times of much wetter conditions.*
    - *We look at averages, but it's the extremes that you have to manage. With Water Forward we are working to account for climate change into the future. It is projected that there will be periods of more intense and longer droughts punctuated by wetter rainy periods. Over time, with extended periods of high temperatures and the associated water loss due to evaporation, aquifer storage and recovery storage would help manage this type of hydrologic condition.*

Stakeholder Feedback

Facilitated Table Discussion

Lynda Rife, of Rifeline, invited stakeholders to participate in facilitated table discussions. There were three tables set around the room, and the participants rotated to each one at 12 minute intervals based on randomly assigned groups of three. Project team members facilitated discussion and took notes at each table.

Below are summary points from the discussion on the following three themes: conservation of resources and environmental stewardship, cost and affordability, and water supply reliability. Notes from the discussion can be found in Appendix D

- Conservation of resources and environmental stewardship
  - Implement landscape water efficiency
  - Extend current water supply
  - Implement ordinances for new development to capture rainwater (alternative water)
  - Use decentralized wastewater reuse
  - There are location challenges for decentralized systems
  - Think about soil as part of conservation.
  - Keep more water on landscapes.
  - Storm water capture could help with flooding
  - Consider inclusion of residential in expansion of reclaimed "purple pipe" system option
  - Incentivize large volume users to use less water
  - Encourage/allow reclaimed water filling stations/trucks
  - Utilize AC condensate for beneficial uses
  - Encourage more graywater usage from indoor sinks
  - Encourage irrigation efficiency incentives through education
  - Consider social justice as part of conservation strategies
  - Encourage low-impact development
  - Look at LCRA/Environmental flows as part of the plan

- Cost and Affordability
  - Rainwater harvesting is a good onsite option
  - Enforcement of ordinances will have to be planned to be cost effective
  - Lower water rates by planning better
  - Secure water supply opportunities
  - Increase water rates to encourage conservation
  - Encourage large companies to use reclaimed water
  - Rate payers should see an itemized bill showing what they are paying for
  - The trend is that water utility costs are going up
  - Utilize education to optimize use
  - Effective enforcement is important
  - City should create a fund that developers pay into for future water supplies/buying land for future needs
  - Distribute costs equitably
- Water Supply Reliability
  - Use storage options in excess water years to store available water
  - Maintain water supply for basic needs
  - New water supply for new growth provides water security
  - We need cushion for future needs
  - Utilize aquifer storage & recovery option and off-channel reservoirs to store water for use in dry times
  - Diversify water supplies
  - Having a difficult time seeing the need for seawater desalination
  - It is good to have meetings and evaluate the plan every 5 years
  - Timing is important for planning for the future
  - Consider downstream needs
  - Pay attention to climate change

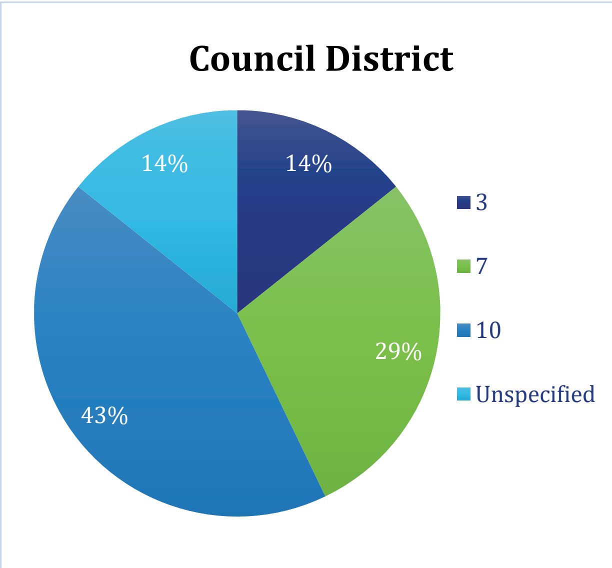
- Need water available to fight fires and other safety measures

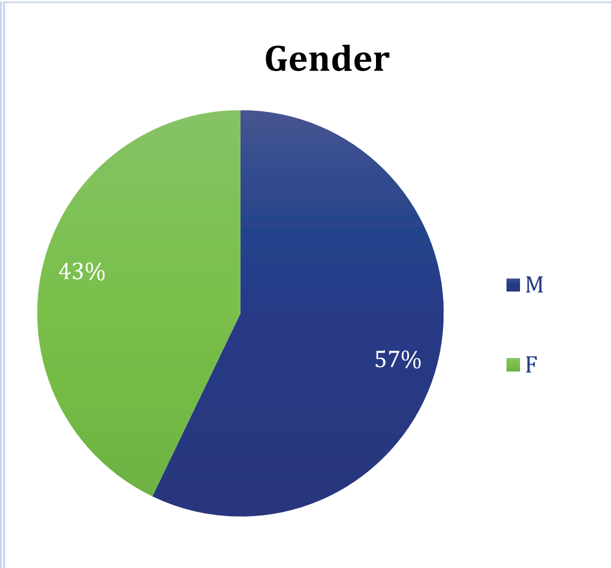
After the facilitated discussion sessions, participants were encouraged to take a look at the information boards around the room and ask questions to Austin Water staff and other workshop presenters.

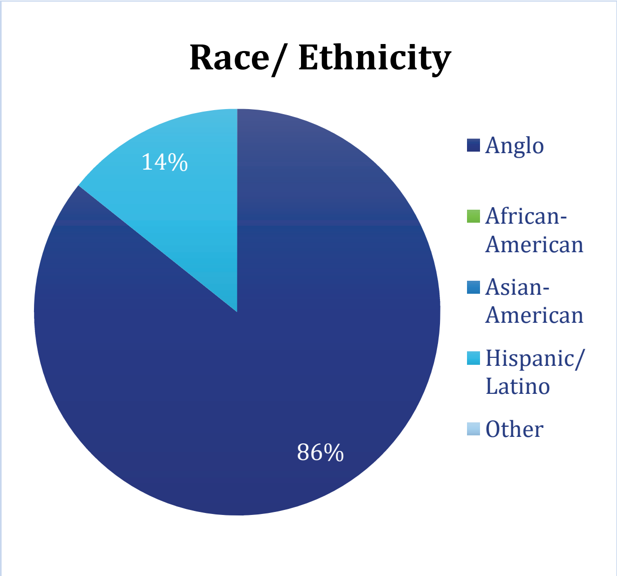
Demographic Breakdown

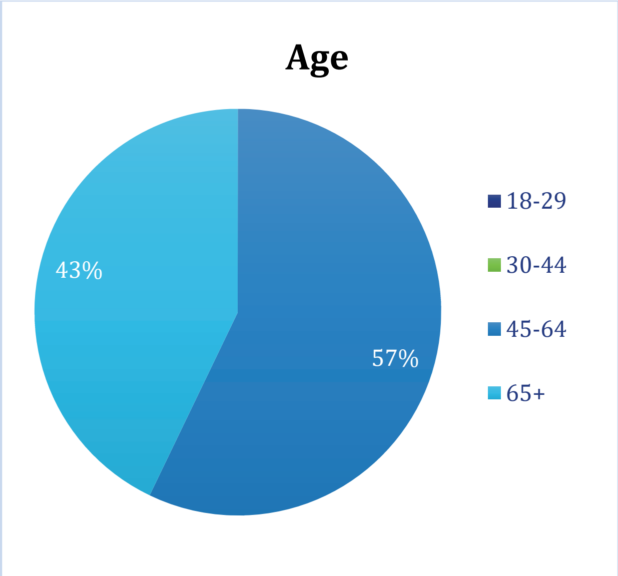
Of the seven demographic surveys completed, the following demographic information was self-reported. Copies of the demographics forms can be found in Appendix E:

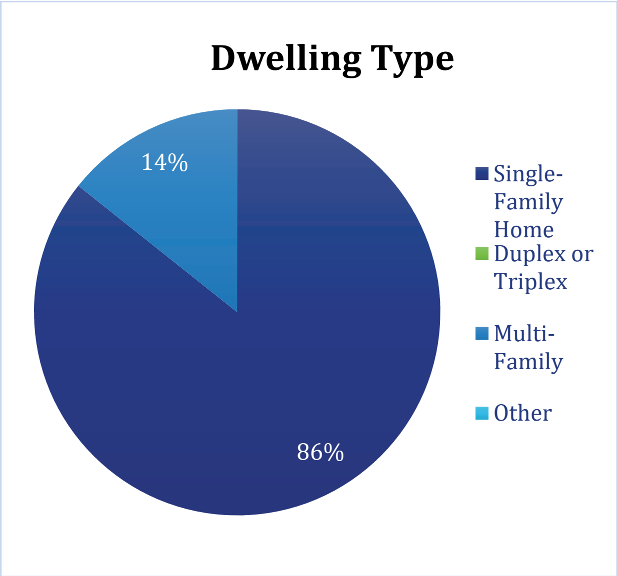
- One respondent did not live in Austin City Council Districts and provided the ZIP code below:
    - 78745

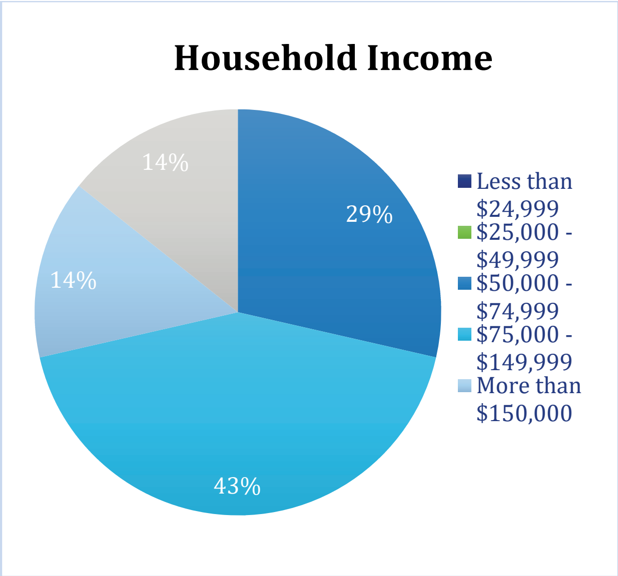





Race/ Ethnicity
14%
86%
Anglo
African-American
Asian-American
Hispanic/ Latino
Other


Age
43%
57%
18-29
30-44
45-64
65+


Dwelling Type
14%
86%
Single-Family Home
Duplex or Triplex
Multi-Family
Other


Household Income
14%
29%
14%
43%
Less than $24,999
$25,000 - $49,999
$50,000 - $74,999
$75,000 - $149,999
More than $150,000

Next Steps

The next Workshop is tentatively set for early 2018. In the meantime, Austin Water and the project team will strive to incorporate stakeholder feedback and begin developing potential portfolio options.

Appendix

Due to large number of additional pages, appendix section available upon request from Austin Water.

Memorandum

To: *Teresa Lutes, Austin Water*
Marisa Flores Gonzalez, Austin Water

From: *Lynda Rife, Rifeline*

Copied: Tina Petersen, CDM Smith
Dan Rodrigo, CDM Smith

Date: *March 21, 2018*

Subject: *Austin Water Integrated Water Resources Plan Workshop 5 Summary Report*
Task 1 – Public Outreach
CDM P/N: 0590-114879

On March 21, 2018, Austin Water hosted the fifth of five public workshops in order to collect public input for the Integrated Water Resource Plan (IWRP). The workshop featured presentations from the project team including a recap of the plan development process, themes from stakeholder feedback, portfolio development and evaluation, and draft plan recommendations and benefits. After presentations, attendees were invited to participate in two Question and Answer sessions followed by an Open House where attendees were invited to view draft plan recommendation benefits and get their questions answered by project team members.

The workshop was held at the Dawson Elementary School Cafeteria located at 3001 S. 1st Street, Austin, TX 78704 from 6:00 p.m. to 8:00 p.m. Twenty-nine (29) members of the community attended (24 attended in person and five (5) attended via webinar).

Outreach & Publicity

Austin Water publicized the event in the following ways:

- Austin Water emailed the following e-newsletter lists a notice about the workshop (see Appendix A for invitation):
  - Water Forward (495 stakeholders)
  - WaterWise Residential List (15,000 stakeholders)
  - WaterWise Commercial List (206 stakeholders)
- Austin Water emailed invitations to groups and individuals on the Water Forward stakeholder list, including:
  - Neighborhood Associations

- Businesses, Developers & Professional Organizations
- Environmental Advocates
- Civic Leaders
- Faith-Based Organizations
- Education Representatives

- Austin Water also:
  - Reached out to City Council members
  - Engaged the IWRP Task Force
  - Emailed staff liaisons for the following commissions:
    - *Water Wastewater Commission*
    - *Resources Management Commission*
    - *Environmental Commission*
  - Made announcements on social media including:
    - *Nextdoor*
    - *Facebook*
    - *Twitter*
  - Water Forward website: http://austintexas.gov/waterforward

Copies of sign in sheets are available in Appendix B.

Presentation

Lynda Rife of Rifeline welcomed attendees and provided a summary of the workshop agenda. She explained that there was a webinar option available enabling attendees to join virtually. The agenda for the workshop included:

- Review Water Forward Plan Drivers
- Understand Evaluation Processes
- Draft Plan Recommendations and Benefits
- Adaptive Management Concept and Next Steps
- Q&A (after each presenter)

- Open House: Draft Plan Recommendations, Benefits and Facilitated Discussion
- Invitation to Complete a Survey and/or Comment Form

See PowerPoint Presentation slides in Appendix C.

Dan Rodrigo of CDM Smith provided a recap of the IWRP process and the themes of public input received to date (key themes include clean safe drinking water, water supply reliability, conservation of resources, cost and affordability, and environmental stewardship). He explained how Austin Water is working to plan for future droughts and water resource needs based on different scenarios. He also explained how needs for portfolio development were considered, how needs would increase over time, and how meeting those needs would require planning well in advance to ensure that resources were available when needed.

After providing an overview of the process for developing and evaluating integrated water portfolios, Dan made note of the five objectives for assessing portfolios: water supply benefits, economic benefits, societal benefits, implementation benefits, and environmental benefits. Finally, Dan reviewed a summary of portfolio evaluations including Hybrid 1, Hybrid 2, Max Conversation, Max Reliability, Max Implementation, Max Local Control, and Max Cost-Effectiveness.

The project team then opened the first of two question and answer sessions, facilitated by Lynda Rife of Rifeline. Questions and answers included:

1. How did you decide on the weights for the different objectives/criteria?

   A Council-Appointed Water Planning Task Force in 2014 developed a final report that included a matrix with listed criteria and weighting information, which was used as a starting point. This set of criteria was fleshed out and refined for the Water Forward process based on process requirements and input from the Water Forward Task Force, the consultant team, city staff and others.

2. Last year, the Texas Legislature passed a law providing for landowners in a city's extraterritorial jurisdiction (ETJ) to vote to decide if they want to be annexed. Will the City of Austin continue to supply water to new developments in the ETJ?

   Time will tell on the long-term effects of that law; the Water Forward Plan will be updated on a 5-year cycle and the City will make plan adaptations, as needed, in the future. The City will continue to be actively involved in monitoring potential service area changes as they make occur in the future.

3. Conservation is prominent in each of the portfolios. What is included in this? Behavior? Fixtures?

   Question was saved because the next presentation would go through the contents of portfolios in more detail, where the question might be answered through the presentation.

   During presentation #2 Marisa Flores Gonzalez, Austin Water, addressed these questions during the explanation of Hybrid 1 and Water Conservation Strategies slides.

4. With the City's current Lower Colorado River Authority (LCRA) contract set to expire in 2100, what was assumed with regard to the availability of water for the Austin Water Utility after that point in time?

   It was assumed that in the future the City would renew and extend that contract with LCRA.

5. Since this is an integrated plan, what is the involvement/role of regional providers such as LCRA and surrounding communities and water utilities?

   City of Austin envisions working with regional partners to protect and enhance the water supply. The City will engage in numerous outreach efforts including coordinating with the LCRA and the Regional Water Planning Group (Region K). The City will continue to share information with others in the basin and identify regional issues.

Marisa Flores Gonzalez, Austin Water's Water Forward Project Manager, provided an overview of the Draft Water Forward Plan Recommendations and benefits. The presentation highlighted:

- Hybrid 1 components
- Water Conservation Strategies
- Water Supply Strategies
- Benefits of the Plan, including:
  - Meeting Future Demands & Population Growth
  - Stretching Our Current Supplies
  - Supply Diversification & Resilience
  - Strengthening Drought Resilience & Planning for Climate Change
  - Maximizing Local Water Sources
  - Planning for Climate Change & Uncertainties through Adaptive Management
- Key Points About Plan's Adaptive Management Approach

The project team then opened the second of two-planned question and answer sessions, facilitated by Lynda Rife. Questions and answers included:

1. How is the City planning to fund programs to address future leaks and failures in the city's water infrastructure? Are the funds enough?

   The City continually plans for these types of infrastructure improvements through Austin Water's Renewing Austin Program; infrastructure improvements are typically incorporated into the City's Capital Improvements Program (CIP) process.

2. The most cost-effective strategy is to change how we develop properties. Has there been any analysis/modeling to determine whether the proposed changes in CodeNEXT will help us

achieve our demand-side management goals to be set forth in Water Forward? Are any of the strategy options being incorporated now in CodeNEXT or otherwise?

For the recommended Water Forward options requiring code changes, the City will be holding public input forums to receive public input on the implementation requirements for the options. For example, for future ordinances that may be required to implement recommendations on alternative water options, Austin Water plans to seek public input throughout the ordinances development process, including aspects of applicability, requirements, etc. Throughout the process Austin Water has continued to track the CodeNext process and is not aware of any incompatibilities with Water Forward recommendations.

3. When Aquifer Storage Recovery (ASR) was discussed previously (approx. 2010), Austin Water (AW) suggested it was not feasible due to impacts to the infrastructure (i.e. lime build-up in AW pipes). How have those concerns been resolved?

   The City has looked at ASR in the past. Previously the city had looked at the Edwards Aquifer for short-term storage and there was concern about injecting lime softened water into the formation which could create scaling in the system/pipelines and cause diminished return of taking water out of the aquifer. The City is currently evaluating ASR in the Carrizo-Wilcox Aquifer for long-term storage for drought supply augmentation. If approved for implementation, there would be additional study and analysis needed and piloting. A suitable aquifer potentially may require additional water treatment prior to injecting and after extracting; long-term storage would be beneficial for stretching water supply over a period of years to manage drought situations.

4. Is the City looking into alternative water sources such as atmospheric water generation to recharge aquifers?

   Cloud seeding did not make it through the screening process early on in the project.

5. Will the City of Austin mandate dual plumbing in new, single family homes which makes it easy for greywater reuse?

   Draft Water Forward Plan Recommendations do included recommendations regarding dual plumbing; the City is recommending to initially require dual plumbing in larger-scale commercial and multi-family new development. Part of the implementation process will include determining sector applicability and phasing.

6. If developers are taking on costs such as rainwater harvesting, why is it so expensive?

   Unit costs were included on one of the presentation slides. The costs shown are community costs which include costs that may be borne by both developers and Utility customers. Although rainwater harvesting is one of the higher cost options on a unit costs basis, it serves multiple benefits.

7. Where is the supply diversification? Brackish is the only new supply, which will be implemented in 60 years.

   While a number of the options originate from Colorado River supplies, they include aspects that benefit supply diversification, such as the storage options like aquifer storage and recovery and a *new off-channel reservoir. Some of the options are from new local sources such as storm water and rainwater capture; brackish groundwater desalination is projected to be implemented later in the plan timeline; additionally, this plan will be updated every five years and new water supply options that may emerge can be evaluated at each plan update.*

8. If you pump water into an aquifer, anyone can pump it out under Texas law. How will you regulate this situation?

   The City will be looking at developing conservation easements, purchasing acreage, or other approaches, in the area of an ASR project in order to help protect the "bubble" of stored water.

9. Are advanced water meters currently available? The costs associated with some of these options will be incurred regardless which portfolio is selected (i.e. repair and maintenance of infrastructure to reduce loss). Are the costs indicated on the slide above and beyond what can be anticipated?

   The City is currently testing technology with an Advanced Metering Infrastructure (AMI) Pilot Study in River Place and is working with a consultant to develop an AMI plan to expand the program to all Austin Water customers (completion is expected within the next five to seven years). The City spends approximately $20-25 million per year on replacing leaking pipes; the City is using several different innovative strategies (i.e. imagery, leak detection equipment, etc.). While the City is currently making expenditures in these areas, future planned expenditures will be incorporated in future capital improvements plans.

10. Where is the brackish water coming from? Matagorda Bay? Why not state that up front?

    The recommended brackish groundwater option would not coming from Matagorda Bay; the City is still identifying a suitable brackish groundwater aquifer, which would be located generally in the Central Texas area

11. How will the plan be implemented? Partnership with homeowners, commercial, businesses? How enforceable is this plan?

    For some options, the plan will be implemented through future changes to codes and ordinances, where applicable. For some options, the plan will be implemented through incentive programs. Other options will be implemented through completion of projects through Austin Water's Capital Improvements Program (CIP).

12. Does Water Forward propose incentives or changes to regulations to encourage indoor reuse, not just reuse for landscaping?

    Requirements for installation of on-site dual plumbing for new developments with a phased implementation approach are recommended; through the implementation process, the City will work to determine sector and scale applicability. The recommendation is for the initial phase to apply to new development in the larger commercial and multi-family sector.

Questions and comments noted by participants in comment cards are attached in Appendix D

Stakeholder Feedback

Open House

Following the presentations and Q&As, participants were invited to participate in an Open House where display boards detailed Draft Water Forward Plan Recommendation benefits and project team members were available to answer questions and engage in deeper conversation.

Below is a list of the boards displayed (see Appendix E for details):

- Meeting Future Demands & Population Growth
- Stretching Our Current Supplies
- Supply Diversification & Resilience
- Strengthening Drought Resilience & Planning for Climate Change
- Maximizing Local Water Sources
- Planning for Climate Change & Uncertainties through Adaptive Management

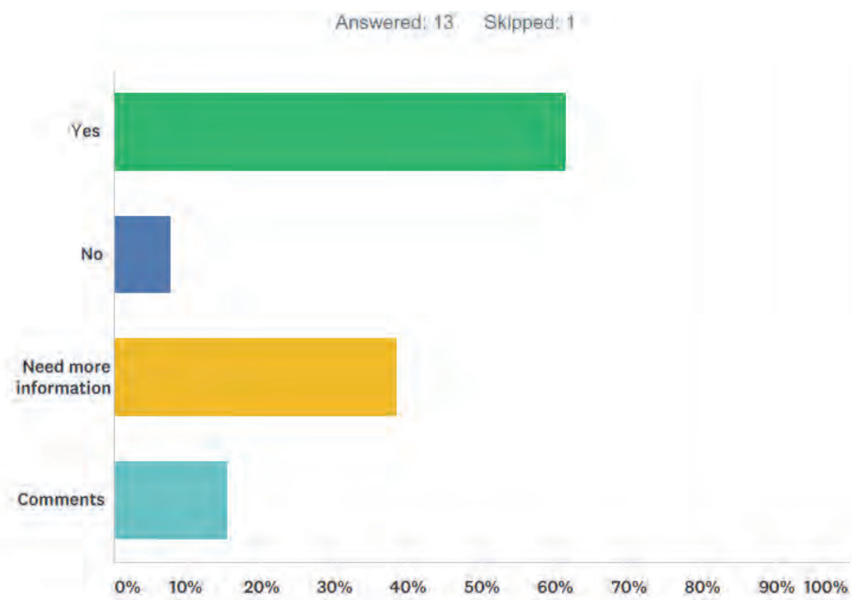
A recap of what was heard from participants is outlined below:

- Atmospheric conditions (an attendee was interested in removing moisture from the atmosphere to develop water, not focused on cloud seeding)
- Concern to make sure enough water is returned back to the lakes/rivers for the environment and downstream users
- Discussed climate change assumptions
- Discussed how the City potentially plans to incorporate the Draft Water Forward Plan Recommendations into the Region K and State Water Plan
- Concern expressed over how firm 325,000 ac-ft/yr will be available for the City of Austin down the road
- Interest expressed regarding if other entities using the same water supplies as Austin have been incorporated into this plan.

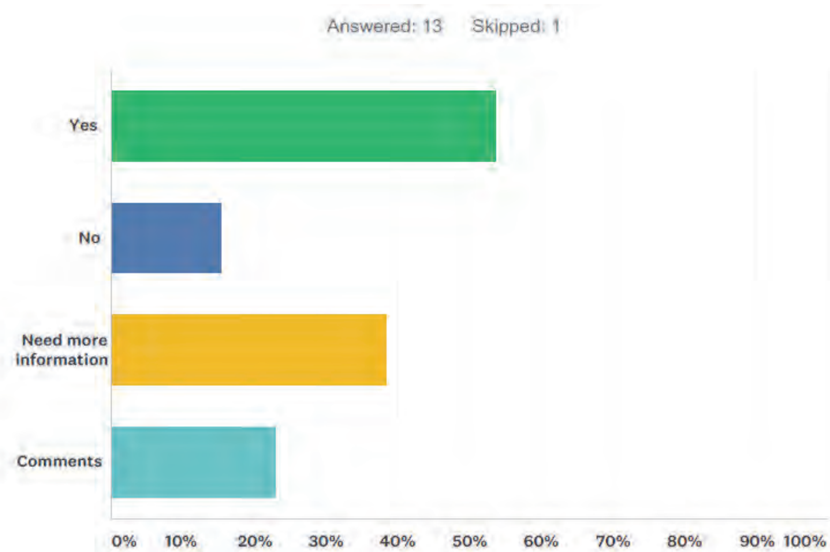
Survey Results

Stakeholders were also invited to complete a survey in order to provide feedback on the Draft Water Forward Plan Recommendations. Of the 29 stakeholders who attended, 14 submitted a survey (48% response rate). See Appendix F for scans of surveys and associated comments.

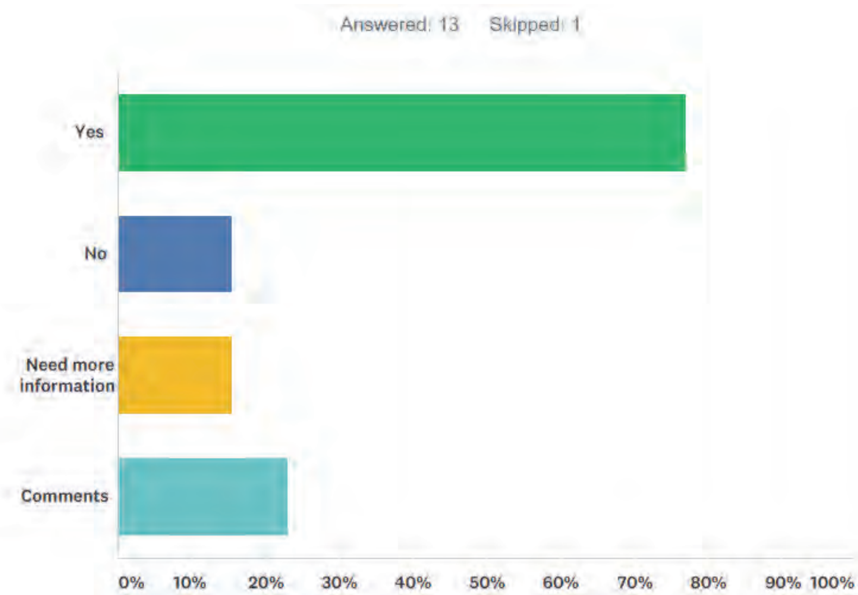
Question #1: Are the recommendations clear?



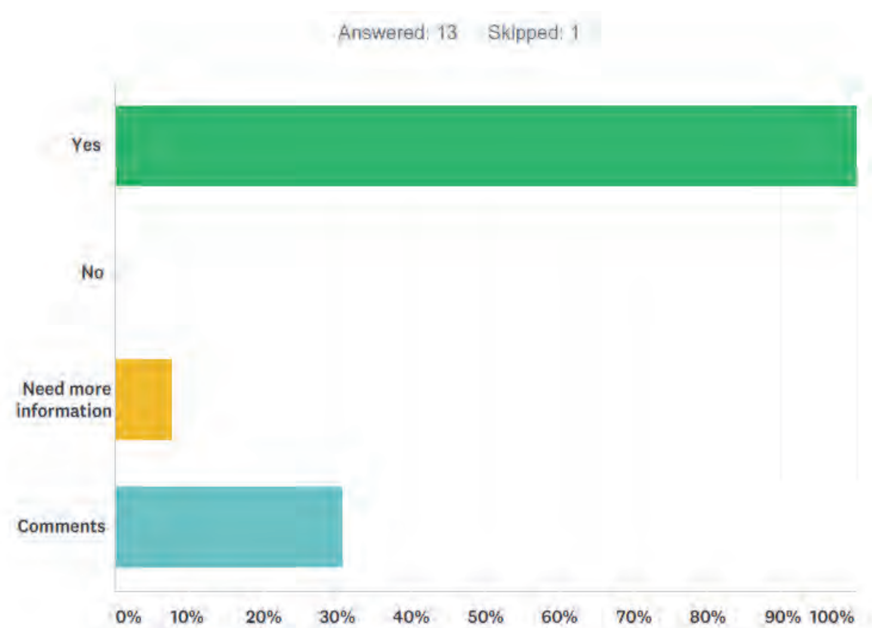
Question #2: Are you comfortable with the recommendations?



Question #3: Have we addressed all the benefits adequately?

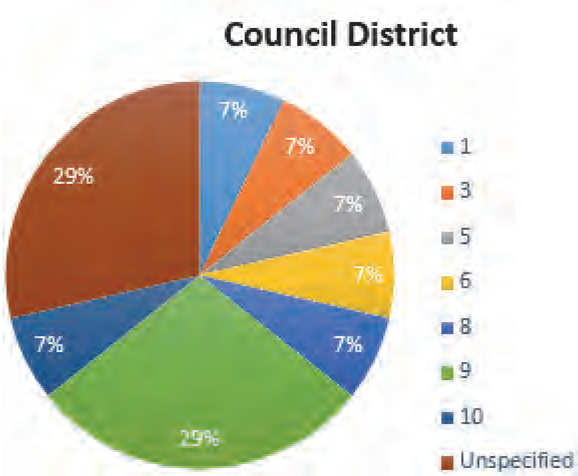


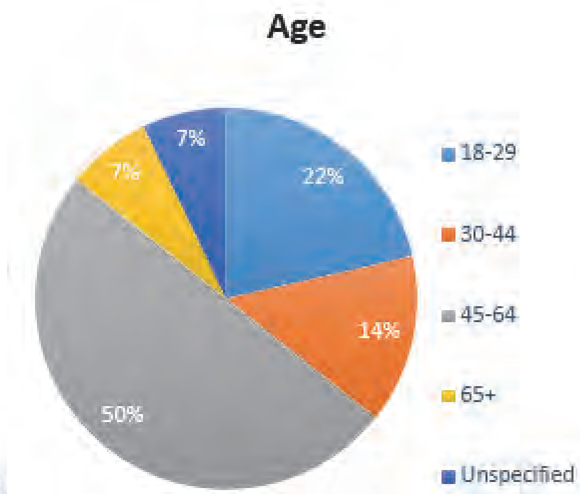
Question #4: Do You Understand the Need for Adaptive Management?

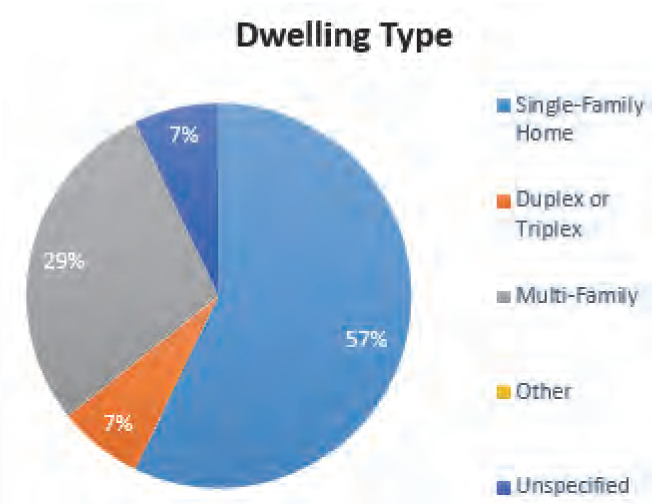


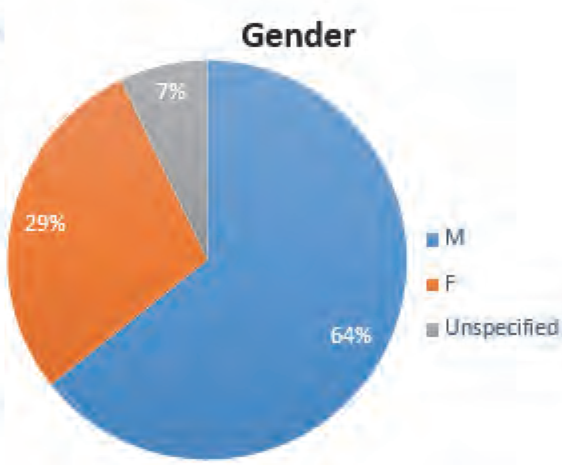
Demographic Breakdown

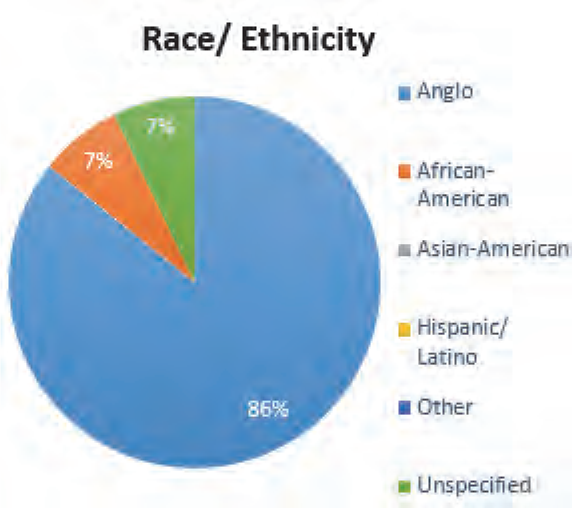
Of the 14 surveys collected, the following demographic information was self-reported (see copies in Appendix F):

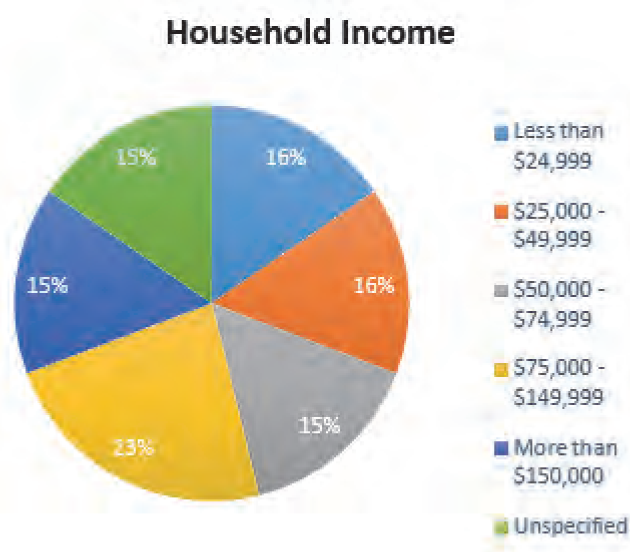












Next Steps

As needed, the Austin Water team will refine the Draft Water Forward Plan Recommendations based on stakeholder input then continue conducting outreach in order to finalize the plan. The final plan will then be presented to City Council for approval. Implementation will only move forward upon Council approval.

Appendix

Due to the large number of additional pages, the appendix section is available upon request from Austin Water.

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APPENDIX B: INTEGRATED WATER RESOURCES PLANNING PROCESS OVERVIEW

The Water Forward Integrated Water Resources Plan (IWRP) is a comprehensive planning process undertaken by Austin Water (AW) to evaluate water supply and demand management options. The Mission Statement for the IWRP is as follows:

The Integrated Water Resource Plan (IWRP) will provide a mid- and long-term evaluation of, and plan for, water supply and demand management options for the City of Austin in a regional water supply context.

Through public outreach and coordination of efforts between City departments and the Austin Integrated Water Resource Planning Community Task Force (Task Force), the IWRP offers a holistic and inclusive approach to water resource planning.

The plan embraces an innovative and integrated water management process with the goal of ensuring a diversified, sustainable, and resilient water future, with strong emphasis on water conservation.

The purpose of this appendix is to provide an overview of how demand-side and supply options were screened and characterized. It also establishes the primary objectives, sub-objectives, and performance measures that were used to evaluate portfolios (combinations of individual options). Above all, it provides the framework for how the IWRP process provided a transparent, unbiased analysis of the tradeoffs between various portfolios to meet the IWRP objectives.

B.1 Preliminary Estimation of Water Supply Needs

An important aspect of the IWRP is to evaluate existing water supplies under different hydrologic conditions and compare these supplies to forecasted water demands. This provided preliminary estimates of short-term, medium-term and long-term water supply needs. The Colorado River Basin Water Availability Model (WAM) was used for evaluation of future water supply needs for the forecasted demands in years 2020, 2040, 2070 and 2115, under different hydrologic scenarios which are planned to include the historical hydrologic period of record, climate change adjusted hydrology, and randomized re-sequenced hydrology.

Forecasted demands were simulated against various hydrologic scenarios, and measures of supply shortage were produced. No portfolios of water supply or demand-side options were used in this preliminary water supply needs analysis. The purpose of this assessment is to gain an understanding of the characteristics of potential water supply needs. Subsequent tasks in the IWRP process took this and other information into account in the development of portfolios.

B.2 Evaluation Process Overview

The Austin IWRP evaluation process is based on an established planning process that explores both demand-side and supply-side options in an integrated manner in order to meet multiple objectives. The IWRP process also explores risks and uncertainty related to different potential hydrologic and climatic futures over the next 100 years.

In development of the IWRP, the following terms were used:

Objectives	• Broadly stated goals of the IWRP that drive the evaluation process.
Sub-objectives	• Adds further clarity to the objectives, and forms the basis for the evaluation criteria used to score portfolios.
Performance Measures	• Metrics that indicate how well sub-objectives are being achieved.
Options	• Individual water supply and demand-side management projects or programs.
Portfolios	• Combinations of options that are evaluated against the performance measures.

The IWRP process is summarized in **Figure B-1**. The process begins with defining the objectives, sub-objectives, and performance measures. The sub-objectives together with the performance measures serve as the evaluation criteria which IWRP portfolios were measured against.

Prior to developing portfolios, identification and characterization of various water supply and demand-side options took place. The process started with a larger number of options, which were screened down to a smaller number using a set of criteria. These criteria include a high-level unit-cost comparison and a high-level implementation risk comparison. Those options that pass the screening process were evaluated and characterized in greater detail.

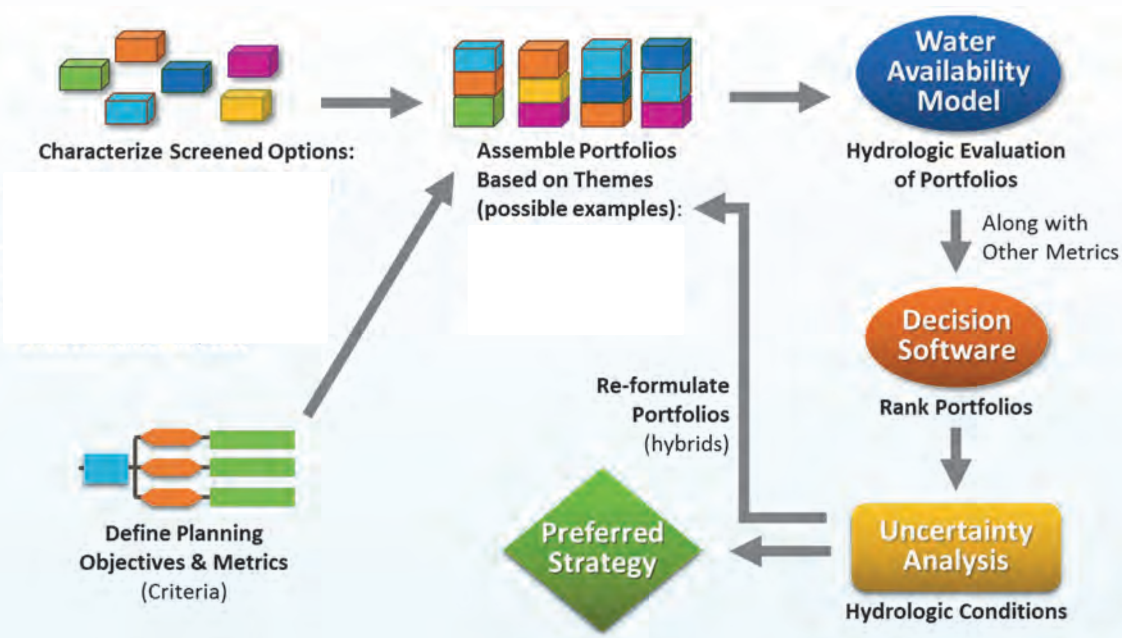

Figure B-1. AW IWRP planning process

To evaluate how different combinations of multiple options score against all of the IWRP objectives and sub-objectives, groupings of options were combined in various ways to develop portfolios. The portfolios were developed around themes such as "Maximize Reliability" or "Maximize Cost-Effectiveness" or "Maximize Conservation". Themes were developed by AW with input from the Task Force and community. Each portfolio was then evaluated in terms of how well it achieves the sub-objectives, under various hydrologic conditions (for example historical and climate change scenarios). Ultimately, the portfolios were ranked and a preferred IWRP strategy was recommended for implementation. A preferred IWRP strategy may be a combination of several high-ranking portfolios using an adaptive management approach that would implement various options within the portfolios based on triggers, such as demand growth, hydrologic conditions and other factors.

B.3 Objectives and Performance Measures

The IWRP planning objectives serve as the framework for how the IWRP is developed. Objectives are usually categorized as primary (objectives) and secondary (sub-objectives). Primary objectives are more general, while sub-objectives help define the primary objectives in more specific terms. Note that throughout this appendix the terms *objective* and *primary objective* are used interchangeably. Based on decision science literature and consulting best practices, sub-objectives should have the following attributes:

- **Be Distinctive:** to distinguish between one portfolio and another
- **Be Measurable:** in order to determine if they are being achieved, either through quantitative or qualitative metrics
- **Be Non-Redundant:** to avoid overlap and avoid bias in the ranking of portfolios
- **Be Understandable:** be easily explainable and clear
- **Be Concise:** to focus on what is most important in decision-making

The IWRP objectives and sub-objectives were developed by AW/consultant team, with input from the Task Force. The objectives were formulated based on the previous 2014 Task Force and centered around principles of sustainability (balanced between economic, environmental, and social needs). Initial sub-objectives were formulated with a "defining question" to establish the intent of the sub-objective. A preliminary list of 25 draft sub-objectives was developed as part of a full day workshop held with the AW/consultant team. Based on input from the Water Forward Task Force (previously referred to as IWRP Task Force) through a survey, the sub-objectives were reduced to 14, which aligns well with decision science literature and consulting best practices.

For each sub-objective, a performance measure is required. The performance measure is used to indicate how well a sub-objective is being achieved. Where possible, quantitative performance measures were established based on a review of available data and anticipated output from the various IWRP analyses, tools, and modeling efforts. In certain instances, a qualitative score is the most suitable performance measure. Qualitative scores were established based on a combination of quantitative analysis, professional judgment, and input from subject matter experts, including AW staff/consultant team. **Table B-1** presents the refined list of primary objectives, sub-objectives and performance measures.

In any decision-making process, primary objectives are generally not all equally important. Thus, developing a set of weights is necessary to better reflect the difference in values and preferences among the various objectives. The AW/consultant team initially developed a draft set of weights for the objectives and sub-objectives. The weighting of objectives from the 2014 Task Force process were considered in developing the initial draft weighting set. A survey was sent to the Water Forward Task Force with draft weightings for objectives and sub-objectives to solicit input. This survey information was provided for review and discussion by the Task Force. Additional input provided was considered by AW and the consultant team in the process of refining the weighting set, which are presented in **Table B-1**.

Table B-1. Refined list of primary objectives, sub-objectives and performance measures

Objective	Sub-Objective	Defining Question	Performance Measure
Water Supply Benefits	Minimize Vulnerability	How much of the water needs[1] identified in the IWRP are met during 12-months of worst-case drought? Vulnerability describes the magnitude of shortages relative to defined water needs, if shortages occur.	Geometric mean of model results from different hydrologic scenarios. Percent of volume of water needs[1] met during worst 12-months of drought under various hydrologic scenarios.
	Maximize Reliability	How many months are water needs[1] identified in the IWRP fully met during the period of simulation? Reliability describes the frequency of shortages relative to defined water needs, if shortages occur.	Geometric mean of model results from different hydrologic scenarios. Percent of time water needs[1] were met during the period of record for various hydrologic scenarios.
Economic Benefits	Maximize Cost-Effectiveness	What is the total capital (construction) and operations/maintenance costs of all projects/programs in the portfolio over the lifecycle, divided by the sum of all water yield produced by the portfolio?	Unit cost ($/AF) expressed as a present value sum of all costs over the lifecycle, including utility and customer costs.
	Maximize Advantageous External Funding	Does the portfolio have an opportunity for advantageous external funding from Federal, State, local, and private sources?	External Funding Score (1-5), where 1 = low potential and 5 = high potential
Environmental Benefits	Minimize Ecosystem Impacts	To what extent does the portfolio positively or negatively impact receiving water quality (e.g., streams, river, lakes), terrestrial and aquatic habitats throughout Austin, and net streamflow effects both up and downstream from Austin?	Ecosystem Impact Score (1-5), where 1 = high combined negative impacts and 5 = high combined positive impacts
	Minimize Net Energy Use	What is the net energy requirement of the portfolio, considering energy generation?	Incremental net change in kWh
	Maximize Water Use Efficiency	What is the reduction in water use from water conservation, and reuse for the portfolio?	Potable per capita water use (gallon/person/day)
Social Benefits	Maximize Multi-Benefit Infrastructure/ Programs	To what extent does the portfolio provide secondary benefits such as enhanced community livability/beautification, increased water ethic, ecosystem services, or others?	Multiple Benefits Score (1-5), where 1 = low benefits and 5 = high benefits
	Maximize Net Benefits to Local Economy	To what extent do the supply reliability and water investments of the portfolio protect and improve local economic vitality, including permanent job creation?	Local Economy Score (1-5), where 1 = high negative impact and 5 = high positive impact;
	Maximize Social Equity and Environmental Justice	To what extent does the portfolio support social equity and environmental justice, with emphasis on underserved communities?	Social Equity and Environmental Justice Score (1-5), where 1 = significant support and 5 = minimal support
Implementation Benefits	Minimize Risk	How significant are the major risks and uncertainties associated with implementation of projects?	Qualitative score (1-5), where 1=more water supply provided from high risk projects and 5 = less supply provided from high risk projects.
	Maximize Local Control/Local Resource	To what extent does Austin Water control operations of the water resource and is the resource from the local area?	Qualitative score (1-5), where 1=less water under Austin Water's control and from local water sources 5=more water under Austin Water's control and from local water sources.

[1] Water needs identified in the IWRP are referred to as Type 1, 2, and 3 Need. These needs are described Appendix F

Table B-2 Objective and Sub-Objective Weights

Primary Objective	Objective Weight	Sub-Objective	Sub-Objective Weight
▪ **Water Supply Benefits**	35%	Minimize Vulnerability	28%
		Maximize Reliability	7%
▪ **Economic Benefits**	20%	Maximize Cost-Effectiveness	15%
		Maximize Advantageous External Funding	5%
▪ **Environmental Benefits**	20%	Minimize Ecosystem Impacts	8%
		Minimize Net Energy Use	6%
		Maximize Water Use Efficiency	6%
▪ **Social Benefits**	13%	Maximize Multi-Benefit Infrastructure/Programs	5%
		Maximize Net Benefits to Local Economy	4%
		Maximize Social Equity and Environmental Justice	4%
▪ **Implementation Benefits**	12%	Minimize Risk	7%
		Maximize Local Control / Local Resource	5%

B.4 Options Screening and Characterization

Prior to developing portfolios for detailed evaluation, it is important to evaluate individual supply and demand-side options. This allows for more informed portfolio development and ultimately portfolios that are better at meeting overall IWRP objectives. To do this, two key steps are required: options screening and a standardized options characterization process.

B.4.1 Options Screening Method

Through a process with Task Force and community input that started with a "blue-sky" list of options, approximately 21 water supply options and 25 demand-side options were identified for initial screening by AW/consultant team. Through the screening process these 47 options were narrowed down to a total of 25 supply and demand-side options (13 supply-side and 12 demand-side) that were carried forward for further characterization. The list of options identified for screening generally fall under the following main categories:

- Water Conservation Options
- Lot-scale Decentralized Options (e.g., rainwater harvesting, stormwater harvesting, graywater reuse, blackwater reuse, or A/C condensate reuse)
- Centralized and Community-Scale Decentralized Wastewater Reuse Options
- Storage Options (e.g., Aquifer Storage and Recovery or a New Off-Channel Reservoir)
- New Supply Options (e.g., desalination of brackish groundwater)

The screening process compared high-level, order-of-magnitude unit costs of the options to an index score of implementation risks created specifically for option screening. All of the options were plotted together for these two parameters to see where outliers exist (meaning those options that have higher unit costs and higher implementation risks). The outlier options were recommended for elimination from more detailed characterization.

B.4.2 Options Characterization Method

For options carried forward from screening to portfolio evaluation, a summary characterization was developed. Each of these options were characterized using a standardized *Options Characterization Template* (including, for example, estimated yield and cost). The resulting set of characterized options were used as a "menu" for forming thematic portfolios (for example, a portfolio that has "High Resiliency" as its theme, as described in more detail below). A list of the characterization metrics, associated units, and a metric definition are provided in **Table B-3** for demand management options and **Table B-4** for supply options. Option characterizations were based on the best available technical information; however, more detailed analysis of these options will be required prior to implementation.

Table B-3. Demand Management Options Characterization Template

Metric Name	Unit	Metric Definition
Average Annual Yield	AFY	The estimated average annual demand savings achievable by the measure
Supply Type	Qualitative Selection	Annual or emergency/drought
Unit-Cost	$/AF	Total annual cost of the measure for both the utility and the customer minus cost savings from reduced water production and wastewater treatment costs (in 2017 dollars) divided by the estimated average annual yield
Benefit Cost Ratio	Ratio	Average annual yield divided by the unit cost
Climate Resiliency	Qualitative Index	The relative susceptibility of an option to future hydrologic variability
Advantages	Qualitative Description	Narrative on positive attributes of option, including as it relates to portfolio evaluation sub-objectives
Disadvantages	Qualitative Description	Narrative on negative attributes of option, including as it relates to portfolio evaluation sub-objectives

Table B-4. Supply Options Characterization Template

Metric Name	Unit	Metric Definition
Estimated Yield	AFY	The estimated incremental average annual new supply (or demand saving) to AW
Supply Type	Qualitative Selection	Annual or emergency/drought
Unit-Cost	$/AF	Total annual cost of the option (in current dollars) divided by the new supply yield. Cost will include both customer and utility perspectives and will include a high-level estimate of likelihood of use if designated as an emergency/drought-only supply
Climate Resiliency	Qualitative Index	The relative susceptibility of an option to future hydrologic variability
Advantages	Qualitative Description	Narrative on positive attributes of option, including as it relates to portfolio evaluation sub-objectives
Disadvantages	Qualitative Description	Narrative on negative attributes of option, including as it relates to portfolio evaluation sub-objectives

B.5 Portfolio Development and Evaluation

Options carried forward from screening and through characterization were available for inclusion in IWRP portfolios. Water supply and demand-side options were combined into portfolios that will meet supply needs under different hydrologic scenarios to various degrees of reliability.

Portfolios were formed based on objective-based themes and then evaluated against the IWRP sub-objectives and performance measures. The IWRP produced analyses and demand/supply comparisons for the forecast years 2020, 2040, 2070, and 2115, and portfolios were compared and ranked using combined scores factoring in the different forecasts.

B.5.1 Method for Formulation of Portfolios

To evaluate how different combinations of multiple options score against all of the IWRP objectives and sub-objectives, groupings of options were combined in various ways to develop portfolios. The number of potential combinations of options (i.e. portfolios) is too large to produce a meaningful analysis for the AW IWRP. As a result, portfolios were developed around major themes that align with the IWRP objectives. For example, what would a portfolio look like if the only objective is to maximize supply resiliency? Based on the options characterization results we can develop a portfolio whose sole focus is on supply resiliency and does not consider other objectives such as cost or environmental impact. By developing these initial portfolios that "push" the bounds of each of the most important objectives, trade-offs can be easily identified which can then provide insights in developing "hybrid" portfolios that are more balanced and have a better likelihood of meeting numerous objectives well.

Initial thematic portfolios were developed by the AW/consultant team based on input from stakeholders, including the Water Forward Task Force, and the community.

The initial portfolio themes were:

- **Minimize Cost:** Options with the lower unit costs ($/acre-foot) were selected.
- **Maximize Conservation:** Demand management options and those supply options seen to most sustainably utilize water already available as part of the existing water supply system, such as decentralized lot- and community-scale options.
- **Maximize Resiliency:** Options that produce consistent supply benefits under all hydrologic variability were considered for this portfolio.
- **Maximize Ease of Implementation:** Options that were considered easy or moderately easy to implement were selected for this portfolio.
- **Maximize Local Control:** Options in which Austin Water would have control over the projects and the water supply sources in terms of cost, yield, development, and operations.

B.5.2 Portfolio Evaluation Method

When evaluating a diverse set of portfolios against multiple objectives it is typically not possible to find a single portfolio that meets the needs or priorities of every stakeholder. Instead, the goal is to evaluate trade-offs between options and objectives, which were used to make an informed decision on selecting a preferred portfolio. To do this, the AW IWRP utilized multi-criteria decision analysis (MCDA) to evaluate portfolios. The MCDA process relies on the performance measures and performance weights (outlined in previous sections) and a suite of tools. It is important to note that final recommendation will be "human-based," not computer model-based.

B.5.2.1 Overview of IWRP Tools

The software Criterium Decision Plus (CDP), developed by Infoharvest Inc., is the primary software used to conduct MCDA; however, it is dependent upon input from other IWRP tools and also input from stakeholders and subject matter experts. Each portfolio underwent modeling and assessment that generated raw quantitative and raw qualitative performance measure scores. The tools below served major roles in development of performance measure scores for the AW IWRP:

- **Colorado Basin Water Availability Model (WAM)** – computer-based simulation model, developed and used by the Texas Commission on Environmental Quality (TCEQ) quantifying the amount of water that would be flowing in the Colorado River and available to water rights under a specified set of conditions (e.g. water use, naturalized hydrology, etc.)

- **Geospatial Decentralized Supply Suite of Tools** –set of geospatial analysis processes that evaluates the end user demands, supply yield, cost, and avoided costs associated with storm/gray/black water capture infrastructure

- **Disaggregated Demand Forecasting Model** – end-use based water demand forecast model including residential, multifamily, and commercial sectors; includes impacts of conservation (including Drought Contingency Plan implementation).

- **Portfolio Evaluation Spreadsheet Tool** – spreadsheet tool utilized to assemble options into portfolios based on supply needs (difference between existing supplies and future demands under different hydrologic scenarios), and used to estimate total portfolio costs from individual unit costs for each option.

- **Criterium Decision Plus** – an industry-leading commercial software to compare and rank portfolios based on multiple criteria (see below for detailed description).

B.5.2.2 Description of Water Availability Model Use in Portfolio Evaluation

In order to evaluate the robustness of the portfolios, each portfolio was evaluated under four hydrologic scenarios:

1. **Historic Hydrology**: based on the historical period of record from 1940 to 2016 maintaining the historical sequence of years.

2. **Extended Sampling of Historic Hydrology:** based on an extended 10,000-year simulation made up of resequenced years from the historic hydrology, this sequence is used to develop a range of conditions worse than the drought of 2007-2016

3. **Historic Hydrology with Climate Change Adjustments:** based on a climate change scenario ensemble that adjusts the historical hydrology, but maintains the historical sequence of years.

4. **Extended Sampling of Historic Hydrology with Climate Change Adjustments**: based on an extended 10,000-year simulation made up of resequenced years from the climate change-

adjusted historic hydrology, this sequence is used to develop a range of conditions worse than the drought of 2007-2016

Additional detail related to each future climate condition is included in Appendix X. Where applicable, for each future hydrologic and climate condition new raw performance measure scores will be generated for each portfolio for use. Not all performance measure scores will be impacted by a change in future climate conditions; however, sub-objectives such as Maximize Water Reliability showed a level of sensitivity.

B.5.2.3 Description of Criterium Decision Plus Software

Criterium Decision Plus (CDP) was used to rank portfolios. This software tool converts raw performance measured in different units into standardized scores so that the performance measures can be summarized into an overall value. Through CDP, a multi-attribute rating technique was applied to score and rank the selected portfolios. One advantage of the multi-attribute rating technique is that the resulting scores are non-relative and thus not dependent on the number of portfolios. This allows for the addition of portfolios, such as hybrid portfolios, without impact to the scores of those portfolios previously evaluated. **Figure B-2** summarizes the multi-attribute rating technique that is used by CDP to compare and rank portfolios.

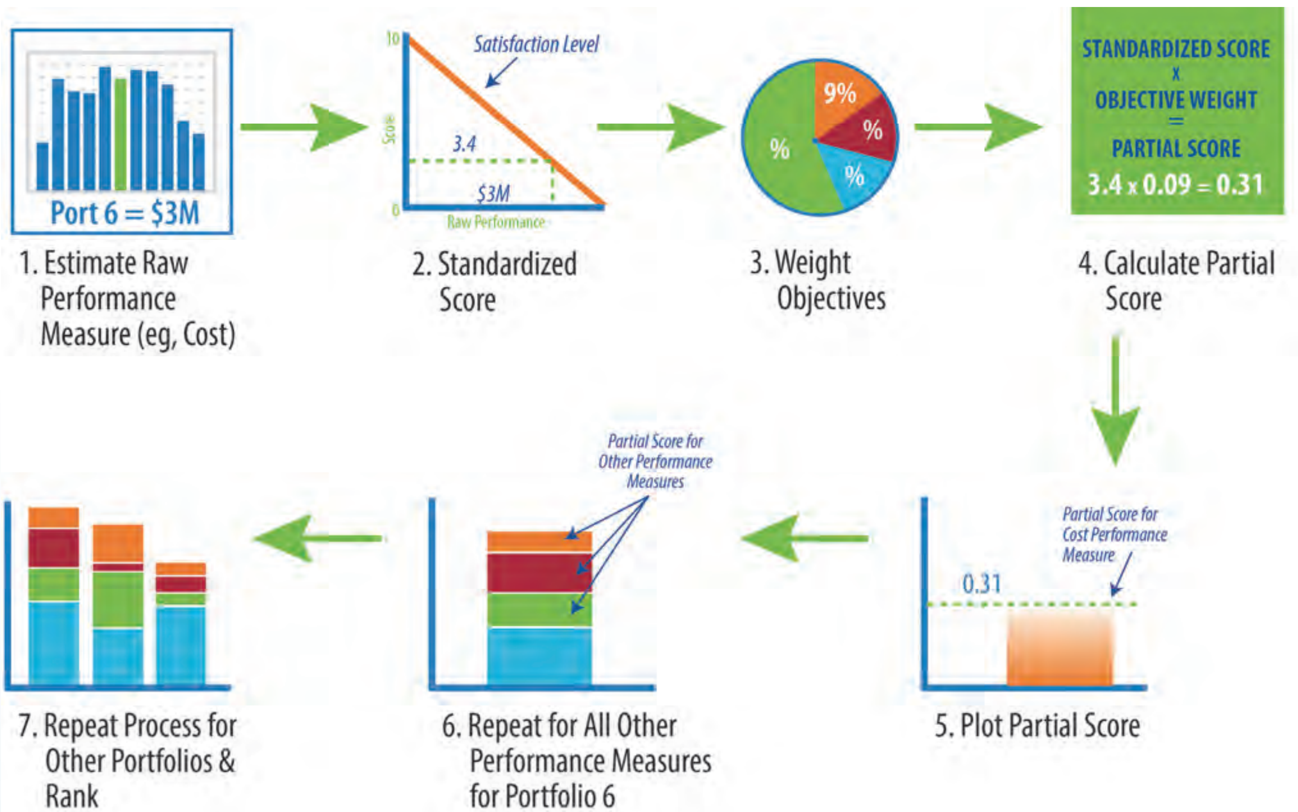

Figure B-2. Multi-attribute rating technique used by CDP software to rank portfolios

Multi-attribute rating uses 7 steps to score and rank portfolios. In step 1, raw performance for all of the portfolios is compared for a given criterion (in this case cost). Step 2 standardizes the performance into a score from 0 to 10. In this example, Portfolio 6's cost performance is fairly expensive so its standardized score is fairly low (e.g., 3.4 out of 10). This step is important because performance is measured in different units (i.e., cost in dollars, reliability in AFY). Step 3 assigns weights to the objective and Step 4 calculates a partial score for a given portfolio based on the multiplication of the standardized score (Step 2) and weight (Step 3). The partial score is plotted (Step 5), and then the whole process is repeated for a given portfolio for all of the other performance measures (Step 6). This creates a total score that can then be compared to other portfolios. Steps 1-6 are repeated for all portfolios and compared so they can be ranked (Step 7).

B.5.2.4 Example of Portfolio Ranking

As outlined above, there are two primary inputs to CDP: (1) raw performance of a portfolio against each performance measure; and (2) the relative importance, or weights, of the objectives and performance measures (see **Figure B-3**).

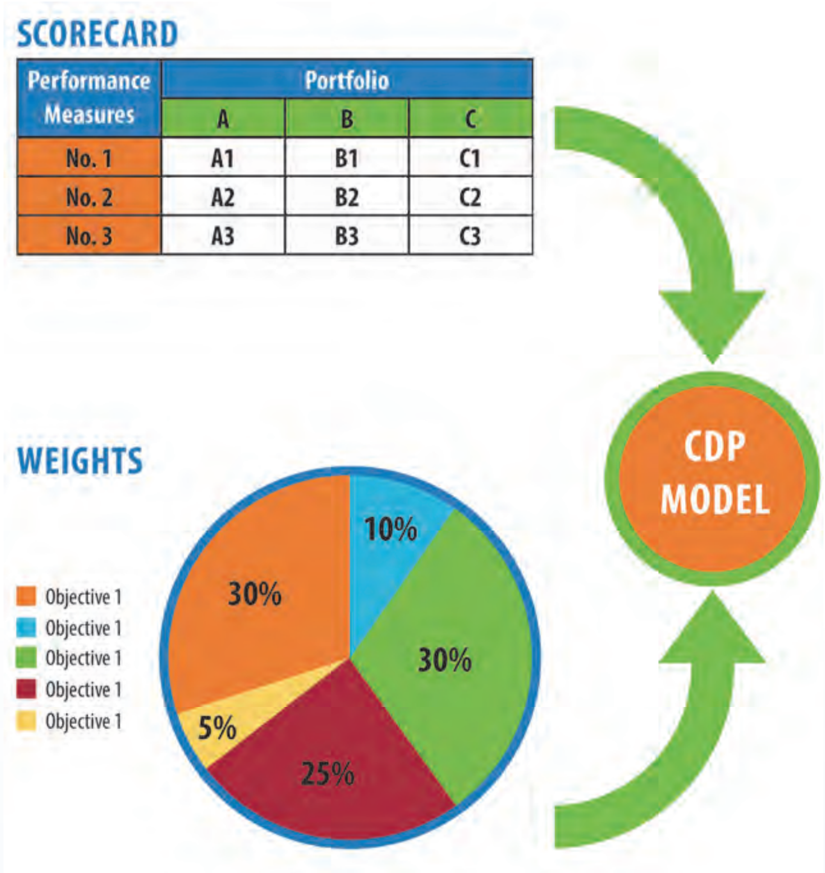

Figure B-3. Inputs to CDP

The raw performance measure scores were standardized by CDP to a unitless scale that ranges from 0 to 1 using the multi-attribute rating technique (described above). The CDP model then multiplied the unitless performance scores by the relative weight of each associated sub-objective. These weighted unitless scores were then aggregated to the objective level and an overall portfolio score was determined. This process was repeated for each portfolio and the portfolios were ranked based on their overall scores. **Figure B-4** presents an example of how portfolios are ranked based on a set of primary objectives and their weights of importance. This process is powerful because it not only ranks portfolios but clearly shows tradeoffs between the objectives.

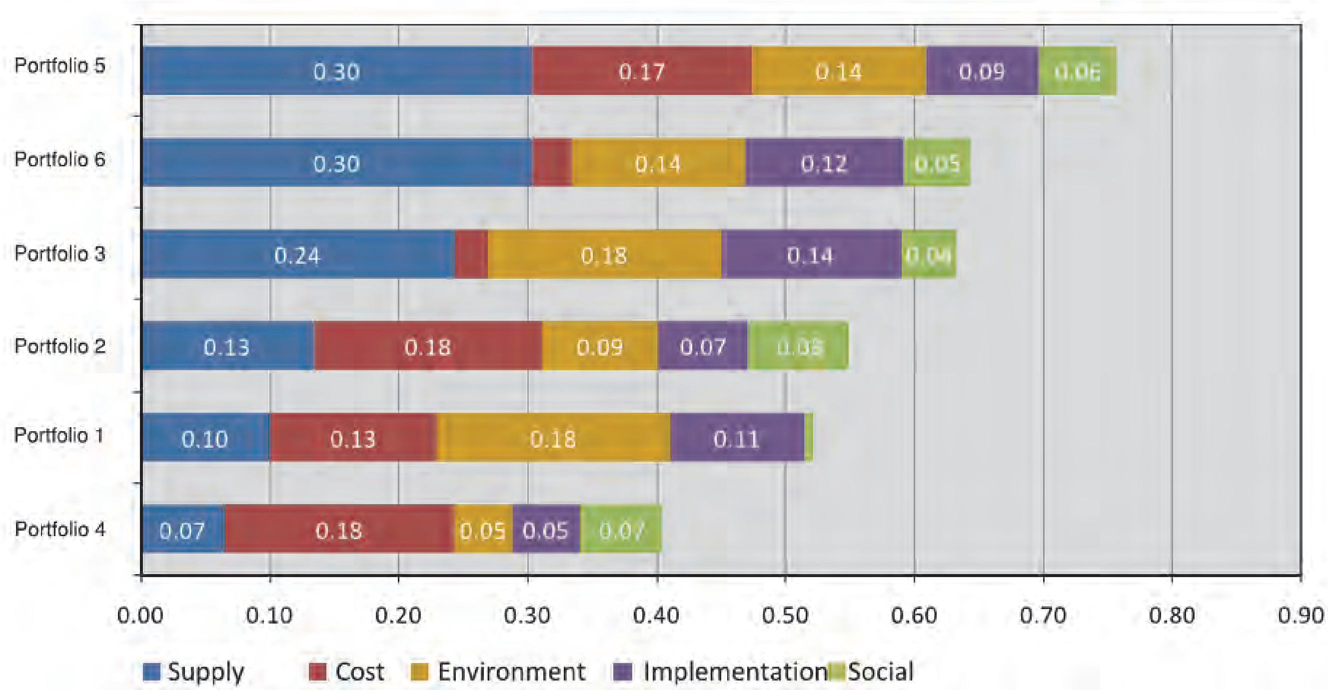

Figure B-4. Illustrative example of portfolio ranking using CDP software

In this example of portfolio ranking, the larger the color bar segments the better the portfolio performs for a given objective. For example, Portfolio 5 has the best supply reliability and hence the longer bar segment for the supply objective. Portfolio 6 also has the best supply reliability score, but it is not as cost-effective (meaning it is higher in cost) than Portfolio 5 and hence it has a relatively small bar segment for the cost objective.

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APPENDIX C: WATER FORWARD DISAGGREGATED DEMAND MODEL

This document presents an overview of the Disaggregated Demand Model developed by Austin Water staff as part of the IWRP. The Disaggregated Demand Model (DDM) was developed and refined as part of an ongoing collaboration between Austin Water and the IWRP Consultant, CDM Smith. The DDM makes use of historical billing, historical land use, and historical and projected demographic data to project potential water use for each IWRP planning horizon (2020, 2040, 2070, 2115).

The foundation of the IWRP water demand estimates is the underlying DDM, which was used to produce the baseline water demand assessment, among other things. Austin Water staff began development of the DDM in advance of the IWRP, and refinements to the DDM have continued throughout the process. The DDM is a Microsoft Excel-based tool that forecasts water use by sector, subsector, and end use at the geographic planning unit-scale for current demands as well as the key planning periods of 2020, 2040, 2070, and 2115. The DDM provides the analytical environment for assessing potential water savings from demand management measures which were evaluated during plan development. The DDM also includes functionality to assess water demands under future climatic scenarios and tracks water consumption by end use (such as toilets, sinks, and irrigation) which informs the assessment of yield potential for decentralized supply options. The following sections describe the DDM attributes, development, and primary data sources.

C.1 Disaggregated Demand Model Attributes

For analysis purposes, it is useful to group water demands according to similar user characteristics. These groupings are known as sectors. The DDM model sector classifications are listed below. The water use sectors are further refined into subsectors and outdoor and indoor end uses, as shown in **Figure C-1**.

DDM sectors include:

- Single family residential (SFR)
- Multi-family residential (MFR)
- Commercial (COM), which includes large volume customers in the Industrial and University subsectors
- Wholesale Customers (WHL)
- City of Austin (COA)

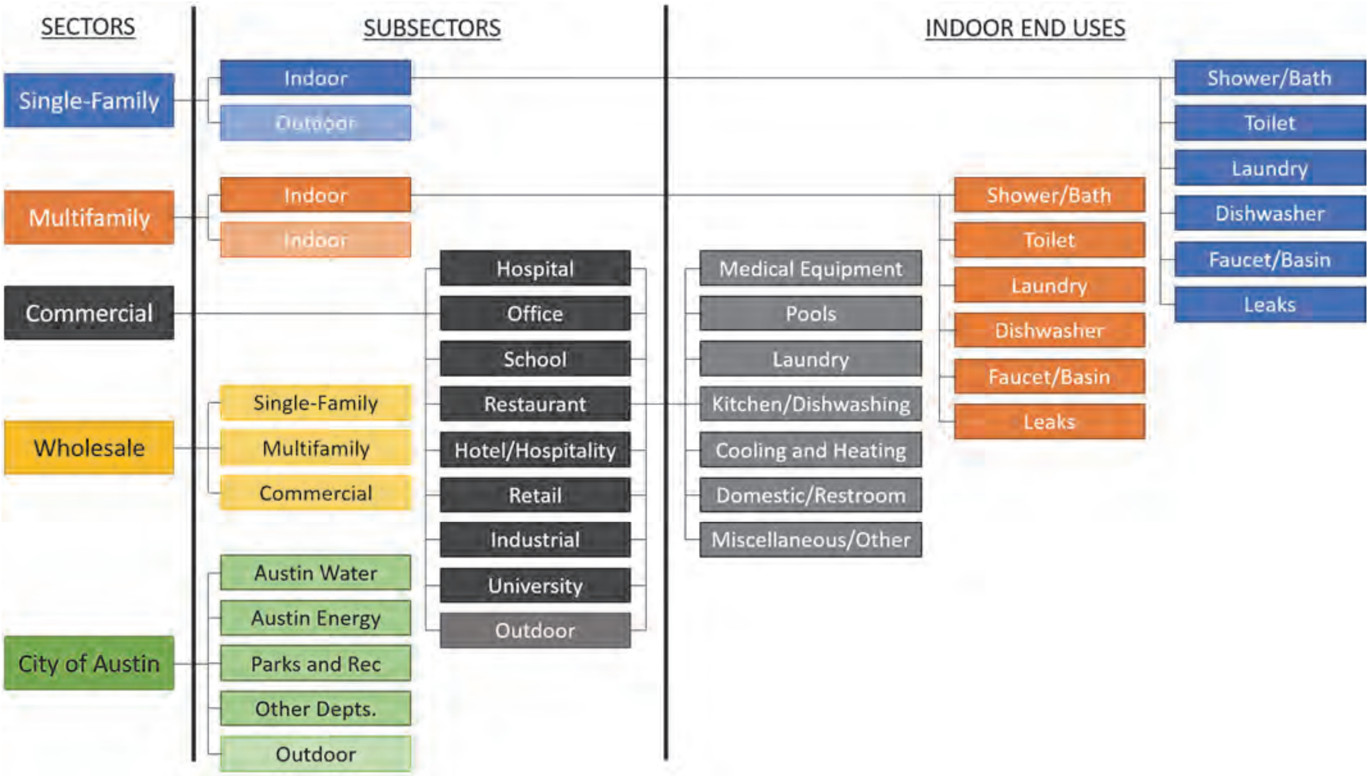


Figure C-1. Disaggregated demand model sectors, subsectors, and end uses

Analysis was conducted using geographic units developed in harmony with Imagine Austin, Austin's comprehensive plan. The geographic units are known as the Delphi, Trends, and Imagine Austin (DTI) polygons and they divide the city into 230 contiguous polygons. The area coverage by the DTI polygons includes the City of Austin's full and limited purpose jurisdictions as well as the city's extra-territorial jurisdiction, as shown in **Figure C-2**. Census blocks within the DTI polygons were used to create a comprehensive 2010 baseline count of the population and number of single-family and multi-family residential units in each polygon. Employment estimates were also generated for each polygon. These baseline and projected demographics are the primary drivers of water use in the city. So, for each DTI polygon, the tool provides an estimate of existing and future water demands by sector, subsector, and end use.

The DDM also produces a number of summary charts, tables, and graphics that support and inform the IWRP. For example, the tool allows for relatively quick assessment of the impact of a demand management measure on overall system, sectoral, or source water demand.

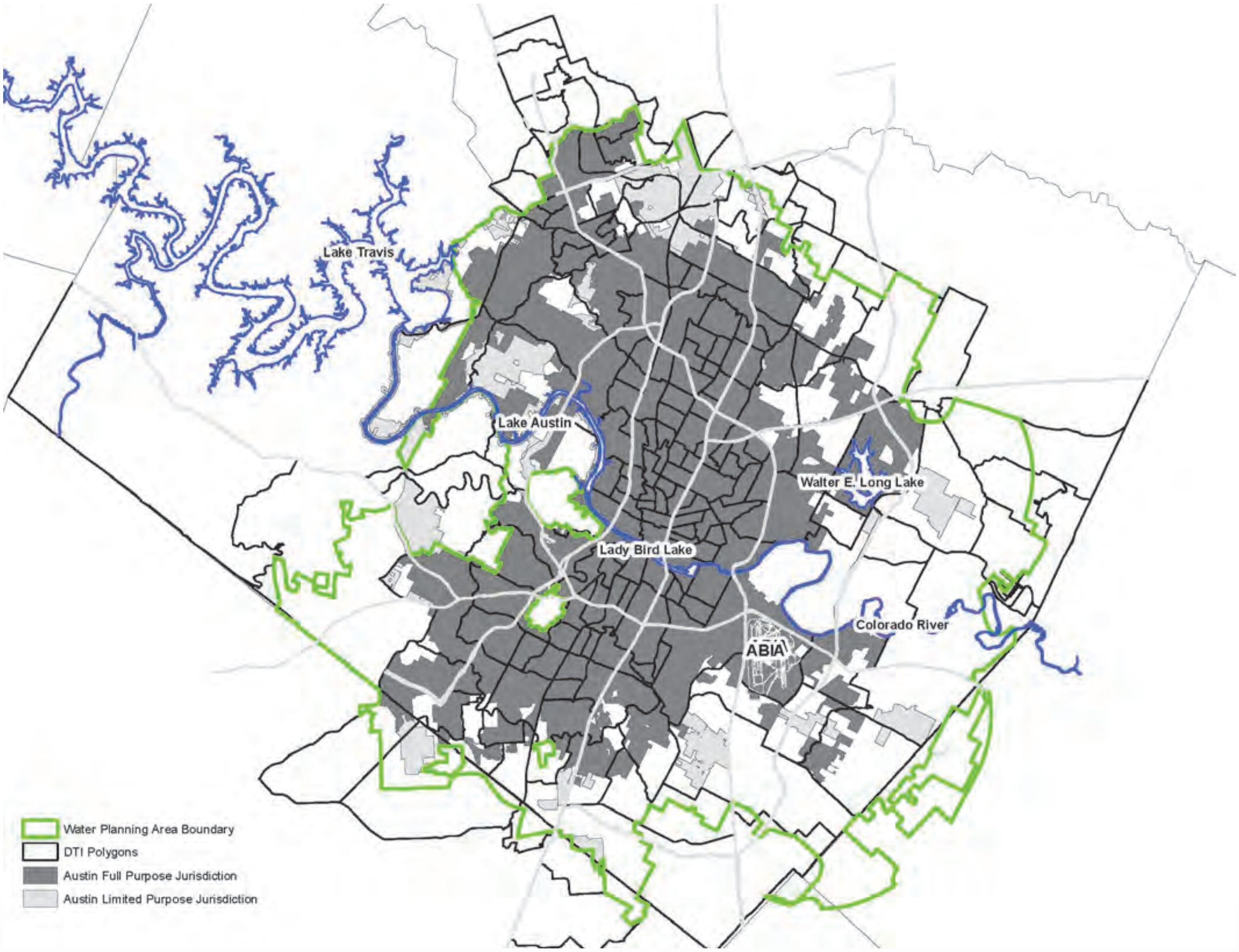


Figure C-2. Disaggregated demand model DTI geographic units

Primary Data Sources

The primary data sources for developing the DDM are described below:

- Delphi – Trend – Imagine Austin (DTI) Polygons - Geographic unit of analysis for Austin Water DDM. The data include long-range, small-polygon-based population and employment forecasts produced by the City Demographer in conjunction with Austin Water. Contains estimates of water service population, single family and multi-family units, and employment for 2010, as well as projections for 2020, 2040, 2070, and 2115.
- SOCRATES Employment Dataset - Standardized Occupational Components for Research and Analysis of Trends in Employment System (SOCRATES). Feature point dataset created by the Texas Workforce Commission featuring a complete listing of employers within Austin as well as pertinent data (minimum and maximum number of employees, North American Industry Classification System code, sales volumes, etc.) for the year 2010.

- Austin Water Billing Accounts and Consumption Data - Historical billing records (in the form of GIS feature point datasets) for every Austin Water customer in 2010 and 2012-2015. Note that 2011 data were excluded due to errors introduced when the city switched billing systems.
- COA Building Permit Data - All approved building permit data provided by the city's Development Services Department in the form of a database (the Application Management and Data Automation database, known as AMANDA) and Shapefiles of permits by year.
- 2010 Land Use GIS polygon.

C.2 Population and Employment Projections

The City of Austin Demographer worked closely with Austin Water staff to develop estimates of retail and wholesale water service population that built off historical 2010-2015 estimates and extended projections through 2115. These estimates are shown in numerical form in **Table C-1** and illustrated in **Figure C-3**.

Table C-1. Long-range population forecast scenario for the Austin Water planning aarea

Year	Austin Water Served Population Forecast – Retail and Wholesale	Annualized Growth Rate
2010	875,936	
2015	977,491	2.2%
2020	1,101,632	2.4%
2025	1,216,291	2.0%
2030	1,342,884	2.0%
2035	1,464,571	1.7%
2040	1,577,760	1.5%
2045	1,692,174	1.4%
2050	1,808,586	1.3%
2055	1,927,901	1.3%
2060	2,051,178	1.2%
2065	2,179,649	1.2%
2070	2,314,769	1.2%
2075	2,458,265	1.2%
2080	2,610,656	1.2%
2085	2,772,495	1.2%
2090	2,944,366	1.2%
2095	3,126,892	1.2%
2100	3,320,732	1.2%
2105	3,526,590	1.2%
2110	3,745,208	1.2%
2115	3,977,380	1.2%

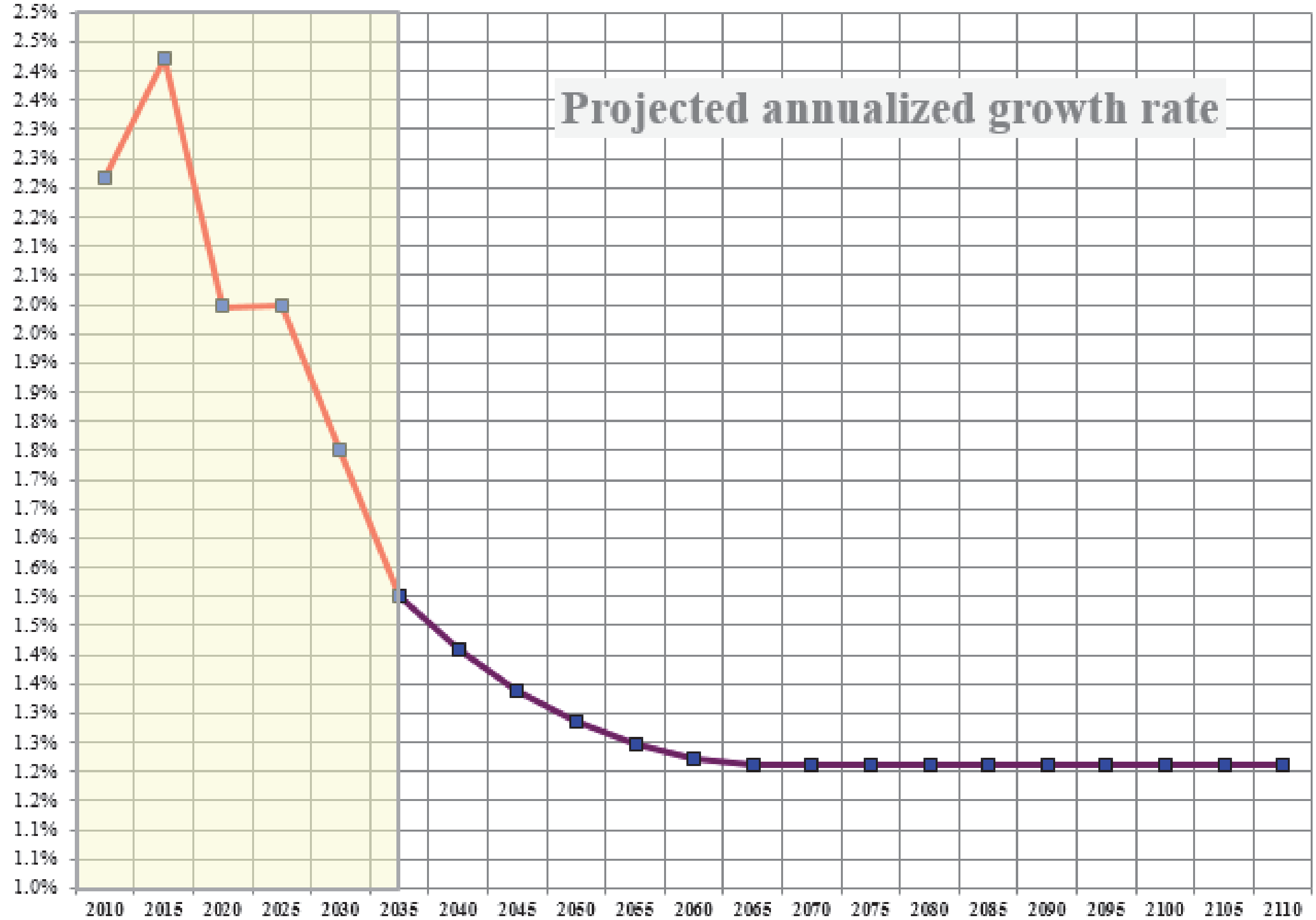


Figure C-3. Long-range population forecast projected annualized growth rate

C.3 Billing Data Preparation

C.3.1 Billing Data Processing

Historical billing data was taken from several sources. The 2010 billing data was collected from the City of Austin's Customer Information System (CIS). The 2012 through 2015 billing data was collected from the City of Austin's Customer Care and Billing (CCB) system. 2011 billing data was excluded from the model due to inconsistencies introduced in the data when the City of Austin switched from the CIS to the CCB system.

Account information from the CIS and CCB billing systems was spatially located to create billing point layers for 2010 and 2012, 2013, 2014, and 2015. Billing point layers are geospatial representation of the locations of water use points that include data on monthly water usage, and water use sector classifications in the form of rate classes. All billing data sets were normalized so that usage amounts corresponded with calendar month usage rather than billing cycle usage. This was accomplished using the daily average of the billing cycle and the number of days in the billing cycle that occurred in each calendar month.

C.3.2 Billing Data Classification

The 2010 billing point layer was overlaid on the City's 2010 land use layer to look for inconsistencies between the billing point rate class and the land use type. Edits were made to both the billing point layer and the land use layer where appropriate so that they matched each other (i.e. single-family accounts on single family land use parcels, commercial accounts on commercial parcels, etc.). If there was no change to land use after 2010 for billing points with corrected rate classes, the rate class correction was automatically assumed to apply to all future years.

For new accounts added post 2010, the new billing points were overlaid on the City's building permit data and given the rate class that corresponded to the type of development indicated by the building permit data. All remaining unmatched new accounts were given the rate class that corresponded with the account information contained in CCB.

For the purpose of the disaggregated demand model, rate classes were assigned to residential accounts to match census housing unit classifications as shown in **Table C-2**.

Table C-2. Disaggregated demand model rate class and development type classifications

Type of Development	DDM Rate Class	Census Unit Classification
Detached single family residences	R - Residential	Single Family Detached
Duplex (shared vertical wall)	D*- Duplex	Single Family Attached
Duplex (shared horizontal wall)	D*- Duplex	2 units per structure
Mobile homes	R - Residential	Mobile Homes
Townhomes/Condos 1 unit in structure	R - Residential	Single Family Attached
Townhomes/Condos 2 units in structure	D*- Duplex	Single Family Attached
Townhomes/Condos 3+ units in structure	M – Multi-family	Single Family Attached
Three to Fourplex	M – Multi-family	Three to Four
5+ Units	M – Multi-family	Five plus

*all dual-family accounts (New Rate Class of D) were included in the multi-family sector in the model

C.4 Demographic Data Preparation

C.4.1 Development of Single Family and Multi-Family Unit Estimates

For 2010 through 2015, each single family residential billing point contained a count of residential units at the location. To develop estimates of multi-family units, the sum of all single-family units was subtracted from the number of occupied units in a DTI polygon as estimated from 2010 decennial Census data. Estimation of 2010 through 2015 total multi-family units by DTI polygon was further validated by a significant research effort that aimed to develop unit counts for all multi-family developments where unit count information could be found.

To create projections, two constraints were used:

- The ratio of single family to multi-family units per DTI polygon as derived from 2010 unit estimates (described in the previous paragraph). Note that the ratio of single family to multi-family units was trended toward a larger share of multi-family in future planning horizons, in keeping with development trends.

- Single family and multi-family household sizes per DTI polygon were scaled from 2012 five-year American Community Survey. Household sizes were scaled to recreate the relationship between 2010 single family and multi-family units (described above) and the estimated 2010 population per DTI polygon. Once calculated for each DTI polygon, the scaled household sizes were held constant through all future planning horizons.

The ratios of single family to multi-family units and the scaled household sizes were used to break down total projected population for each DTI polygon into single family and multi-family units for the years 2020, 2040, 2070, and 2115 by an iterative optimization process to satisfy both constraints.

C.4.2 Commercial Subsector Classification of Employees

The total estimate of employees in 2010 was disaggregated into seven commercial subsectors: Hospitals, Offices, Schools and Universities, Restaurants, Hospitality Services, Retail/Commerce, and Industrial (which includes Large Volume).

Classifications were developed using the SOCRATES dataset, which is a product developed by the Texas Workforce Commission that contains average employment estimates for every employer within the DTI polygons, categorized by industry type using the North American Industry Classification System. These average employment figures were classified into one of seven commercial (COM) subsectors.

Then, employment was trended linearly to create 2115 estimates for each DTI polygon, maintaining the same ratios of each subsector's share of employment, unless discrepancies from the linear trend were observed via billing data (i.e., the emergence of new subsector employment within a DTI).

C.4.3 Wholesale and Large Volume Customer Estimates

Wholesale customers were contacted by Austin Water staff for information pertaining to relative ratios of single family and multi-family populations and employment, where possible. Large Volume customers were also contacted for information regarding potential to expand and plans for facility growth.

C.5 Development of Historical Water Use Factors

Historical water billing data was classified into customer sectors and subsectors, and then sector or subsector annual water usage was aggregated to the DTI polygon level. This annual total was then divided by either the appropriate number of units or employees, depending on the sector or subsector, to develop water use factors (WUFs). For example, single family residential households were analyzed by DTI polygon, and WUFs were estimated by dividing annual water usage within the single-family sector for a DTI polygon by the estimated number of single family housing units within the DTI for each of the years of record (2013-2015).

In this fashion, WUFs were calculated for each customer class of Austin Water: Single Family, Multi-family, Commercial (including commercial subsectors), Wholesale, and City of Austin. Therefore, WUFs are presented as either annual gallons per housing unit (for residential customers) or annual gallons per employee (for nonresidential customers) for each of the years between 2013 and 2015. Reference years of 2013-2015 were chosen due to consistency in billing classifications, as well as the observed variability in climate conditions. The mathematical average WUF for each sector or subsector in each DTI polygon was calculated using these reference years to develop a Base Year WUF used for projections.

In some cases, demographic growth was predicted for DTI polygons with zero historical water usage. For these polygons, future demand projections were calculated by multiplying the expected demographic counts by the median WUF of all DTIs within the same customer sector subsector. For example, future water demand within a DTI polygon with no historical (2013-2015) single family usage but with single family units projected in a planning horizon year was accounted for by multiplying the projected number of single family units by the median base year WUF among all other single-family base year WUFs. This same process was applied for the multi-family and commercial subsectors.

C.6 Development of End Use Data

C.6.1 Indoor and Outdoor Water Use

For the single family residential sector, a minimum month analysis was performed using single family residential billing data aggregated to the DTI polygon level to estimate outdoor water use and determine the ratio of outdoor to indoor water use within each DTI polygon. Monthly water use totals were divided by the number of days in each month to obtain an average daily water use value for each month. The month that contained the lowest average daily water use value was determined to be the "minimum month" and taken as the assumed daily value for indoor water use. This minimum daily water use value was multiplied by 365 (or 366 in 2012) to obtain an estimate for annual indoor use. The estimate for annual indoor use was subtracted from the total annual use to obtain an estimate for annual outdoor use, at the DTI level.

The "outdoor ratio," assumed to be the percent of water use for outdoor and irrigation purposes, was obtained by dividing the estimate for annual outdoor use by total annual use. An outdoor ratio was calculated for each DTI polygon. A city-wide median value for outdoor ratio was calculated using the outdoor ratios developed for each DTI Polygon. In calculating this median value, DTI Polygons with 12 or fewer total units were excluded. The city-wide median was then used as the outdoor ratio for DTI Polygons with 12 or fewer units, which was about 10 DTI polygons per year.

A minimum month analysis was also conducted for Multi-family Residential, Commercial, and City of Austin to estimate indoor and outdoor usage by parcel within each DTI polygon. Parcels with a dedicated irrigation meter were first identified. When a parcel contained a dedicated irrigation meter, other usage within the parcel was assumed to be only indoor and thus was excluded from minimum month calculations of indoor usage. Once parcels with dedicated irrigation meters were identified, a minimum month calculation was conducted for all other parcels. Specifically, the lowest monthly usage for each parcel without a dedicated irrigation meter was identified. This value was multiplied by 12 to get the total annual indoor usage for each parcel. The difference between the total parcel water usage and the calculated indoor usage was identified as annual outdoor usage. Parcels were then aggregated to the DTI polygon level retaining the overall outdoor and indoor usage. This process was conducted for all sectors as data were available.

C.6.2 Indoor End Use Ratios

In the DDM, the user inputs the distribution of indoor water use among specific end uses of water for each sector for the historical years 2013, 2014 and 2015. End use ratios were developed for the Single-family Residential, Multi-family Residential, and Commercial sectors and subsectors, including University and Industrial Large Volume, as described in the following sections.

C.6.2.1 Single-family Residential

Table C-3 shows the distribution of indoor water by end use for the single-family sector as determined by a 2015 Austin Water analysis. For the baseline water use, the most recent distribution for 2015 is assumed.

Table C-3. Distribution of indoor water use for the single-family residential sector

Year	Showers/ Baths	Toilets	Clothes Washers	Dishwashers	Faucets / Basins	Leaks
2010	24.5%	21.7%	19.3%	1.7%	15.8%	17.0%
2012	23.7%	20.7%	18.9%	1.7%	16.4%	18.5%
2013	23.9%	19.9%	18.6%	1.7%	16.9%	19.1%
2014	24.1%	18.9%	18.3%	1.7%	17.4%	19.6%
2015	24.1%	18.4%	17.9%	1.7%	17.8%	20.1%

C.6.2.2 Multi-family Residential

A literature review was conducted to identify relevant estimates of indoor multi-family residential water use by end use. Different studies use different classifications of end uses to represent the total indoor water use. Note that some studies provide estimates for some indoor end uses, but do not provide sufficient information to permit a total allocation (100%) of all indoor uses. For example, some studies simply estimate the toilet, shower and clothes washer usage in gallons per day without reference to the total indoor water use. These data limitations make the calculation of these uses as percentages of total indoor use more difficult.

Three studies were identified in which multi-family residential indoor water use is adequately identified to calculate the percent of water use by end use. These studies are:

- Los Angeles Department of Water and Power (LADWP) Conservation Potential Study 2016 by CDM Smith – multi-family water use parameters for the LADWP end use model were derived from surveys of multi-family property managers and owners
- Embedded Energy in Water Studies Study 3: End-use Water Demand Profiles by Aquacraft, 2011
- University of Arizona Water Resources Research Center (WRRC), City of Tucson Water Use 2007

The distribution of multi-family residential indoor water use from each of these studies is summarized in **Table C-4**. The data are averaged according to the six DDM multi-family residential indoor end use categories.

Table C-4. Distribution of indoor water use for the multi-family residential sector

End Use	LADWP	Tucson	Aquacraft	Average
Toilet	13.8%	23.0%	35%	23.9%
Shower	17.8%	16.2%	23%	
Bath	1.7%		2%	
Shower/Bath	19.6%	16.2%	25%	20.3%
Faucet	20.7%	17.6%	24%	20.8%
Dishwasher	1.0%	1.4%	1%	1.1%
Washing Machine	12.2%			
Central Laundry Facility	8.9%			
Laundry	21.1%	14.9%	5%	13.7%
Water Quality System	4.1%			
Cooling/Condensing	1.6%			

End Use	LADWP	Tucson	Aquacraft	Average
Leaks			9.5%	
Other Indoor	18.2%		0.5%	
Other/Leaks	23.9%	26.9%	10%	20.3%
Total	100%	100%	100%	100%

C.6.2.3 Commercial Sector

End uses for the Commercial sector include:

- Medical Equipment (MEQ)
- Pools (POL)
- Laundry (LND)
- Kitchen (KCH)
- Heating and Cooling (HVC)
- Domestic (DOM) (bathroom uses)
- Miscellaneous (MSC)

A literature review was conducted to identify relevant estimates of indoor water use by end use among the seven Commercial subsectors for the end uses in the DDM. Four studies were identified in which Commercial, Institutional, and Industrial indoor water use is adequately identified by sector and end use to calculate the percent of water use by end use as required for the model. These studies are:

- Los Angeles Department of Water and Power (LADWP) Conservation Potential Study 2016 by CDM Smith – CII sector water use parameters for the LADWP end use model were derived from an extensive literature review of CII end use studies.
- Gleick, P. A. (2003), Waste Not, Want Not: The Potential for Urban Water Conservation in California.
- EPA. (2016) EPA WaterSense - Commercial Buildings.
- Water Research Foundation (WRF, formerly the AWWARF) 2000, Commercial and Institutional End Uses of Water.

As with the multi-family residential findings, the distribution of indoor water use by end uses were aligned and averaged across reports for end use classifications specified in the DDM. Not all reports had data for all seven Commercial subsectors. In particular, data were limited for the Retail and Industrial subsector as Hospitals, Offices, Schools, Restaurants and Hotels have been the primary focus of CII studies. These percentages are shown in **Table C-5** and summarized in **Table C-6**. As with the multi-family residential sector, the average value is assumed for the current water usage in the forecast.

For the Hospital subsector, the literature review provides a distribution of end uses for traditional hospitals. However, the Austin Water customer billing classification of Hospitals includes medical and dental offices. Therefore, the end use distribution for the Hospital sector is adjusted to reflect proportionally more domestic (restroom) use and less kitchen and laundry uses for this sector.

For the Retail subsector, studies of end use provide a distribution of end uses for establishments with kitchen/deli services and HVAC systems (e.g., grocery stores) and establishments where the water use is primarily restroom usage (e.g., gas stations). For this analysis, it is assumed that the AW Retail customer subsector is about half represented by establishments with kitchen/deli and HVAC, and about half represented by establishments with mostly domestic use. For the Industrial subsector, process water is listed under the Miscellaneous end use.

Table C-5. Indoor water use distribution studies for select commercial sectors

Offices	LADWP	Gleick	EPA	WRF	Average	
Domestic	38.2%	41.9%	47.4%	46.9%	43.5%	
Kitchen	1.2%	4.8%	16.7%	0.0%	5.8%	
Laundry	0.0%	0.0%	0.0%	0.0%	0.0%	
Medical Equipment	0.0%	0.0%	0.0%	0.0%	0.0%	
HVAC	30.8%	37.1%	35.9%	41.5%	36.3%	
Miscellaneous	29.8%	16.1%	0.0%	11.5%	14.4%	
Restaurants	**LADWP**	**Gleick**	**EPA**	**WRF**	**Average**	
Domestic	49.0%	36.2%	32.3%	32.2%	37.4%	
Kitchen	38.7%	48.9%	54.2%	50.9%	48.2%	
Laundry	0.0%	0.0%	0.0%	0.0%	0.0%	
Medical Equipment	0.0%	0.0%	0.0%	0.0%	0.0%	
HVAC	0.0%	2.1%	1.0%	1.9%	1.3%	
Miscellaneous	12.3%	12.8%	12.5%	15.0%	13.1%	
Schools	**LADWP**	**Gleick**	**EPA**	**WRF**	**Average**	
Domestic	60.5%	71.4%	63.4%	68.7%	66.0%	
Kitchen	5.8%	7.1%	9.9%	8.9%	7.9%	
Laundry	0.5%	0.0%	4.2%	3.5%	2.0%	
Medical Equipment	0.0%	0.0%	0.0%	0.0%	0.0%	
HVAC	12.5%	0.0%	15.5%	7.0%	8.7%	
Miscellaneous	20.8%	21.4%	7.0%	11.9%	15.3%	
Hospitals	**LADWP**	**Gleick**	**EPA**	**WRF**	**Average**	**Hospitals & Medical Offices, adjustment**
Domestic	22.3%	29.8%	37.6%	29.7%	29.8%	35%
Kitchen	4.2%	9.5%	7.5%	6.6%	7.0%	5%
Laundry	0.3%	2.4%	9.7%	6.5%	4.7%	3%
Medical Equipment	4.8%	26.2%	16.1%	6.6%	13.4%	13%
HVAC	50.3%	32.1%	21.5%	33.8%	34.4%	34%
Miscellaneous	18.1%	0.0%	7.5%	16.9%	10.6%	10%
Hotels	**LADWP**	**Gleick**	**EPA**	**WRF**	**Average**	
Domestic	42.9%	56.7%	35.7%	30.0%	41.3%	
Kitchen	14.8%	11.1%	16.7%	16.6%	14.8%	
Laundry	11.1%	15.6%	19.0%	15.1%	15.2%	

Offices	LADWP	Gleick	EPA	WRF	Average
Medical Equipment	0.0%	0.0%	0.0%	0.0%	0.0%
HVAC	10.7%	11.1%	14.3%	9.5%	11.4%
Miscellaneous	20.5%	5.6%	14.3%	28.7%	17.2%
Retail	**LADWP Grocery Stores**		**LADWP Gas Stations**		**Average**
Domestic	18.2%		86.0%		52.1%
Kitchen	15.4%		2.9%		9.2%
Laundry	0.0%		0.0%		0.0%
Medical Equipment	0.0%		0.0%		0.0%
HVAC	46.4%		0.0%		23.2%
Miscellaneous	20.0%		11.1%		15.5%
Industrial	**LADWP**				**Average**
Domestic	10.5%				10.5%
Kitchen	0.0%				0.0%
Laundry	0.0%				0.0%
Medical Equipment	0.0%				0.0%
HVAC	48.0%				48.0%
Miscellaneous	41.5%				41.5%

Table C-6. Distribution of indoor water use for commercial subsectors

	MEQ	POL	LND	KCH	HVC	DOM	MISC
Hospitals	13.0%	0.0%	3.0%	5.0%	34.0%	35.0%	10.0%
Offices	0.0%	0.0%	0.0%	5.8%	36.3%	43.5%	14.4%
Schools	0.0%	0.0%	2.0%	7.9%	8.7%	66.0%	15.3%
Restaurants	0.0%	0.0%	0.0%	48.2%	1.3%	37.4%	13.1%
Hotels	0.0%	0.1%	15.2%	14.8%	11.4%	41.3%	17.2%
Retail	0.0%	0.0%	0.0%	9.2%	23.2%	52.1%	15.5%
Industrial	0.0%	0.0%	0.0%	0.0%	48.0%	10.5%	41.5%

C.6.2.4 Universities

End use ratios for universities in the DDM were based on an analysis of water use among campus facilities at the University of North Carolina – Chapel Hill that was performed for the Orange Water and Sewer Authority (OWASA) which serves the UNC campus. The UNC study included multiple research and laboratory facilities, a large hospital complex, and a state-of-the-art centralized steam/cooling facility in addition to the traditional campus classrooms, offices, and dormitories. There is a subcategory of 'Other' which includes facilities such as the student center, rec center, stadium, basketball arena, theaters, etc.

The data used in this analysis is from 1991 to 1998. However, it is the only detailed end use analysis of a university campus found by the study team. At the time of the study, UNC was very progressive in terms of implementing water conservation on campus and it was assumed that subsequent improvements in water use efficiency would likely have progressed equally among the various campus facilities.

Table C-7 displays an aggregated percent of water use for each of the university subsectors into the seven end use categories of the AW model. These percentages are weighted across the seven UNC subsectors based on the average annual water use of each subsector. The resulting recommended end use distribution is highlighted in bold in the row called "weighted %".

Large volume industrial end-uses were estimated based upon correspondence with facility operators from AW's current large volume customers. The end-uses employed were similar to those found in the Industrial subsector, with different assumptions regarding the distribution of end-use shares.

Table C-7. Distribution of Indoor Water Use for Universities (From end use study at UNC-Chapel Hill, '91-98)

	MEQ	POL	LND	KCH	HVC	DOM	MISC	Average MGD	% Total Volume
Classroom/Faculty	0%	0%	0%	0%	0%	78%	22%	0.07	3.3%
Laboratory/Research	0%	0%	0%	0%	0%	45%	55%	0.38	18.1%
Offices/Administration	0%	0%	0%	0%	0%	58%	42%	0.03	1.6%
Student Housing	0%	0%	12%	11%	0%	63%	14%	0.31	14.6%
Hospital/Patient Care	10%	0%	11%	5%	0%	30%	44%	0.24	11.3%
Other (Theaters, Stadium, Student Center)	0%	3%	29%	1%	0%	53%	14%	0.22	10.0%
Utilities (Centralized Facility)	0%	0%	0%	0%	99%	0%	1%	0.87	41.1%
Weighted %	**1.1%**	**0.3%**	**5.9%**	**2.3%**	**40.6%**	**29.5%**	**20.3%**		

C.7 Water Use Projection Methodology

C.7.1 Passive Conservation

Changes to plumbing and/or housing code that would impact future water use were analyzed per sector and used to develop percentage reductions in total (indoor + outdoor) water demand. These passive reductions in water use were then applied to each of the four planning horizon years (2020, 2040, 2070, and 2115) as a percent reduction in the WUF for the year of interest.

Below are the two best management practice options that were modeled in the DDM as passive conservation:

- Require or incentivize government-recognized energy and water efficiency-labeled residential and commercial fixtures (included in baseline assumptions in portfolios).
- Incentivize or require toilet, urinal, and bathroom faucet aerator efficiencies (included in baseline assumptions in portfolios).

C.7.2 Consumption, Pumpage, and Diversions

Water demand was projected as the mathematical product of the sector/subsector base year WUF and demographic count for each DTI for each planning horizon year. End use level projection estimates were developed by multiplying the base year WUF by the appropriate end use ratios for each sector and subsector. Projected demand for all DTI polygons were then aggregated so that city-wide total consumption for each customer sector/subsector could be calculated in each planning horizon year. In this fashion, total consumption by sector/subsector and city-wide was calculated and tallied for each planning year of interest.

Consumption estimates were then added to estimates of non-revenue water losses to determine a city-wide pumpage estimate. Non-revenue water losses were related to historical distribution system attributes (length of distribution mains, number of connections, etc.) for the study period, and projected into the future based on anticipated distribution system attributes based on population and density projections. Finally, city-wide pumpage was also multiplied by a loss factor representing the historical difference between water diversions from the Colorado River and water pumped from city-owned water treatment plants (caused by water used in the water treatment process train). Therefore, a final estimate of water diversions from the Colorado River could be estimated for each planning horizon year.

C.8 Baseline Model Results

The baseline projections found within the DDM results summary represent the trended water use based upon water use patterns occurring between 2013-2015 in each DTI polygon and customer sector/subsector. These baseline projections include historical conservation efforts and projected savings from passive conservation, but do not reflect additional savings from recommended Water Forward options. Therefore, they do not attempt to predict actual water consumption, as total water consumption will likely differ as the Austin community implements additional conservation and reuse strategies. The baseline results of the DDM are meant to be a starting place to assess the various demand management and supply strategies considered in the Water Forward planning process. **Figures C-4** to **C-9** illustrate the baseline results of the DDM.

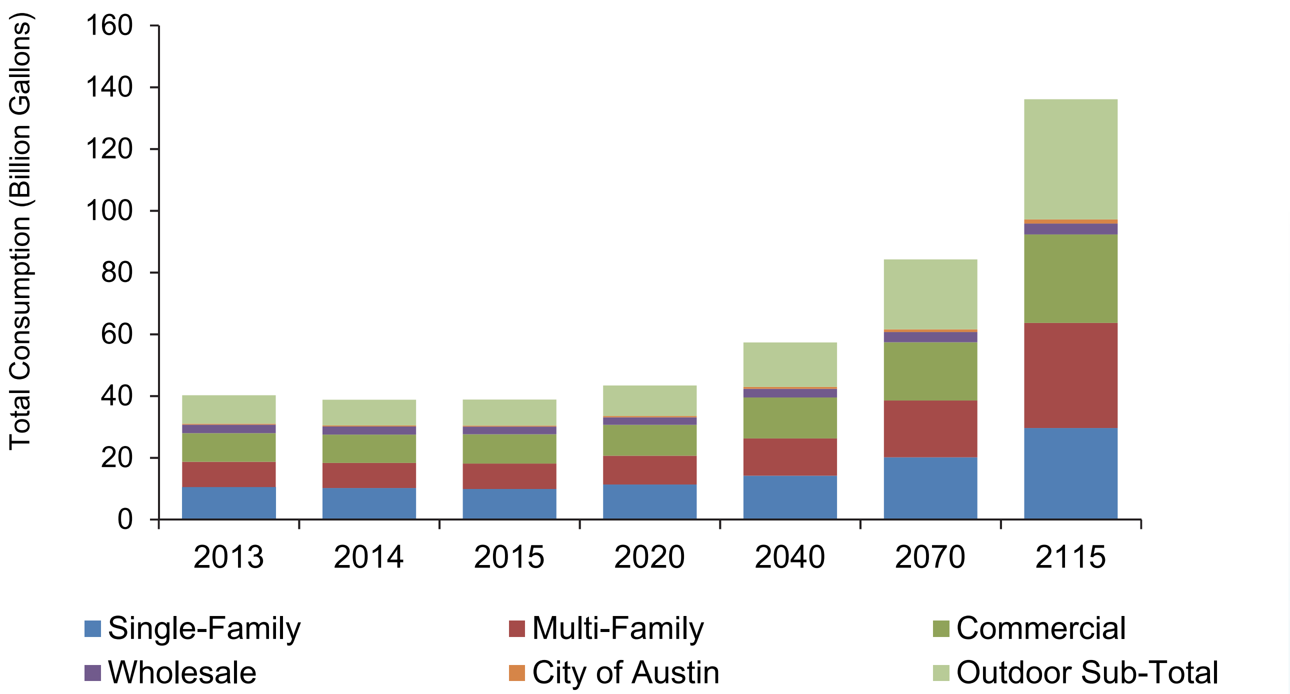


Figure C-4. Citywide baseline demand forecast

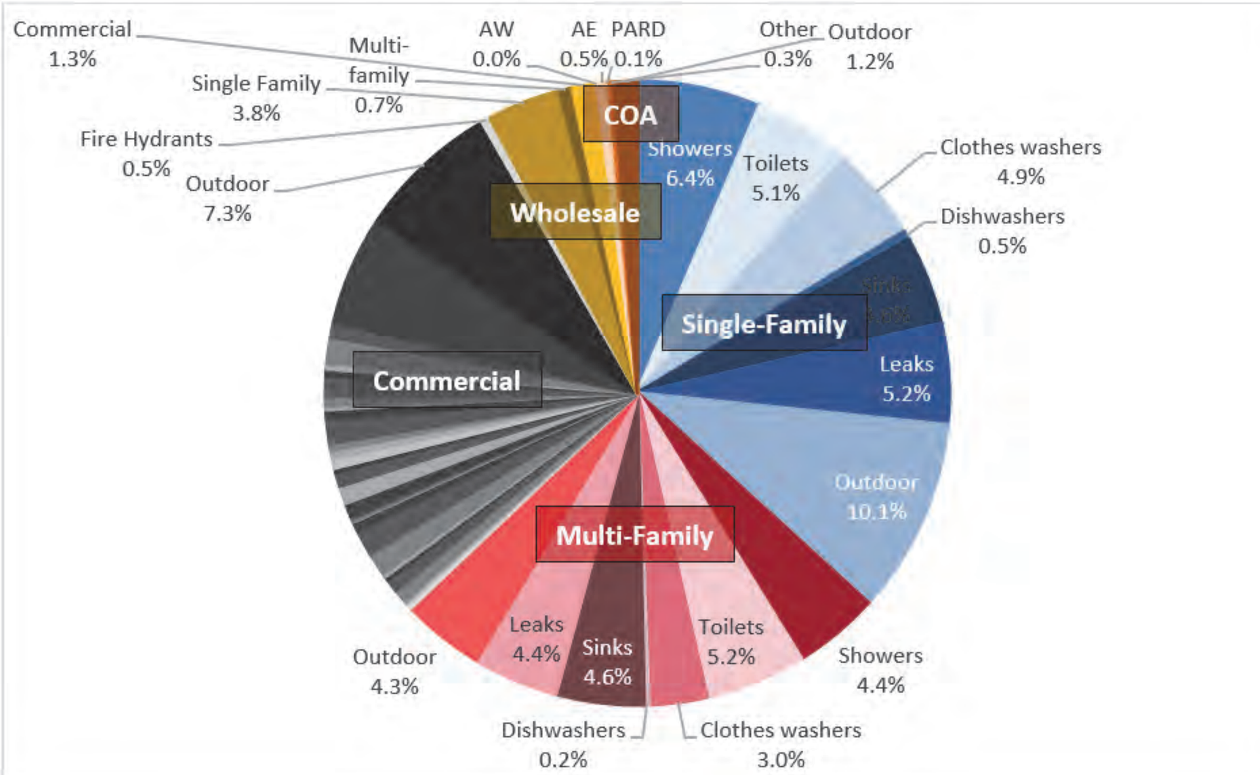


Figure C-5. Baseline 2020 demands

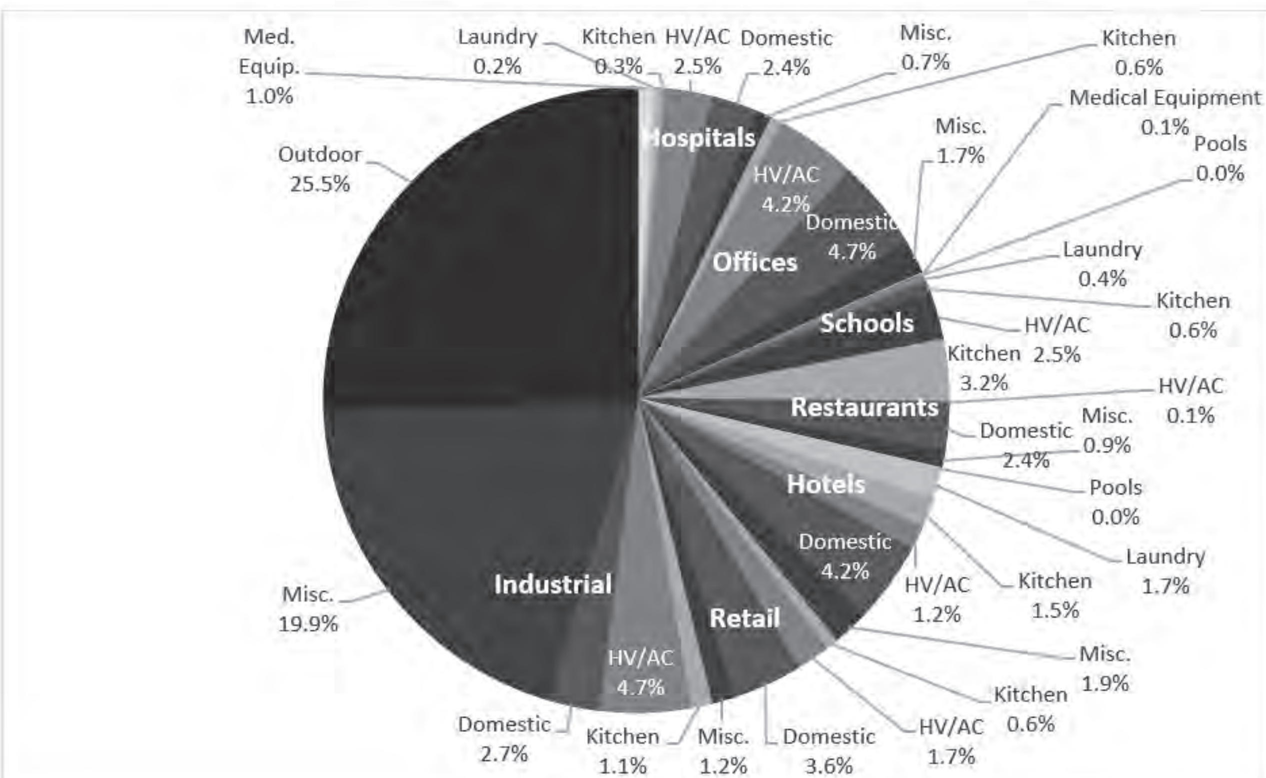


Figure C-6. Baseline 2020 commercial subsector demands

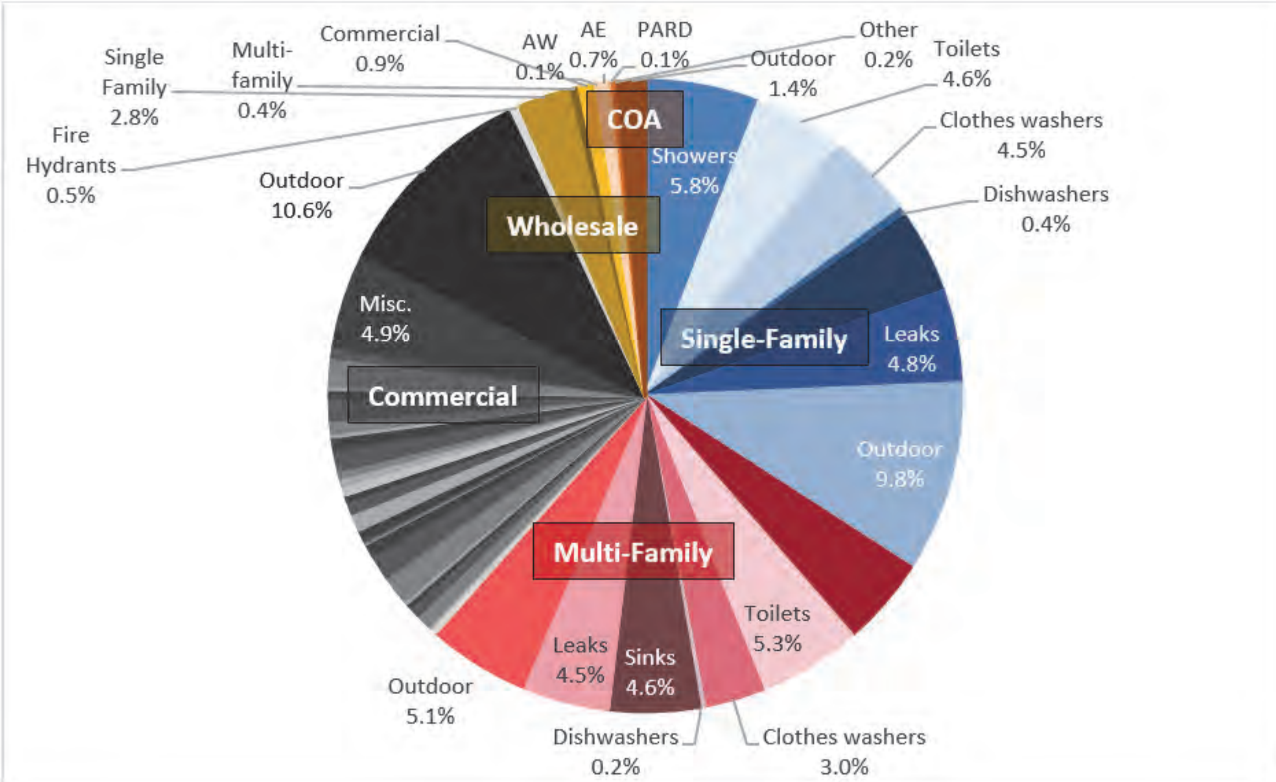


Figure C-7. Baseline 2115 demands

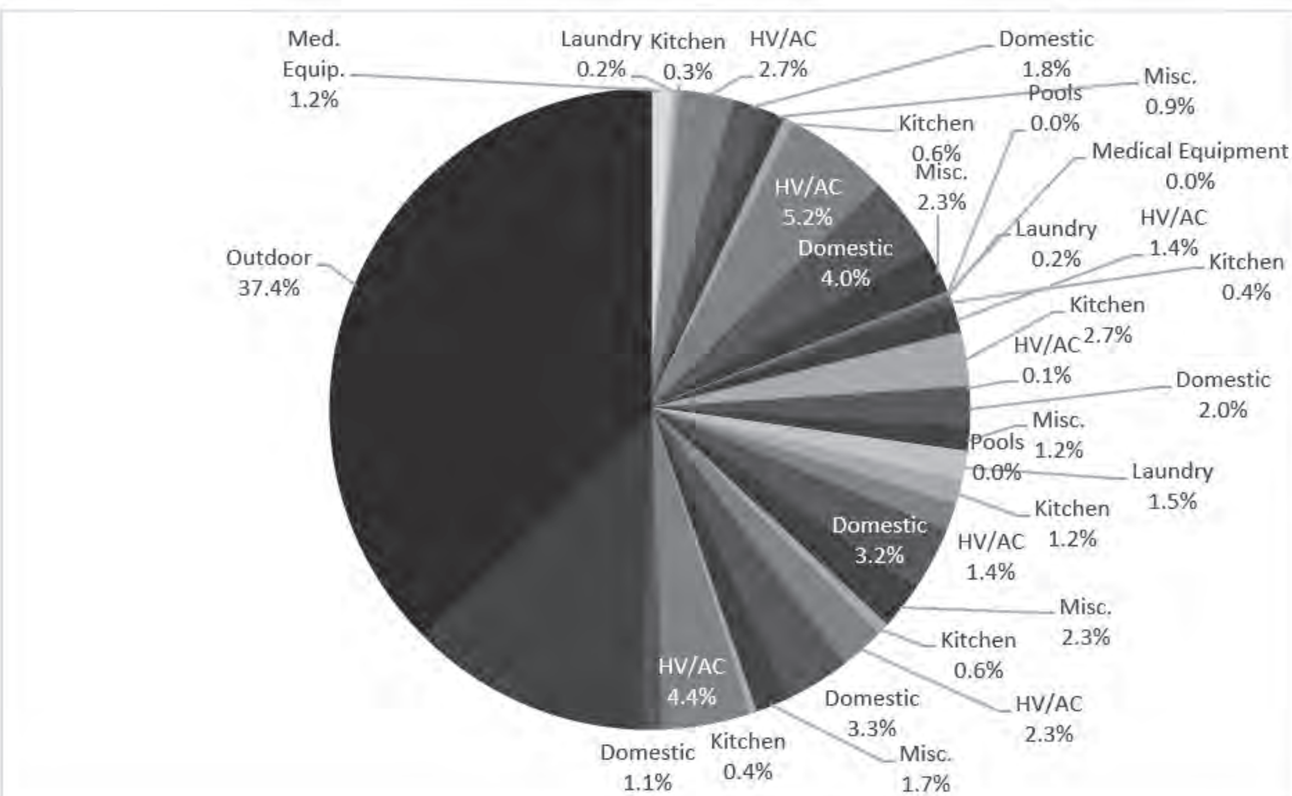
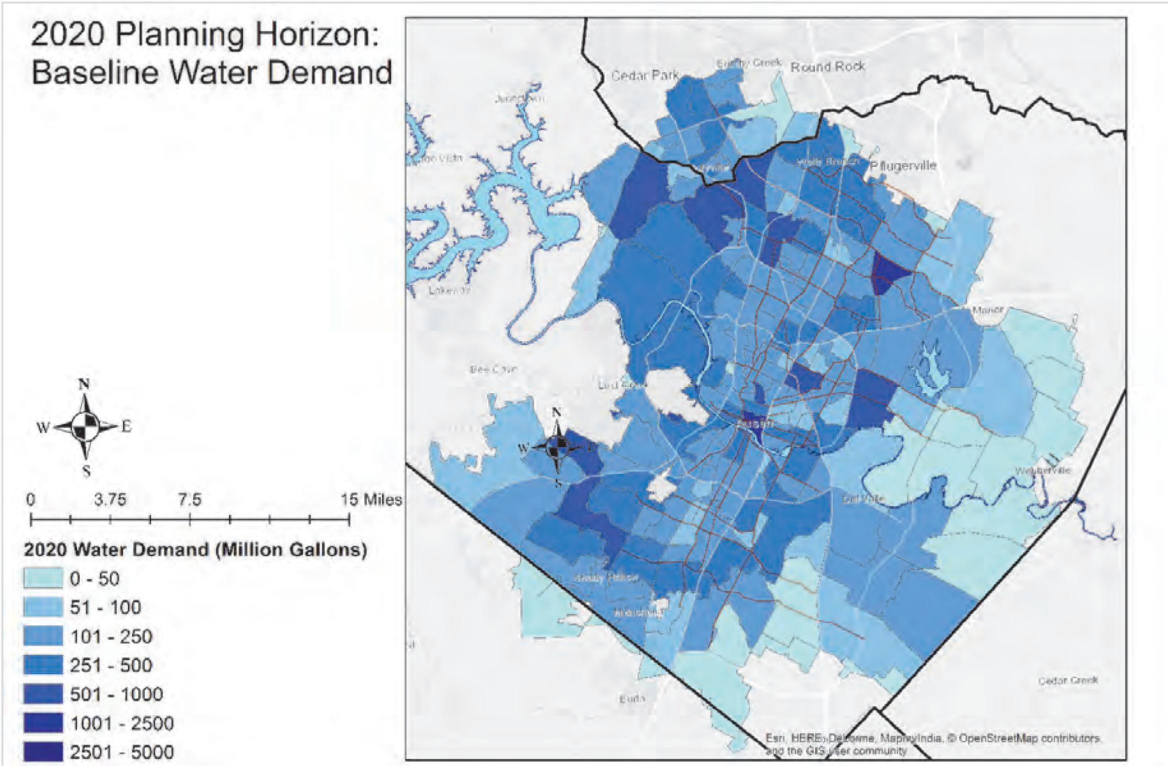


Figure C-8. Baseline commercial subsector demands



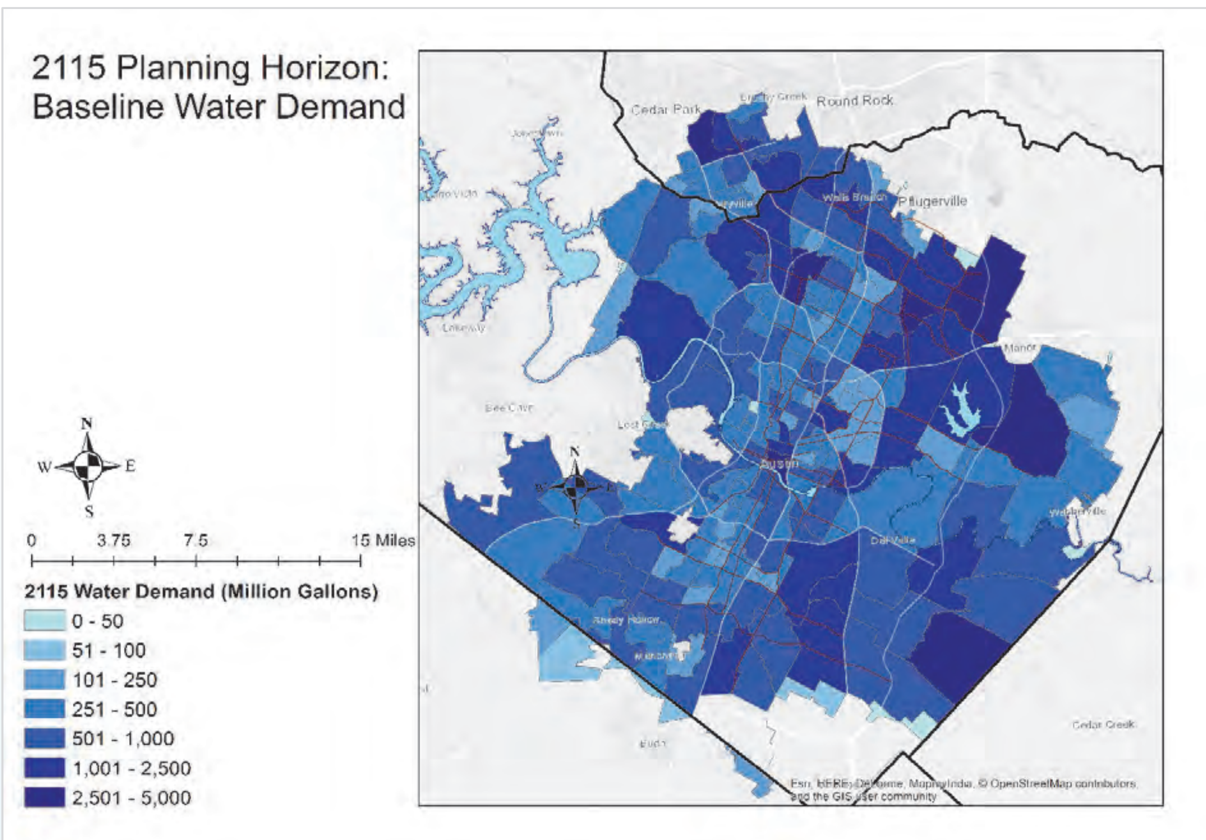


Figure C-9. Map of DTIs by DDM water demand in 2020 and 2115

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APPENDIX D: CLIMATE CHANGE AND HYDROLOGY ANALYSIS

Rising temperatures, increased evaporation rates, and an acceleration of the hydrological cycle is increasing the intensity of heavy precipitation and the duration and severity of droughts in many places around the world (IPCC, 2012). These and other changes that have been attributed to human-induced climate change are projected to continue over the remainder of this century and beyond.

In the United States, both flooding and short-term droughts are expected to intensify in the future (Georgakakos et al., 2014), raising concerns regarding their impacts on water supply for cities such as Austin, Texas that are located in drought-prone regions. The southern Great Plains are expected to see longer dry spells and more intense long-term droughts, even in areas where average precipitation is not expected to change significantly (Walsh et al., 2014). These impacts are expected to affect water supply and demand, leading the Third US National Climate Assessment (NCA3) to conclude that, “in most U.S. regions, water resources managers and planners will encounter new risks, vulnerabilities, and opportunities that may not be properly managed within existing practices” (Georgakakos et al., 2014).

Across Texas, average temperatures are increasing, the risks of extreme temperatures are changing, and precipitation patterns are shifting, with heavy precipitation becoming more frequent in many locations. As climate changes, the past can no longer serve as a reliable guide to the future. Instead, climate projections are needed to assess the potential impacts of human-induced change on our communities and our natural resources. This appendix documents the development, evaluation, and application of a new approach to generating streamflow projections for individual river gauges under future climate conditions for Austin’s Integrated Water Resource Plan. This appendix describes the methodology and summarizes the results of an analysis of the potential impacts of climate change on Austin’s future water supply that combines observations and existing models and methods with the development of new statistical models and analysis techniques.

D.1 Study Area and Data Overview

D.1.1 Study Area

Long-term daily streamflow data for 43 gauges in the Colorado River Basin study area was obtained from the United States Geological Survey (USGS) website. Gauge locations relative to the study region are shown in **Figure D-1**. The gauge locations represent a wide range of watershed scales with upstream contributing drainage areas of approximately 120 to nearly 31,000 square miles.

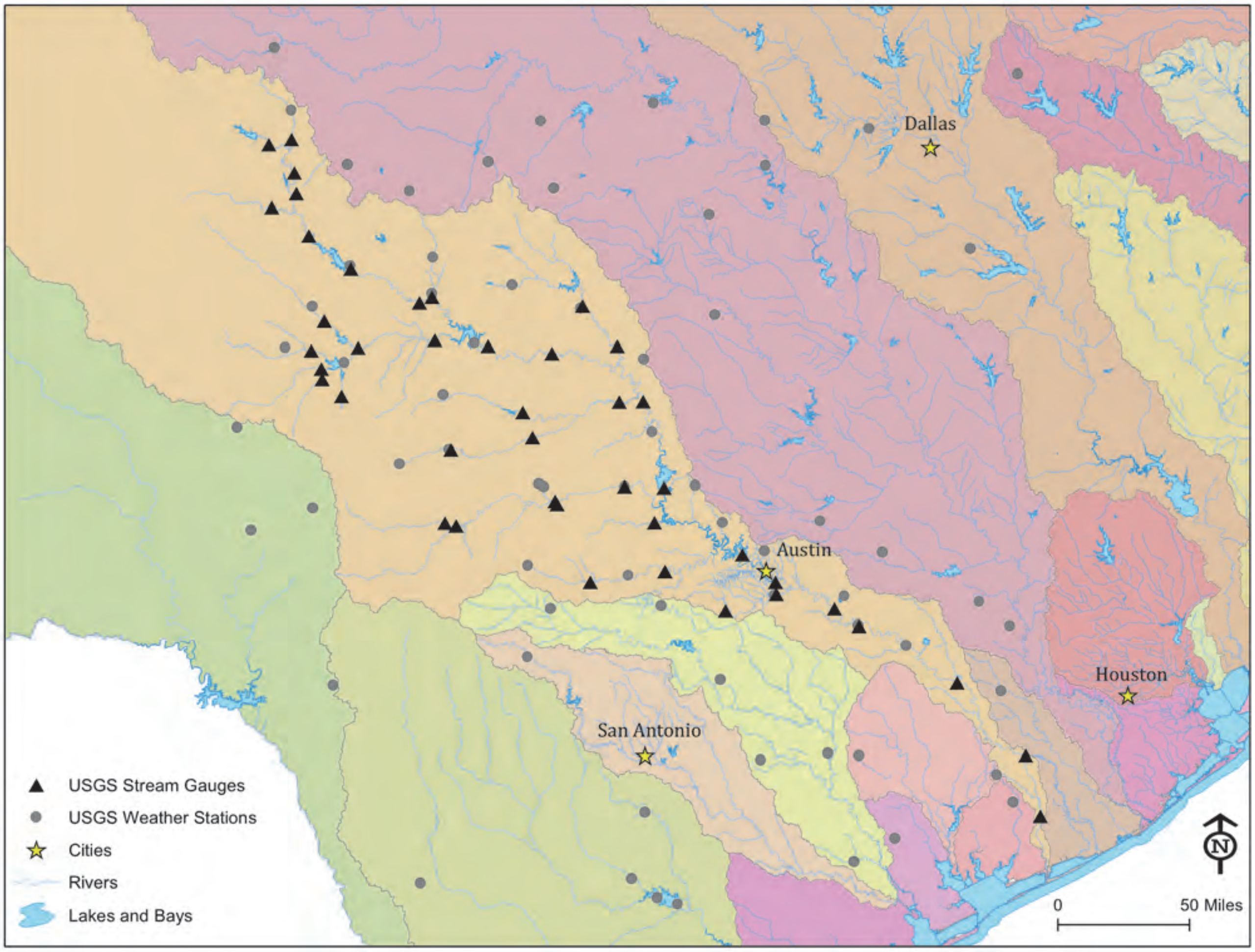

Figure D-1. Locations of streamflow gauges (black triangles) and weather stations (gray circles) used in this analysis.

Gauge names, identification numbers, and locations presented in the figure are listed in **Table D-1**. Water availability model (WAM) properties such as control point ID, drainage area, and closest weather station are also presented in the table.

Table D-1. WAM primary control point identification numbers, drainage area, USGS identification numbers, locations, latitude and longitude of the gauges used, and corresponding weather stations.

WAM CP ID	WAM Drainage Area (mi^2)	USGS ID	Gauge Name	Lat	Lon	Weather Station
A30000	1,074	08119500	Colorado River at Hwy 350 near Ira	-101.054	32.538	USC00418433
A20000	193	08120500	Deep Creek near Dunn	-100.908	32.574	USC00418433
A10000	1,575	08121000	Colorado River at Colorado City	-100.879	32.393	USC00418433
B40000	176	08123600	Champion Creek Reservoir	-100.858	32.281	USC00418433
B30000	1,974	08123800	Beals Creek near Westbrook	-101.014	32.199	USC00418433
B20000	4,559	08123850	Colorado River above Silver	-100.762	32.054	USC00418433
B10000	5,046	08124000	Colorado River at Robert Lee	-100.481	31.885	USC00417743
D40000	6,090	08126380	Colorado River near Ballinger	-100.026	31.715	USC00417743
D30000	464	08127000	Elm Creek at Ballinger	-99.948	31.749	USC00410493

WAM CP ID	WAM Drainage Area (mi²)	USGS ID	Gauge Name	Lat	Lon	Weather Station
C30000	258	08128000	South Concho River at Chrisoval	-100.502	31.187	USC00418449
C60000	1,613	08128400	Middle Concho River above Tankersley	-100.711	31.427	USC00418449
C50000	340	08129300	Spring Creek above Tankersley	-100.640	31.330	USC00418449
C40000	164	08130500	Dove Creek at Knickerbocker	-100.631	31.274	USC00418449
C70000	1,202	08134000	North Concho River near Carlsbad	-100.637	31.593	USC00410493
C20000	4,139	08136000	Concho River at San Angelo	-100.411	31.455	USC00410493
C10000	5,185	08136500	Concho River at Paint Rock	-99.920	31.516	USC00410493
D20000	12,548	08136700	Colorado River near Stacy	-99.574	31.494	USC00412741
D10000	13,788	08138000	Colorado River at Winchell	-99.162	31.468	USC00411875
F30000	1,654	08143500	Pecan Bayou at Brownwood	-98.974	31.732	USC00411875
F20000	2,074	08143600	Pecan Bayou near Mullin	-98.741	31.517	USC00411138
E40000	1,137	08144500	San Saba River at Menard	-99.786	30.919	USC00415650
E30000	1,636	08144600	San Saba River near Brady	-99.269	31.004	USC00415650
E20000	589	08145000	Brady Creek at Brady	-99.335	31.138	USC00415650
E10000	3,048	08146000	San Saba River at San Saba	-98.719	31.213	USC00411138
F10000	19,830	08147000	Colorado River near San Saba	-98.564	31.218	USC00411875
G50000	897	08148500	North Llano River near Junction	-99.806	30.517	USC00418449
G40000	1,859	08150000	Llano River near Junction	-99.735	30.504	USC00418449
G30000	3,251	08150700	Llano River near Mason	-99.109	30.661	USC00415650
G20000	215	08150800	Beaver Creek near Mason	-99.096	30.644	USC00415650
G10000	4,201	08151500	Llano River at Llano	-98.670	30.751	USC00415650
I40000	20,521	08148000	Lake Buchanan near Burnet	-98.418	30.751	USC00411250
I30000	346	08152000	Sandy Creek near Kingsland	-98.472	30.558	USC00411250
H20000	370	08152900	Pedernales River near Fredericksburg	-98.870	30.220	USC00414782
H10000	901	08153500	Pedernales River near Johnson City	-98.399	30.292	USC00410832
I20000	27,357	08154500	Lake Travis near Austin	-97.907	30.392	USC00411250
I10000	27,611	08158000	Colorado River at Austin	-97.694	30.245	USC00418415
J50000	124	08158700	Onion Creek near Driftwood	-98.008	30.083	USC00415193
J40000	324	08159000	Onion Creek at US Hwy 183, Austin	-97.689	30.178	USC00418415
J30000	28,580	08159200	Colorado River at Bastrop	-97.319	30.105	USC00415193
J20000	29,062	08159500	Colorado River at Smithville	-97.162	30.013	USC00418415
J10000	30,244	08161000	Colorado River at Columbus	-96.537	29.706	USC00418415
K20000	30,601	08162000	Colorado River at Wharton	-96.104	29.309	USC00411048
K10000	30,862	08162500	Colorado River near Bay City	-96.012	28.974	USC00411048

D.1.2 Data Overview

Given the long time horizon of the data, the high population density of the region, and the abundance of reservoirs throughout these watersheds, it is clear that these flows have been modified through the years via impoundment, withdrawals, and other human activities. For that reason, daily streamflow data were developed to replicate naturalized streamflow on a monthly volumetric basis. A naturalized streamflow dataset is maintained by the Texas Commission on Environmental Quality as a part of the statewide Water Availability Modeling System. Naturailzed streamflow is derived from adjustments to gauged streamflow to reverse all human activities that are represented in the WAM simulation, such as diversion from the river. WAM naturalized streamflow is an estimate of the flow which would have occurred each month in the absence of diversions, discharges, or storage reservoirs for water supply and flood control purposes.

Sythnetic daily naturalized discharge data were calculated directly from the monthly naturalized streamflow time series at each WAM primary control point using a linear spline that was fit to match the variation in monthly flows (Wurbs and Hoffpauir, 2015). The area under the linear spline was divided by the number of days per month to produce daily naturalized flows. The method of calculating daily naturalized flows using a linear spline is included as an algorithm within the daily simulation model of the Water Rights Analysis Package (WRAP). WRAP is the modeling software within the TCEQ WAM System (Wurbs, 2005).

Weather stations reflecting characteristics of daily maximum and minimum temperature and 24-hour cumulative precipitation encompassing the time period of the gauge data from 1950 to 2015 were identified for each gauge. The identification numbers of the stations and their geographic locations are listed in **Table D-1** and shown on the map in **Figure D-1**. Observations for each station were obtained from the National Climatic Data Center Cooperative Observer Network Summary of the Day, and then quality-controlled for anomalous data points. Data points were removed if nighttime minimum temperature was greater than daily maximum temperature, values were greater or less than state-wide daily records, non-zero identical values to within a tenth of a degree Celsius or a millimeter were repeated over five or more consecutive days, or outliers were not validated by neighboring stations.

Next, a set of more than 120 secondary climate indicators to be used as predictors in the correlation analysis was dervied as described in Gelca et al. (2015). These indicators represent a broad range of permutations of temperature and precipitation over time scales ranging from 1 day to 2 years. Quantifying both long-term averages as well as the frequency of extreme conditions, the indicators are intended to capture changes in mean and extreme temperature and precipitation of relevance to water availability. Some examples of the indicators used are one-week average precipitation, number of dry days in the previous two weeks, or the three-month average temperature.

D.2 Future Climate Uncertainty

Future climate projections are uncertain for four main reasons:

1. **Natural variability**, which causes temperature, precipitation, and other aspects of climate to vary from year to year and even decade to decade;

2. **Scientific uncertainty**, as it is still uncertain exactly how much the Earth will warm in response to human emissions and global climate models cannot perfectly represent every aspect of Earth's climate;

3. **Scenario or human uncertainty**, as future climate change will occur largely in response to emissions from human activities that have not yet occurred; and

4. **Local uncertainty**, which results from the many factors that interact to determine how the climate of one specific location, such as Austin, will respond to global-scale change over the coming century.

D.2.1 Natural Variability

To address the first source of uncertainty, natural variability, the climate projections summarized here are averaged over 30-year time scales: historical (1971-2000), near-term (2011-2040), mid-century (2041-2070) and end-of-century (2071-2100). In other words, the number of days per year over 100°F were first calculated for each year from 1960 to 2100, and were then averaged over the 30 years corresponding to each historical or future time period. Natural variability is an important source of uncertainty over shorter time scales. Averaged over longer time scales of multiple decades, the contribution of natural variability to overall uncertainty becomes virtually negligible.

D.2.2 Scientific Uncertainty

To address the second source of uncertainty, scientific uncertainty, future projections were based on simulations from 20 global climate models from the Coupled Model Intercomparison Project phase 5 (CCSM4, CNRM-CM5, CSIRO-Mk3.6.0, MPI-ESM-LR, HadGEM2-CC, INMCM4, IPSL-CM5A-LR, MIROC5 and MRI-CGCM3; Taylor et al. 2012). Differences between the models represent the limitations of scientific ability to simulate the climate system. Scientific uncertainty is an important source of uncertainty in determining the magnitude and sometimes even the direction of projected changes in average precipitation, as well as dry days and extreme precipitation.

D.2.3 Human Activities

To address the third source of uncertainty, that of human activities and heat-trapping gas emissions, future projections use two different scenarios, the Intergovernmental Panel on Climate Change lower Representative Concentration Pathway (RCP) 4.5 scenario where global carbon emissions peak and then decline by end of century, and the higher RCP 8.5 scenario where continued dependence on fossil fuels means that carbon emissions continue to grow throughout the century (Moss et al. 2010; see **Figure D-2**). Scenario labels (4.5 and 8.5) refer to the projected change in radiative forcing in units of watts per square meter. Radiative forcing is a measure of the magnitude of the human influence on the naturally-occurring greenhouse effect described previously. Scenario uncertainty is an important source of uncertainty in temperature-related projections, particularly over the second half of the century as the scenarios diverge (see **Figure D-2**). The higher emission scenario was selected for use in Water Forward (Scenario B and Scenario D hydrology) because it represents the current trajectory of carbon emissions and results in a distinctly different outcome of future hydrologic conditions when compared to the historical observations of basin hydrology.

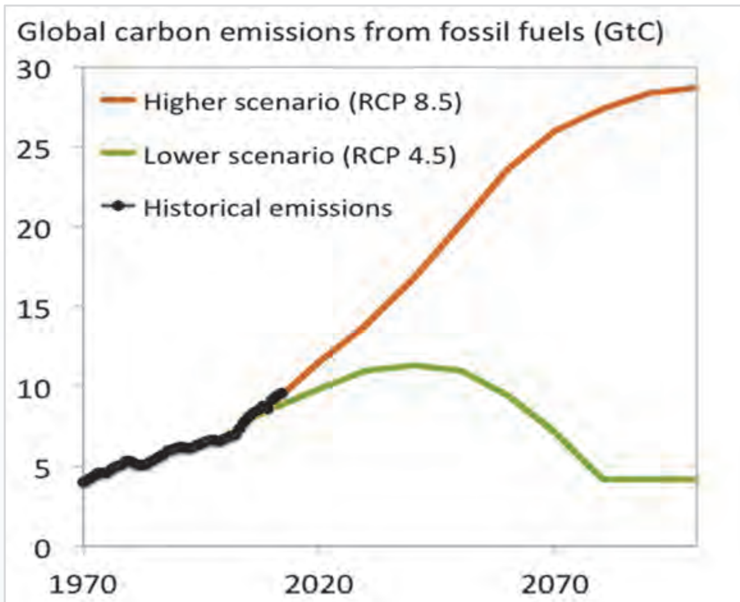

Figure D-2. Historical carbon emissions (black) continue to increase. Data: CDIAC, IIASA

D.2.4 Local Changes

Finally, to address the fourth source of uncertainty, that of local change, global climate model simulations for daily maximum and minimum temperature and 24-hour cumulative precipitation were downscaled to each long-term weather station using the Asynchronous Regional Regression Model as described in Stoner et al. (2012). From these daily simulations from 1950 to 2100, a set of more than 120 secondary climate indicators were calculated to be used as predictors for future streamflow. Quadrangle scale monthly precipitation and monthly potential evaporation were created from the precipitation and temperature outputs of the global climate models (see **Appendix E** for more detail on quadrangles and evaporation). Potential evaporation was developed using the Hargreaves equation (Kra, 2013) and converted to lake evaporation using regional pan-to-lake coefficients.

D.3 Historical Climate Data Analysis

D.3.1 Developing Climate Indicators

Streamflow gauges used for this analysis were all located within the Colorado River Basin and share the same broad topographical characteristics. As such, it would be reasonable to expect them to be affected by similar climatic indicators. At the same time, however, the gauges are located on rivers and creeks with very different watershed characteristics: from deep rivers with high flow volumes year-round to intermittent creeks. For that reason, each gauge was considered separately when deriving a statistical regression model for the flow at each, based on the hypothesis that the resulting predictors should represent a combination of common factors, reflecting their co-location and shared geography, as well as unique indicators that influence the physical processes of flow generation at each gauge.

To determine which of the 120 climate indicators from the relevant weather stations have the greatest explanatory power as predictors in the statistical regression model for each gauge, the Spearman rank coefficient was used to calculate the relationship between water flow at each gauge and the climate indicators from each of the weather stations in this geographic region. The analysis was not limited to only the station closest to each gauge, as weather affecting upstream conditions can play an important role downstream. Spearman rank coefficient is an effective method for quantifying both linear and nonlinear correlations, previously shown to reproduce the results of both Pearson correlation and Mann-Kendall τ for water data in Texas (Gelca et al., 2015). Correlations with p-values < 0.1 were considered significant.

The results of this analysis for all gauges are summarized in **Figure D-3**, which groups climate indicators with the strongest correlation to streamflow in all gauges combined into three categories. The first consists of "primary" indicators that are selected as predictors for nearly every gauge. These consist of precipitation and dry days over time scales ranging from 1 to 6 months. The second consists of "secondary" indicators that are selected as predictors for most but not all gauges. These include precipitation over both shorter (1 week) and much longer (12 month) time horizons, as well as extreme heat days. Finally, the third category consists of indicators that tend to modify streamflow in more shallow or intermittent rivers: precipitation over shorter time frames and more extreme heat.

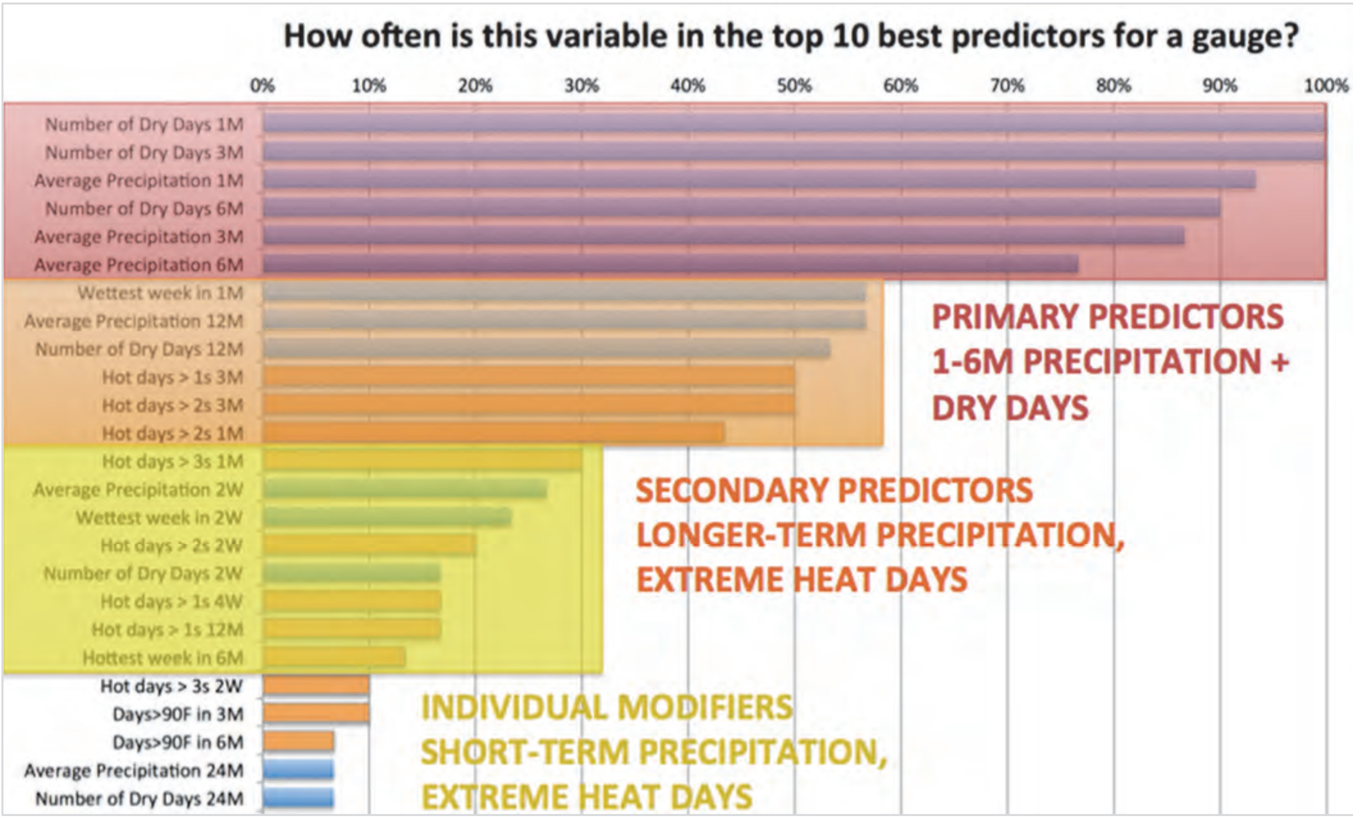

Figure D-3. Climate indicators with the strongest correlation to streamflow in all gauges combined, including primary predictors that are significant at 75 to 100% of the gauges (red); secondary predictors significant at 40-60% of the gauges (orange); and individual modifiers significant at 10-30% of the gauges (yellow).

Although the top predictors varied from one river and gauge to the next, in general the climate indicators showing the strongest correlations with streamflow were the 1-6 month average precipitation and number of dry days, as well as hot days, as measured by calculating the number of days over periods ranging from 1-3 months with maximum temperature 1, 2, and 3 standard deviations above the mean. The most important predictors for gauges located on a deep river with high flow volume are all precipitation-related indicators (Colorado River at Austin and at San Saba). The Colorado River flows towards the Gulf of Mexico, and as a result, drainage area increases in the direction of increasing average precipitation. The stream gauges representing deeper rivers therefore have increasing average precipitation in addition the lagged contribution of flows from previous precipitation events over upstream intermittent shallow rivers. The natural flow characteristics of deeper rivers in the Colorado River Basin are also influenced by baseflow created by shallow sub-surface discharge from alluvial formations. For spring-fed and more shallow rivers such as Llano and San Saba, longer-term precipitation indicators play a role and there is some influence from hot days. The Llano River in particular receives perineal spring flow discharge from its upper-most tributaries. These spring discharges are naturally more responsive to long-term precipitation accumulations. Finally, for very shallow and intermittent creeks, both precipitation and hot temperatures are important, indicating that direct runoff from storm events and intervening periods of evaporation plays an important role in the streamflow.

D.3.2 Selecting Significant Climate Indicators for Each Gauge

The correlation analysis was a necessary step to identify unique predictors to the regression model. However, it is insufficient, as it identifies a large number of predictors that are highly correlated with each other in both space and time. For each gauge, this analysis identified significant correlations with anywhere from 10 to over 60 climate indicators at each of the weather stations, with average correlation coefficients around 0.3. To reduce the pool of predictors to only those that are unique and relatively independent of each other, the second step was to select from significant predictors those to be used as input to the regression model. This was accomplished by grouping the predictors by variable (temperature and precipitation) and by time frame: from 1 to 3 days, from 1 to 4 weeks, from 3 to 6 months, and from 12 to 24 months. For each streamflow gauge we selected a total of fourteen variables most highly correlated with streamflow: two variables were selected from each predictor grouping, one representing extremes and one representing average conditions. For the time period 1 to 3 days, no “average” indicator was used, since by definition this time frame will only capture extremes. We then iterated through statistical models with all possible combinations of variables (including leaving variables out), using the least absolute shrinkage and selection operator regression analysis method to select and regularize variable selection and thereby measure the relative quality of the statistical models that could be built using these variables and to identify the model that explained the majority of the variance.

These regression models were then validated on observed data by dividing the historical data in odd and even years, using one set of the data to build the regression model, and the other for cross-validation, then switching. Modeled data for even (then odd) years obtained by training a regression model on odd (then even) years, then driving that model with observed climate indicators for even years. For the deeper, high-flow gauges of the Colorado River (**Figure D-4** a, b), modeled streamflow data (red line) show a higher density in the middle of the distribution and a lower density for low and high stream flow values compared with the observed streamflow data (black line). This bias is reduced but still visible for the year-round spring-fed rivers (c, d), while for the creeks and intermittent rivers (e, f) there is little difference between modeled and observed.

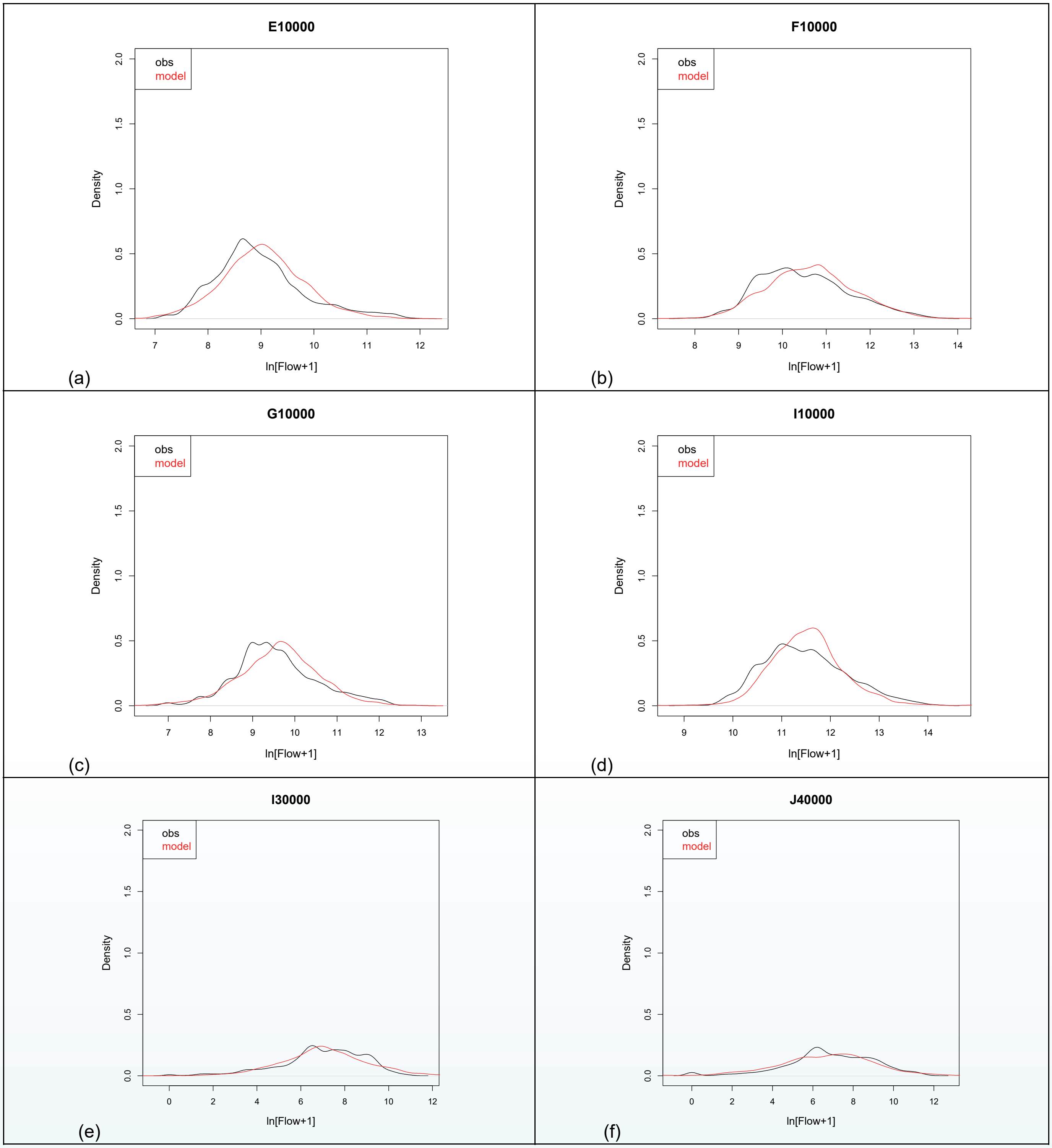

Figure D-4. Cross-validation of streamflow regression models on observed data. Comparisons shown for full data record from 1950 to 2014; plots for data beginning in 1981 and 1998 are virtually identical (not shown). Observational records were divided into odd and even years; the model was trained on each and validated on the other; results show combination of both validation exercises. Observations are indicated by the black lines and model predictions by the red lines.

D.4 Future Streamflow Projections

Once the streamflow regression models were developed and evaluated, they were then driven using climate indicators derived from historical global climate model simulations, statistically downscaled each weather station and the resulting streamflow was downscaled using the same empirical quantile regression method described in Stoner et al. (2012) and compared to observations. Despite the range in historical simulations, largely reflecting the range of natural variability in the historical period, downscaled simulation-based streamflow climatologies strongly resemble observationally-based climatologies.

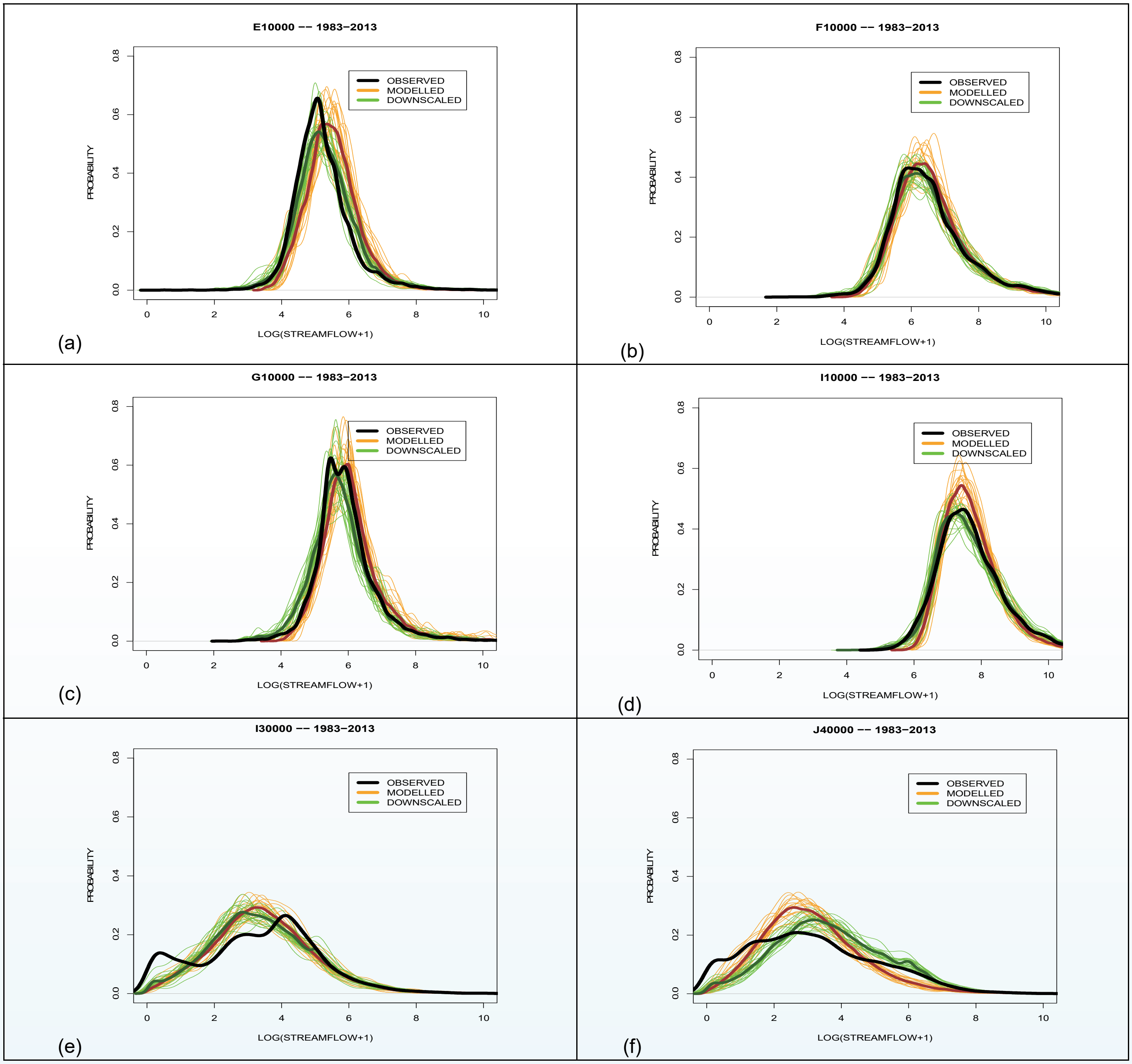

Figure D-5. Comparison of historical model-simulated streamflow (orange lines) with downscaled streamflow (green lines) and observed streamflow (black lines) from 1983 to 2013.

The last step in generating daily streamflow projections is to use projected future climate indicators to drive the streamflow regression models, to quantify potential future changes in streamflow under a changing climate. **Figure D-6** compares the distribution of observed (black lines), historical model-simulated (blue) and future model-simulated (orange) streamflow for two representative gauges. The distributions shift to the left, indicating a trend towards overall lower streamflow, and also become more skewed to the left, indicating more frequent low-flow days. This result is consistent with projections of little change in average and seasonal annual precipitation under both higher and lower future scenarios (Walsh et al. 2014), but increased risk of summer drought (Ryu & Hayhoe, 2017), more frequent extreme heat and higher evaporation rates, and the tendency of long-term (6 to 12 month precipitation) to be a primary driver of median flow volume.

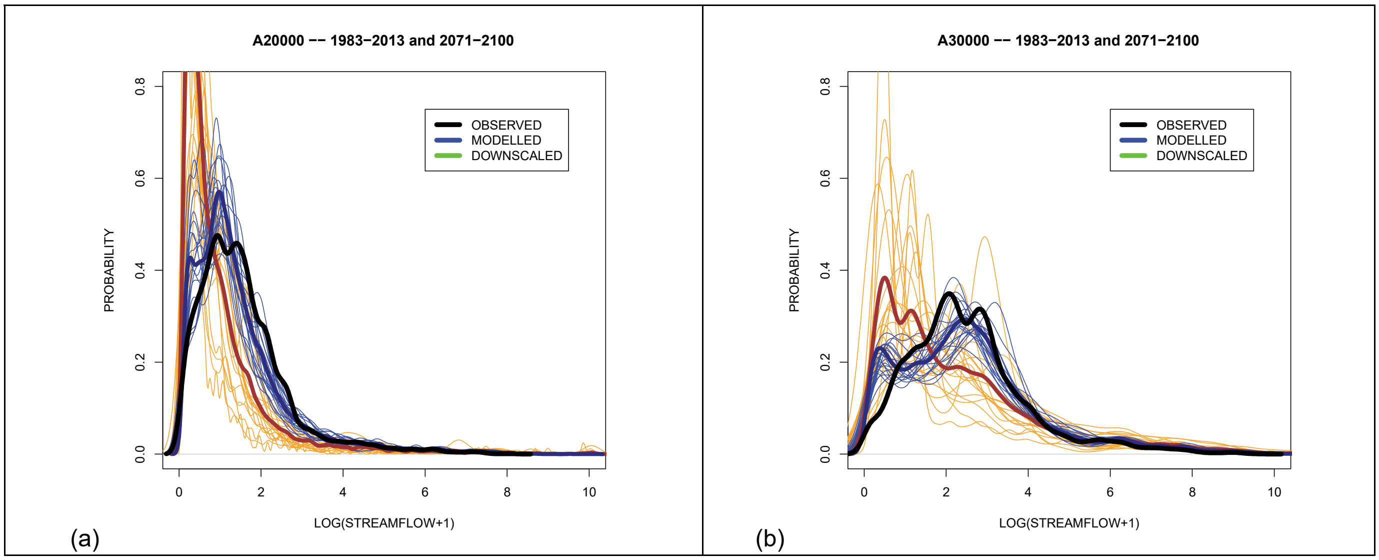

Figure D-6. Comparison of historical downscaled model-simulated streamflow (blue lines) with future streamflow (orange lines) and observed streamflow (black lines) from 1983 to 2013 and 2071-2100 under a higher future scenario.

Finally, in terms of future changes in high and low flow extremes, **Figure D-7** summarizes projected changes in mean winter and summer streamflow as well as consecutive 7-day low flows, and the 5th percentiles of the distribution (which corresponds to streamflow on approximately the 18 driest days of the year, whether consecutive or not).

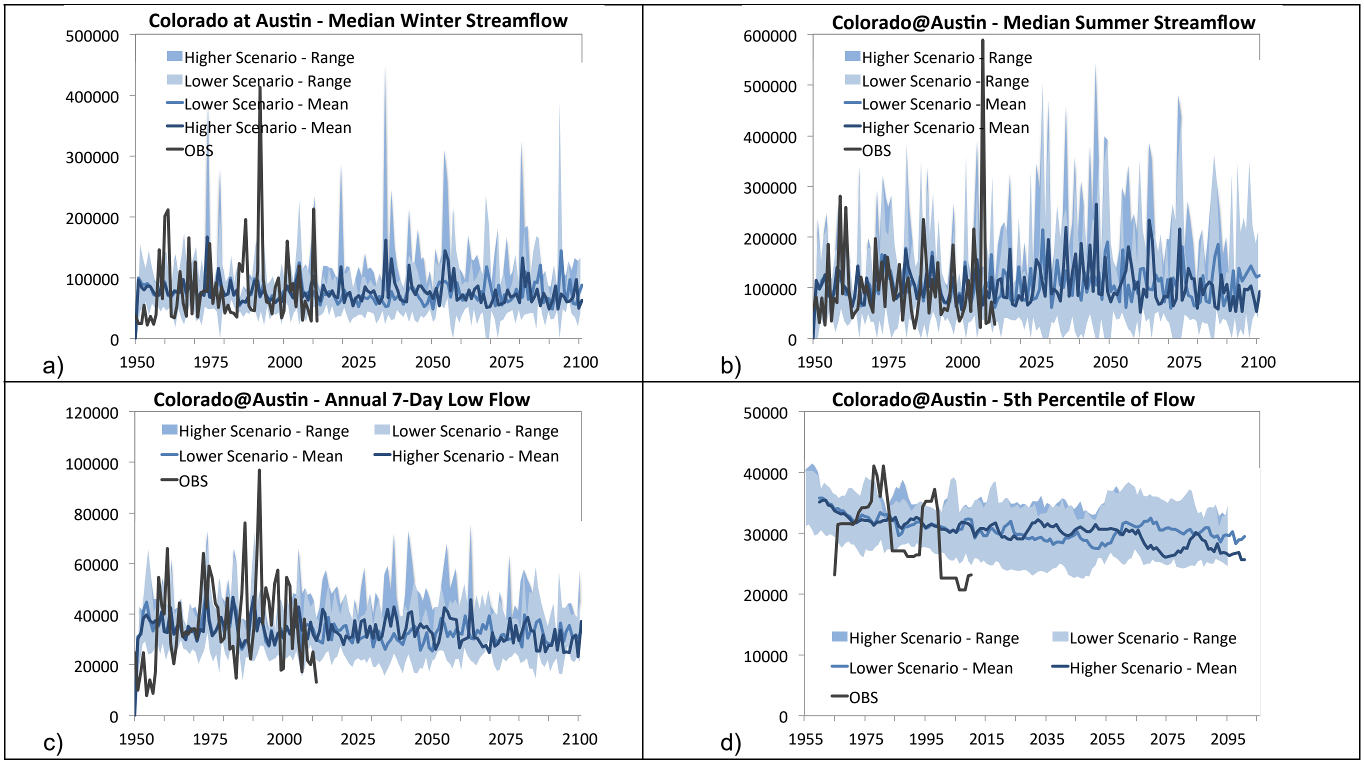

Figure D-7. Simulated historical and projected future change in (a) winter and (b) summer streamflow as well as for (c) the annual seven-day lowest flow amounts and (d) the 5th percentile of streamflow for the Colorado River gauge at Austin. The black line indicates observations, the shaded area the range of historical and future climate model projections and the colored lines, the multi-model mean.

D.5 Climate Change Adjustments to Historical Hydrology

The TCEQ WAM is a surface water availability computer simulation modeling system covering every river basin in Texas, and was created pursuant to Article VII of the 1997 Senate Bill 1, which required the development of new water availability models (WAMs) for the state's river basins. The WAM uses naturalized streamflow, net lake evaporation minus precipitation (net evap-precip), and a water management scenario as its three main inputs. The WAM simulates surface water availability to basin water rights under the specified water management scenario. Outputs include water diversions, reservoir storage content, and remaining streamflow after accounting for the water management activities. The WAM consists of basin-specific input files, supporting geographic information, and a generalized simulation model known as the Water Rights Analysis Package (WRAP).

TCEQ uses the WAM system to evaluate water right applications for water availability under new permits or permit amendments and to assess potential impacts to existing water rights. The Texas Water Development Board (TWDB) and the Regional Water Planning Groups modify the WAMs to estimate surface water supply for the entire state using a 50-year planning horizon. The WAM system is also used by river authorities, other state agencies, and individual water right holders to assess water availability from the river, reservoir operations, and environmental flow conditions.

The City of Austin is using the Colorado River Basin WAM in the development of its Integrated Water Resources Plan (IWRP) as a part of the Water Forward planning process. The Colorado WAM serves as a key modeling tool to assess baseline future needs and the performance of portfolios of options to address those needs. The IWRP is examining water available to the City of Austin and the lower Colorado River Basin for the worst drought conditions experienced since the construction of the Highland Lakes (period of record), drought conditions that are worse than observed in the period of record, and drought conditions that are reflective of future climate change. Creation of WAM hydrologic data which are reflective of future climate change conditions is addressed in this report.

This section of the appendix describes development of hydrologic input data sets to the Colorado WAM, both naturalized flow and net evap-precip, reflective of future climate change conditions developed as part of the climate change analysis discussed previously. The City's IWRP identifies four key periods of time for needs assessment: 2020, 2040, 2070, and 2115. Demand projections were created for these four planning horizons and the WAM's demand scenario is adjusted accordingly. Hydrologic inputs from the existing period of record are used for modeling the 2020 demand period. The remaining three time periods are the focus for developing hydrologic inputs reflective of future climate change to coincide with the future demand projections in the WAM. Because the output of the global climate model simulations ends with 2100, the hydrologic inputs for the WAM will be reflective of climate change conditions up to 2100 and assumed to reasonably approximate 2115 conditions.

D.5.1 Hydrologic Data WAM Inputs Description

Two pairs of data sets are used in development of climate change adjusted hydrology which are ultimately used as WAM simulation inputs. The first pair consist of the known historical naturalized streamflows and net evap-precip for the period from January 1940 through December 2013 and were obtained from the Colorado WAM simulation. Total monthly naturalized streamflows, naturalized surface streamflows plus the contribution of springflow discharge, were used for all WAM control point locations in the development of relationships between climate indicators and naturalized flow discussed in the Historical Analysis section of this report. Historical monthly net evap-precip were obtained directly from the WAM input files for all reservoir locations. The second pair of data sets include monthly naturalized streamflow obtained from aggregation of daily future model-simulated streamflow and future model-simulated net evap-precip. The process of calculating net evap-precip from quadrangles of monthly precipitation and lake evaporation for WAM reservoir locations in the Colorado River Basin is described by Pauls et al. (2013). The second pair of data sets consist of 20 separate time series from 1950 through 2100 corresponding to each global climate model used for each carbon emission scenario.

The hydrololgy for the historical period of record is assumed to reflect a stationary hydrologic condition. Stationary processes have the same statitstical properties over time. Statistical measures, such as the mean and standard deviation, in the early portion of the dataset are equivalent or very similar to statistical measures calculated in the mid or latter portions of the dataset. Stationary hydrologic conditions across the entire simulation period are important for water availability modeling. A static set of demand assumptions are simulated over a long simulation period. If the hydrologic processes that generate wet or dry conditions are changing during the simulation, the water availability measures from one portion of the simulation are not comparable to the measures in other portions of the simulation.

The hydrologic inputs derived from the downscaled local weather of the 20 global climate models have changing statistical properities from 1952 through 2100 as the atmosphere warms in response to the carbon emission scenario. While the long-term mean flow across all hydrologic inputs derived from 20 global climate models is stable for the location shown in **Figure D-8**, this is not the case for all locations in the basin. Additonally, statistical measures other than the long-term mean are changing in the flows shown in **Figure D-8**. To address changing hydrologic conditions over time from the global climate model derived hydrology, and to build a hydrologic input dataset for the WAM that reflects the same underlying hydrologic processes for the entire WAM simulation period, an *ensemble* and adjustment approach was adopted. An ensemble is collection of all results from multiple models for a particular period of time. The ensemble of all 20 global climate model derived hydrolgies are grouped together for periods of time, centered around the future planning horizons. It is assumed that the groupings centered around the future planning horizons are narrow enough to have similar hydrologic statistical properties from the start to end dates of the ensembles. The ensembles are then used to adjust the historical period of record to reflect a consistentent set of future hydrologic statistical properties. The adjustment process is described further in **Section D.5.2**.

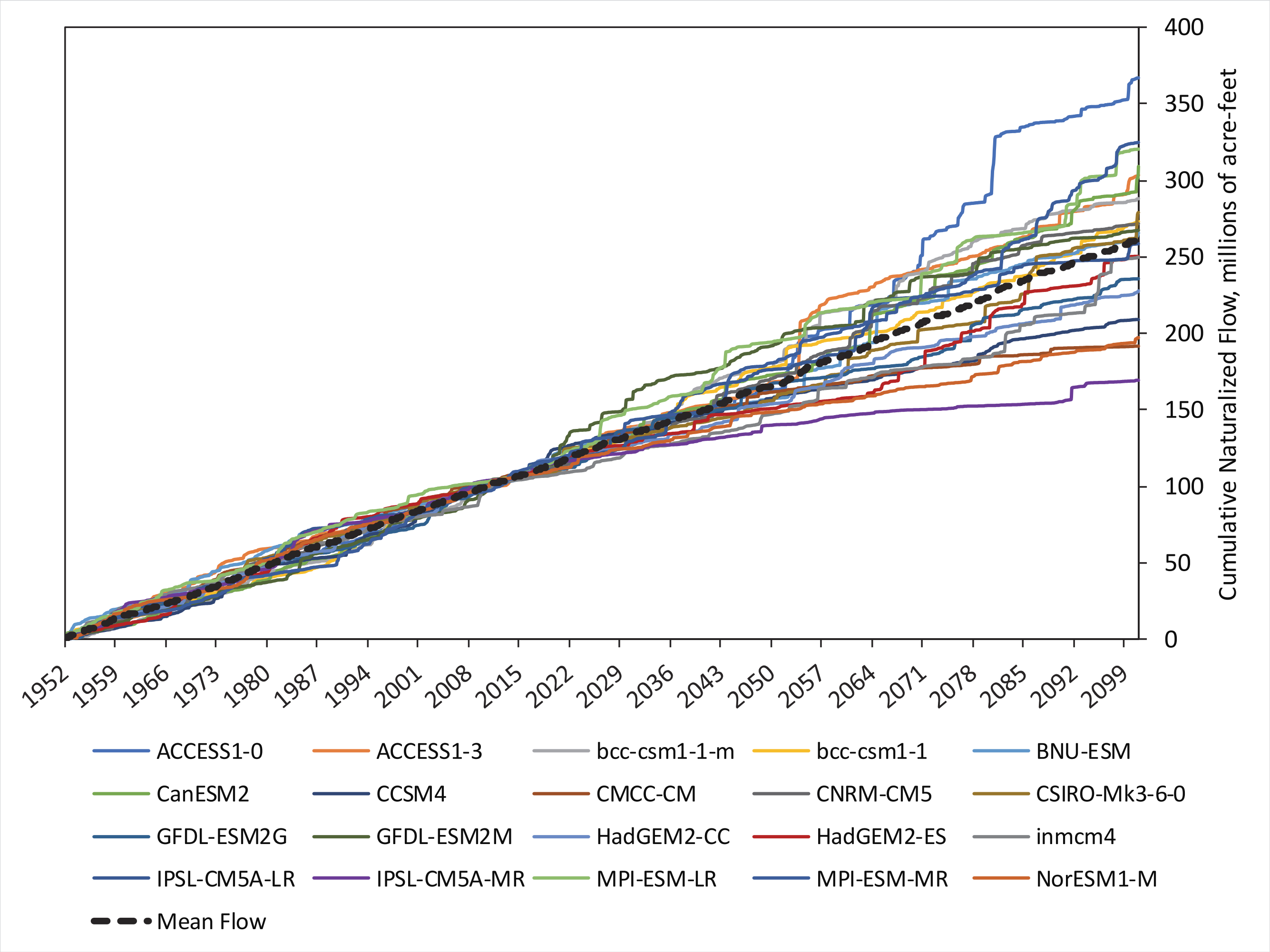

Figure D-8. Cummulative naturalized flow for the Colorado River at Austin

Ensembles of monthly naturalized streamflows, precipitation, and evaporation were created by grouping the results derived from all 20 global climate models. The ensembles were created from 21-year spans of time centered around years 2040 and 2070. Since data from the global climate models were only available through 2100, a third ensemble was created from the last 21 years of the results from 2080 through 2100. The ensembles of global climate models' derived hydrology are as follows: 2030 through 2050 (21 years centered on 2040), 2060 through 2080 (21 years centered around 2070), and 2080 through 2100 (the last 21 years of global climate model results). Each ensemble contains hydrology derived from all 20 climate models, which creates 5,040 monthly samples of projected future hydrologic conditions at each gaging station and considers a narrow enough time window that the data can be considered statistically stationary. The ensembles were centered around the demand projection years 2040, 2070, and 2115. The exception is the third ensemble, which was created from the last 21 years of global climate model results. However, it is assumed to approximate hydrologic conditions matching with the 2115 demand projection.

D.5.2 Hydrologic Adjustment Methodology

Hydrology inputs covering a 77-year period of record are required for the WAM simulations. The hydrology inputs are expected to represent the full range of hydrologic variability, including flooding, average conditions, and droughts. The historical 1940-2016 naturalized streamflows and corresponding net evaporation-precipitation data sets meet such criteria. In order to generate a 77-year sequence of hydrologic conditions that reflect future climate change conditions, the historical hydrologic record was adjusted using the three ensembles of hydrology previously described. The adjusted historical hydrologic record results in three new sequences of 77 years (one for each planning horizon—2040, 2070, and 2115), each corresponding to the same 77 years of historical hydrology, but now reflecting the climate change variability of the ensembles.

The statistical characteristics of the ensembles of future hydrology were mapped onto the existing historical period of record at each gaging location in the basin using a methodology known as *quantile mapping*. The statistical properties of the ensemble, such as the mean and variability, are transferred to the adjusted WAM hydrology, evaporation, and precipitation. Only the sequencing of dry and wet periods of the historical WAM hydrology is retained. In essence, the range of values from the ensemble are adopted, with sequencing according to the pattern of flows from the historical record. Quantile mapping has been applied similarly in other long-term future water planning studies (Wood et al., 2002; Salathe et al., 2007; CH2M Hill, 2008; Hamlet et al., 2009; Bureau of Reclamation, 2010; California Dept. of Water Resources, 2013).

The methodology of quantile mapping is as follows. The naturalized streamflows in the historical record and the selected ensemble are sorted in ascending order on a month-by-month basis at each control point. For example, in the case of the historical record there are 77 monthly streamflow values for January. Correspondingly, there are 420 monthly streamflow values for January from the selected ensemble obtained from 21 years of data and 20 global climate models. The sorted values are assigned cumulative probabilities. Returning to the historical period of record time series, the probability of each month of flow is determined from the ranking. The corresponding flow of the same probability for the same month in the ensemble is selected. The selected flow value from the ensemble replaces the flow in the historical period of record. The process repeats each month until a new, climate-adjusted, time series of flows is created for the period of record, January 1940 through December 2016. The process also repeats at each naturalized flow control point and at each quadrangle of precipitation and evaporation.

The quantile mapping process is shown in **Figure D-9** for January streamflows at an example control point. Step 1 refers to selecting the probability of a flow event of 24,000 acre-feet. Next, in Step 2, the streamflow from the ensemble is selected with the same probability. Finally, in Step 3, the streamflow from the ensemble is used to replace the historical flow event. In this example, a flow event of 24,000 acre-feet in the historical period of record is replaced with a monthly flow of 6,500 acre-feet.

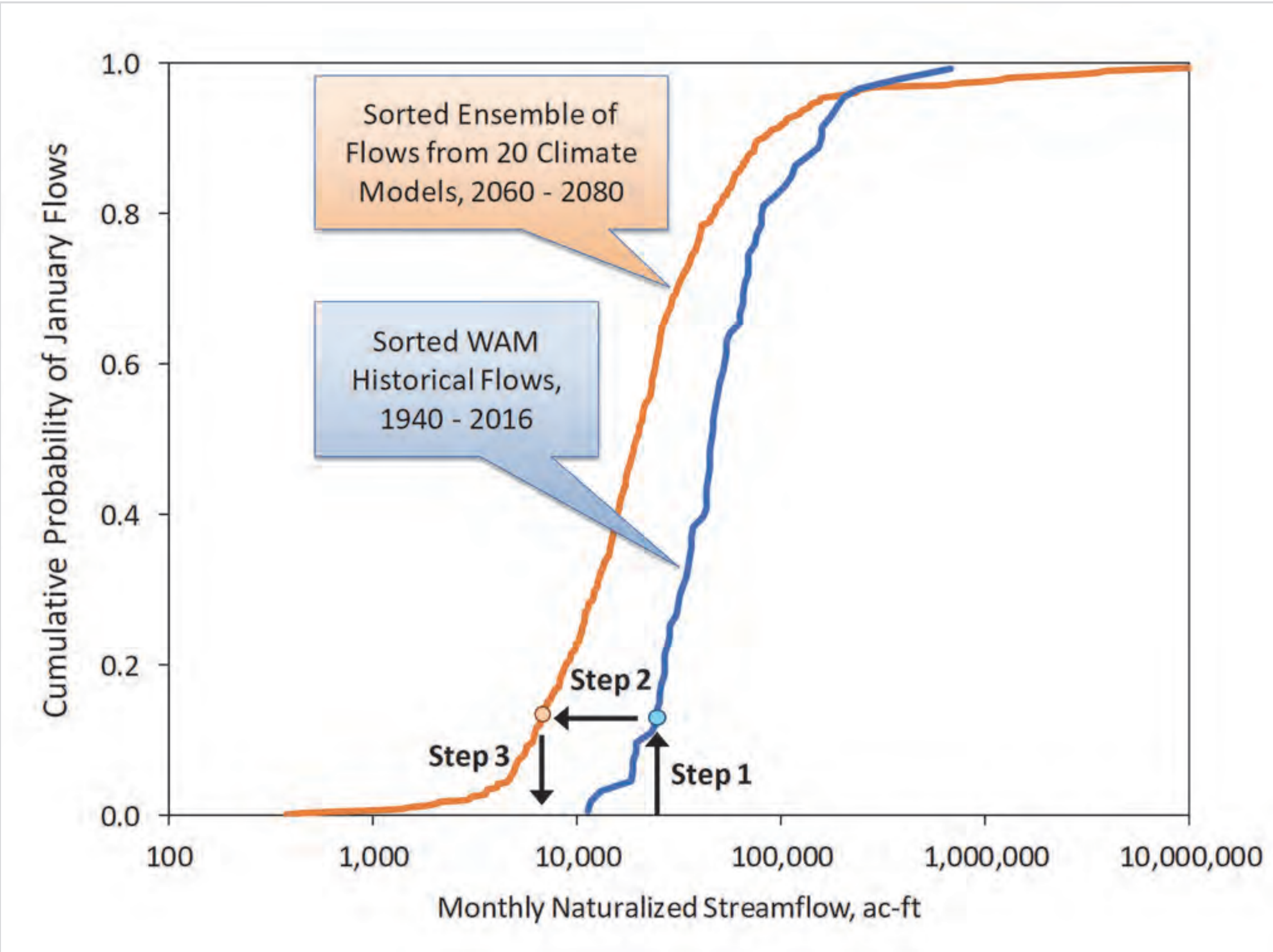

Figure D-9. Example of quantile mapping methodology

The process shown in **Figure D-9** repeats at each control point with a different set of sorted flows and probabilities for each month in the 77-year period of record. **Figure D-9** is fairly characteristic of the climate change effects at each gauge, particularly with the ensembles for 2060-2080 and 2080-2100. Most of the ensemble streamflows have a lower magnitude for the same probability compared to the historical period of record. However, the effects of amplifying the hydrologic cycle due to a warming climate create higher streamflow magnitudes at the upper end of the flow regime. As seen in **Figure D-9**, flow magnitudes are higher than the historical period of record for probabilities in excess of 95%.

Figure D-10 shows an example of implementing the steps exemplified in **Figure D-9** across the historical period of record. Most of the streamflows in the adjusted data set are lower in magnitude compared to the historical period of record. A high flow event is shown in the figure that is greater in magnitude from the ensemble relative to the historical period of record. The final hydrologic input data set for the WAM includes the adjustment results at all control points and all quadrangles.

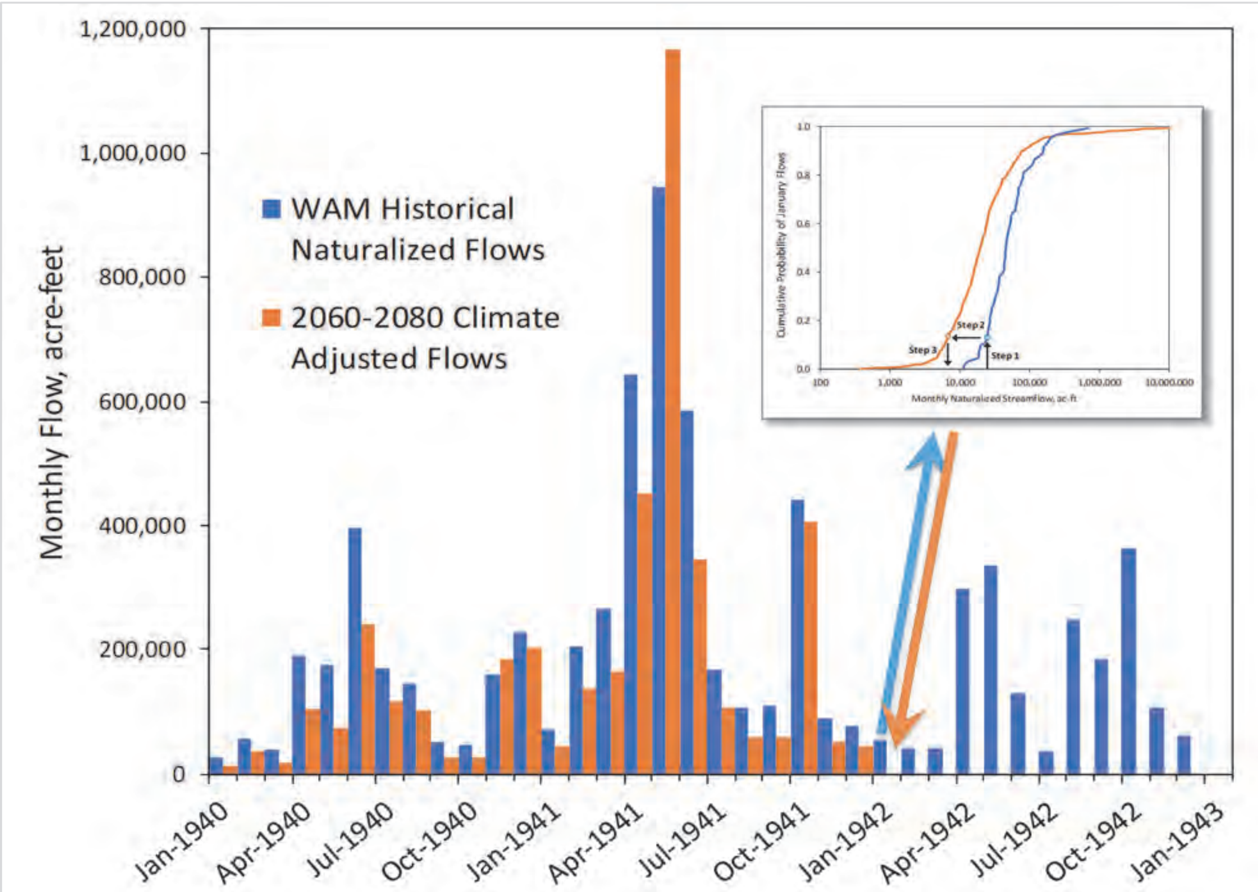

Figure D-10. Example of adjusted naturalized streamflows for the historical period of record

D.6 Results Of Hydrologic Adjustment

The selected carbon emission scenario, RCP 8.5, results in a warming global climate through the end of the 21st century. Downscaled weather for the Colorado River Basin derived from the 20 global climate models results in typically drier conditions that are occasionally interrupted by greater rainfall intensity and higher streamflow events when compared to the historical period of record for 1940-2016. In other words, drought conditions are likely to occur with greater frequency, but major flood events can be expected as flow variability increases across the lower Colorado River Basin.

Figure D-11 and **Figure D-12** show the annual lower basin naturalized flows for control point I10000, the Colorado River at Austin. Lower basin naturalized flows are extracted from the WAM after all water rights in the upper basin priority cutoff areas have been simulated. The lower basin naturalized flows are the remaining naturalized flows available to water rights downstream of the priority cutoff areas. **Figure D-11**

shows the historical period of record data for 1940-2016. **Figure D-12** shows the same period of record but with adjustment using the 2080-2100 ensemble data. Both figures show an average annual flow of approximately 1.2 million acre-feet. However, the effects of adjustment for end-of-century climate conditions result in more years of lower flows with a smaller number of years of substantially higher annual flows.

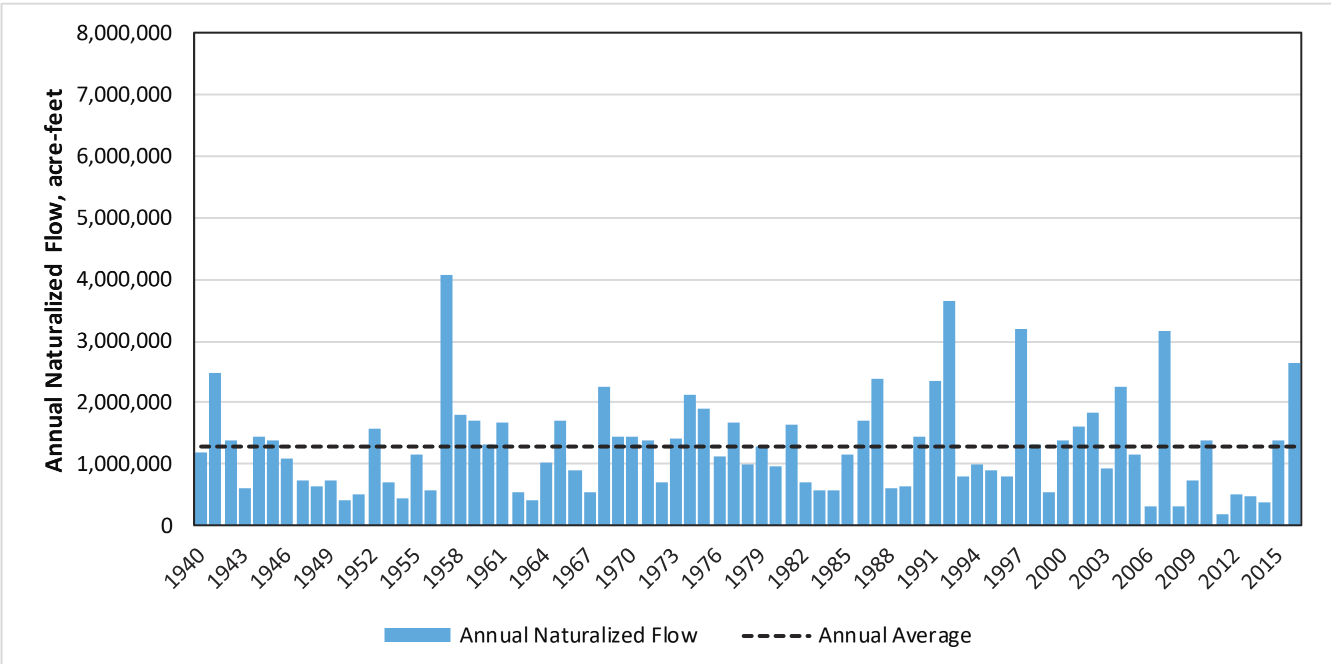

Figure D-11. Historical annual lower basin naturalized flows, Colorado River at Austin

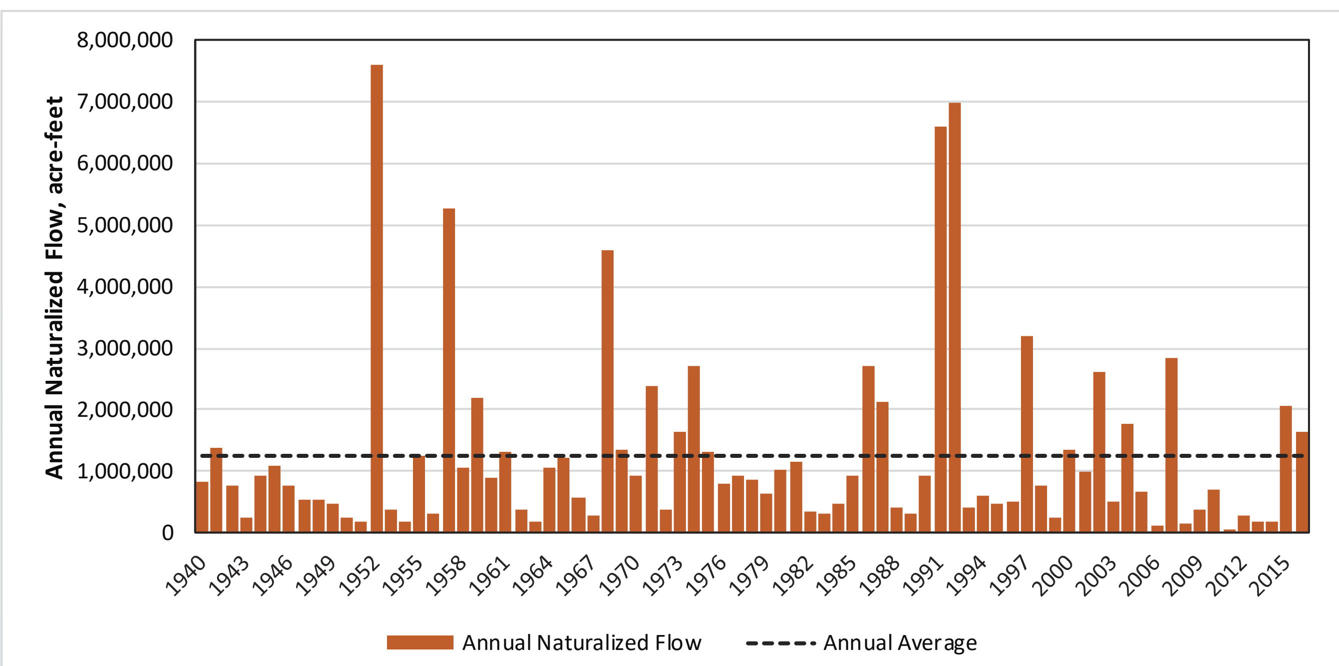

Figure D-12. Adjusted annual lower basin naturalized flows, Colorado River at Austin

Annual lower basin naturalized flows for the Colorado River at Austin are statistically summarized in box-plot form in **Figure D-13**. The flows are summarized for the 1940-2016 period of record for the historical condition and for the three ensemble periods. The X mark in each box indicates the magnitude of the annual average. The line through the middle of each box indicates the magnitude of the annual median. The lower and upper bounds of the box indicate the magnitude of the 1st and 3rd quartiles, or the 25th and 75th percentiles. The whiskers, or vertical lines in the chart, indicate the minimum and maximum values of annual flow that are within 1.5 times the interquartile range below and above the 1st and 3rd quartiles. Outlier values are designated as annual flows less than or greater than the ends of the whisker lines. Outlier values are shown as small circles. The statistical summary shown in **Figure D-13** shows an overall lower flow trend across the ensembles, as the whiskers, median, and 1st and 3rd quartiles fall in magnitude as the ensemble adjustments reach the end of the century. The annual naturalized flow magnitude does not show a consistent trend over time. The increasing magnitude of high flow events, as represented by the outlier dots, tends to offset the annual volume reduction in the other years of the period of record.

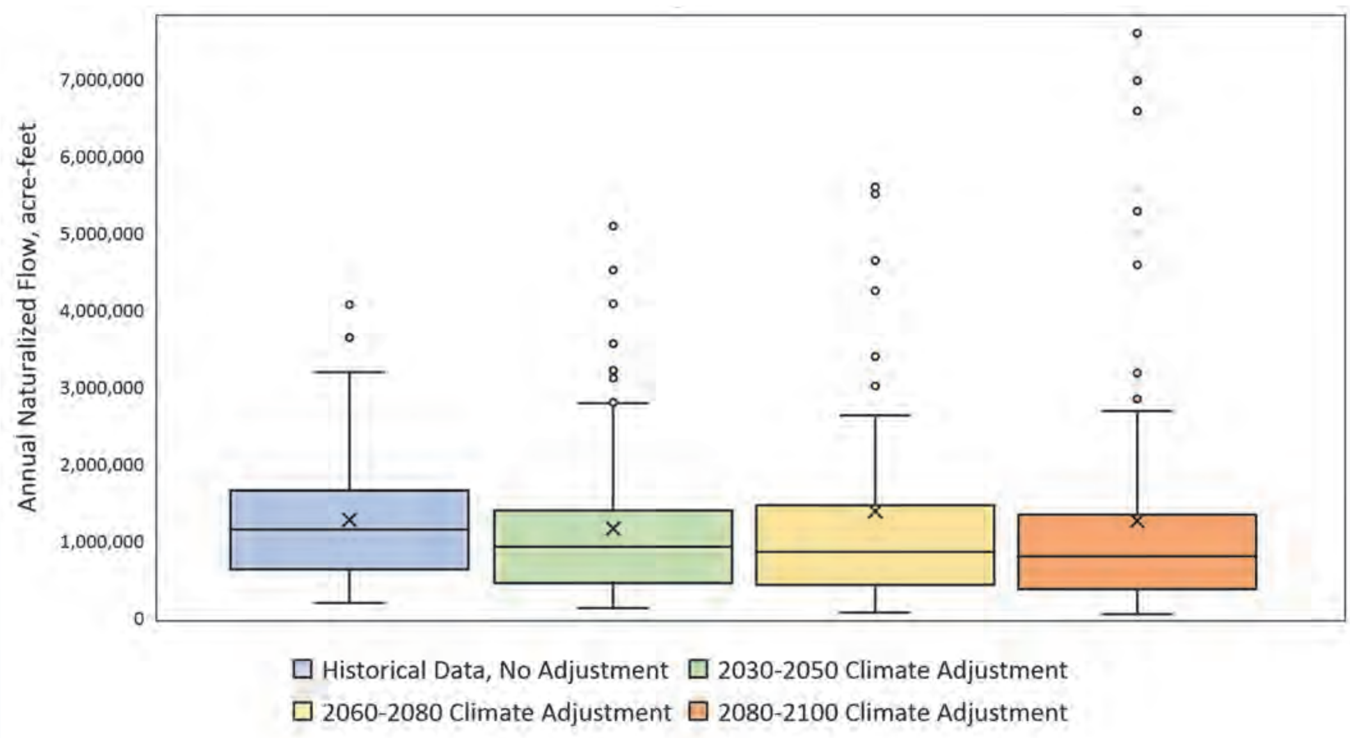

Figure D-13. Box and whisker plots of annual lower basin naturalized flows, Colorado River at Austin

Net evaporation-precipitation depth at Lake Travis is statistically summarized in the box plots shown in **Figure D-14**. Increasing temperature toward the end of the century increases the evaporation rate in each of the three ensemble adjustments. The average, medians, and 1st and 3rd quartiles rise in each adjustment compared to the earlier period and compared to the historical data. The trend is similar throughout the basin over time.

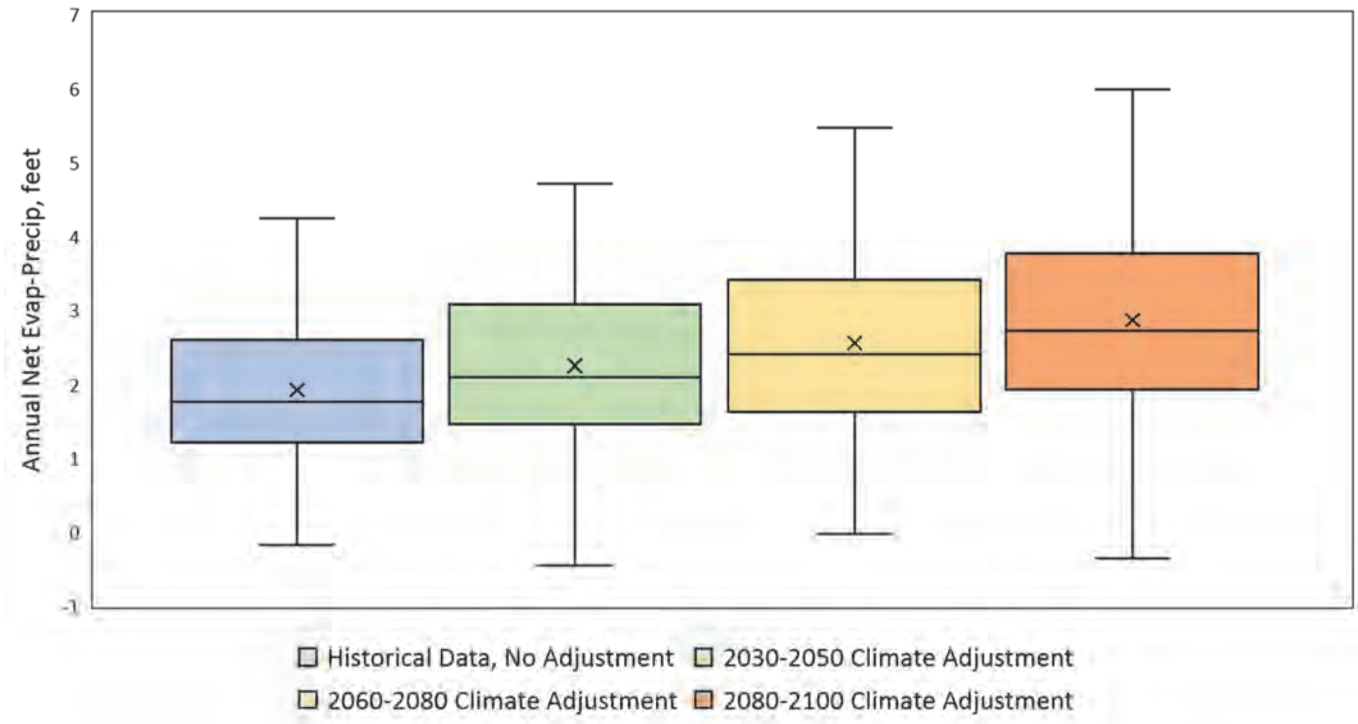

Figure D-14. Box and whisker plots of net evaporation-precipitation depth, Lake Travis

D.7 Conclusions on Climate Change Anlaysis and Climate-Adjusted Hydrology Analysis

Climate in Texas is already changing. Observed changes are consistent with larger-scale trends observed across the U.S. and the world. In the future, climate is expected to continue to change as a result of human emissions of carbon dioxide and other heat-trapping gases including increases in annual and seasonal average temperatures, more frequent high temperature extremes, little change in annual average precipitation, more frequent extreme precipitation, a slight increase in the number of dry days per year, and more frequent drought conditions in summer due to hotter weather as well as decreases in summer precipitation.

This analysis developed statistical regression models based on temperature- and precipitation-related climate variables, and demonstrated their abilities to reproduce the climatology of observed streamflow at individual gauges when driven by both historical observations independent of those used to train the model, as well as when driven by high-resolution climate projections obtained by statistical downscaling of GCM simulations.

This approach was applied using a dataset composed of 43 long-term streamflow gauges and nearby weather stations in relevant river basins upstream and downstream to the city of Austin, Texas. In contrast to many other Texas cities that rely on groundwater, Austin depends on surface water for its water supply. Future projections suggest that, consistent with precipitation projections for the region, no significant change in long-term annual average streamflow is expected for deep rivers with high flow volumes that primarily respond to precipitation. However, occurences of drought and flooding will be different as the pattern of precipitation changes, leading to longer durations of dry conditions broken by intermittent extreme flow events. For shallower rivers, however, the impact of temperature on evaporation rates is expected to increase the risk of low flow events.

These projections were used to develop a comprehensive dataset of daily naturalized streamflow inputs. The daily streamflows were aggregated to monthly naturalized flows and used to adjust the existing inputs of the TCEQ WAM for the Colorado River Basin, a computer based-simulation used by the Texas Commission on Environmental Quality and used by various agencies and stakeholders including the City of Austin to estimate the amount of water that would be in a river or stream under a specified set of conditions. Projections of monthly quadrangle precipitation and evaporation were used to adjust the existing Colorado WAM net evaporation-precipitation inputs. The Colorado WAM hydrologic record, as adjusted for projections of conditions in 2040, 2070, and 2100, give the City of Austin the ability to compare water availability with future demands with a stationary climate (existing hydrologic record) versus hydrology affected by climate change.

D.8 Referenecs

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APPENDIX E: EXTENDED HYDROLOGY ANALYSIS AND WATER AVAILABILITY MODELING

Development of Austin's Integrated Water Resources Plan for the Water Forward planning process required, among many other considerations, a framework for assessing water availability to the City. Water availability models (WAMs) are computer simulations that quantify the amount of water from river and reservoir sources that can be diverted under a specified set of streamflow conditions and a specific water management scenario, which allows comparison of water availability to the City under different portfolios. The Texas Commission on Environmental Quality (TCEQ) WAM for the Colorado River Basin (Colorado WAM) is a widely used computer model for assessing Colorado River water availability for all water rights holders in the basin, including the City of Austin. The City of Austin currently derives its water supply largely from the Colorado River through City-owned water rights and contracts with the Lower Colorado River Authority (LCRA). The City is one of many entities with water rights and reservoirs in the basin, so the Colorado WAM was selected for use in the Water Forward planning process to assess water availability to the City under different scenarios within the context of water rights allocation.

This report documents the steps taken to develop key WAM inputs: hydrology, water demands, and water management scenarios. **Appendix D** covers climate-adjusted hydrology, while this appendix focuses on development of extended hydrology and droughts worse than the drought of record inputs to the WAM and the actual modeling. To develop hydrology inputs for the WAM, naturalized streamflow, evaporation, and precipitation were modeled according to the known historical period of record. The hydrologic inputs were also adjusted in some scenarios to account for future climate change conditions (see **Appendix D** for more detail on climate change modeling). Additional hydrology inputs including severe drought conditions worse than the historical drought of record were developed by extending hydrologic inputs over a very long-period simulation (10,000 years), which is the focus of this appendix. Candidate droughts were selected from the extended period of simulation to represent potential scenarios for droughts worse than the drought of record. To determine water demands for input to the WAM, basin-wide demands, including those for the City of Austin, were developed for four planning horizons: 2020, 2040, 2070, and 2115. Demands for 2040, 2070, and 2115 were adjusted in some scenarios to account for potentially hotter and drier conditions under climate change scenarios.

As mentioned above, another key WAM input is water management scenarios. For Water Forward, this involved using the Colorado WAM in an iterative process to test various combinations of demand management and water supply options to develop groupings of demand management and supply options, known as portfolios. The demand management and water supply options evaluated in portfolios in Water Forward were modeled across the four planning horizons according to their projected implementation yield. Water availability results were summarized from the WAM outputs and used to score the performance of the various portfolios. The water supply scoring was one criteria that was used to evaluate and score portfolios to ultimately arrive at a recommended set of strategies for the Water Forward Integrated Water Resources Plan.

Figure E-1 summarizes the work described in this report. Water demand projections, both climate-adjusted and non-climate adjusted, for four planning horizons were paired with four hydrologic conditions, with the exception of the 2020 demand projection (climate-change-adjusted hydrology was not considered for the 2020 demand projection). The four hydrologic conditions are (A) a repeat of the historical hydrology, (B) historical hydrology adjusted to consider possible future climate change, (C) stochastically-selected droughts worse than the drought of record under historical hydrologic conditions, and (D) stochastically-selected droughts worse than the drought of record adjusted to consider possible future climate change. In total, water availability results were obtained for 14 combinations of the demand projections paired with the array of hydrologic conditions.

Demand Projection Planning Horizons
2020
2040
2070
2115

X

	Historical Hydrology, No Adjustment	Hydrology Adjusted to Consider Possible Future **Climate Change**
Simulate Drought of Record **(Period of Record)**	**Scenario A** Historical Hydrology (77 Years, 1940-2016)	**Scenario B** Hydrology Adjusted for Future Climate Change (77 Years)
Simulate Droughts Worse than the Drought of Record **(Extended Period)**	**Scenario C** Stochastically Sampled Historical Hydrology (10,000 years)	**Scenario D** Stochastically Sampled Hydrology Adjusted for Future Climate Change (10,000 years)

Figure E-1. Conceptual roadmap for water availability modeling

E.1 Water Availability Models (WAMs)

The TCEQ Water Availability Model is a publicly available computer modeling system for simulating surface water availability. The WAM system covers every river basin in Texas, including the Colorado River Basin. It was created pursuant to Article VII of the 1997 Senate Bill 1, which required the development of new WAMs for the State's river basins. The WAM system is comprised of two components: a generalized computer modeling software known as the Water Rights Analysis Package (WRAP) and a set of basin-specific input files and supporting geographic information system (GIS) coverages. The basin-specific input files and GIS coverages were initially developed in the late 1990s and are updated regularly by TCEQ to reflect new conditions.

The WAM uses naturalized streamflow, net lake evaporation minus precipitation, and a water management scenario as its three main inputs. Naturalized streamflows can be thought of as an estimate of what the natural flow in river would have been if no permitted water rights were using that water. These monthly naturalized streamflows are calculated from historical streamflow gaging records by reversing the historical water diversions, changes in reservoir storages, and return flows for all state-granted water rights. The naturalized streamflows represent the total surface water production of the basin in the absence of state-granted water rights. In addition to naturalized streamflows, the WAM uses monthly net lake evaporation minus precipitation as an input for reservoir water balance calculations. Monthly lake evaporation and precipitation data are calculated over quadrangles that cover 1° longitude by 1° latitude as shown in **Figure E-2**.

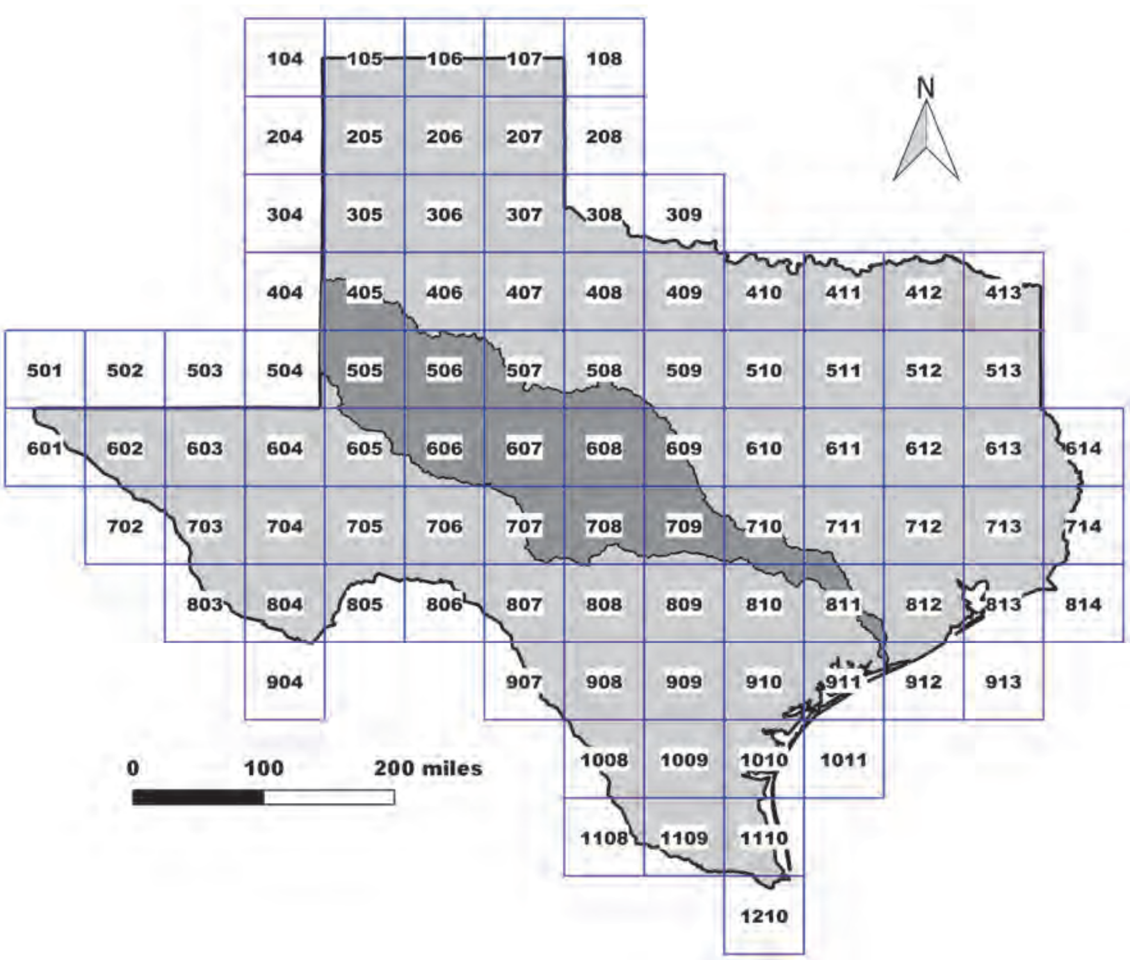

Figure E-2. Texas Water Development Board quadrangle coverage

The WAM simulates surface water availability to basin water rights under the user-specified water management scenario. TCEQ maintains two sets of water management scenarios for every river basin in the WAM system. The full authorization scenario, used for water rights permitting, is more theoretical and assumes all state-granted water rights are utilized to the full extent of their permitted rights, including full reservoir conservation storage. The current conditions scenario assumes that all state-granted water rights are utilized according to recent water-use reporting levels, including return-flow discharge volumes, and that reservoir storage reflects recent sedimentation conditions. Water management scenarios other than those TCEQ maintains can be developed by the user, as in the case of Water Forward.

Simulation outputs include numerous variables such as monthly water diversions, reservoir storage content, and remaining streamflow after accounting for water management activities. As mentioned, TCEQ uses the outputs of the WAM system to evaluate water right applications for water availability under new permits or permit amendments and to assess potential impacts to existing water rights. Other state agencies, planners, and permit holders use the WAM as well. The Texas Water Development Board (TWDB) and the Texas Regional Water Planning Groups modify the WAMs to estimate surface water supply for the State Water Planning process, which spans a 50-year planning horizon. The WAM system is also used by river authorities and individual water right holders to assess water availability from the river, reservoir operations, and environmental flow conditions for various planning or permitting purposes.

E.1.1.1 Colorado River Basin WAM

The Colorado River Basin contains approximately 31,000 square miles of contributing drainage area. The basin extends for over 1,000 river miles, from southeast New Mexico across Texas, where it discharges into the Gulf of Mexico at Matagorda Bay. A map of the Colorado River Basin is shown in **Figure E-3.** Climatic conditions range from arid desert in west Texas to humid subtropical near the eastern gulf coast. Major tributaries within the basin and upstream of the city of Austin include Pecan Bayou and the Concho, San Saba, and Pedernales Rivers. Minor tributaries downstream of the city of Austin include Onion, Willbarger, Cedar, and Cummins Creeks.

The TCEQ Colorado River Basin WAM covers the entire portion of the river basin inside Texas, from the border of southeast New Mexico downstream to Matagorda Bay. The TCEQ input files for this WAM include the Brazos-Colorado Coastal Basin. However, the coastal basin is not used in the modeling described in this report. The Colorado WAM as used in this report refers only to the portion of the TCEQ input files relevant to the Colorado River Basin. There are over 2,000 water rights and over 500 major and minor reservoirs represented within the Colorado WAM.

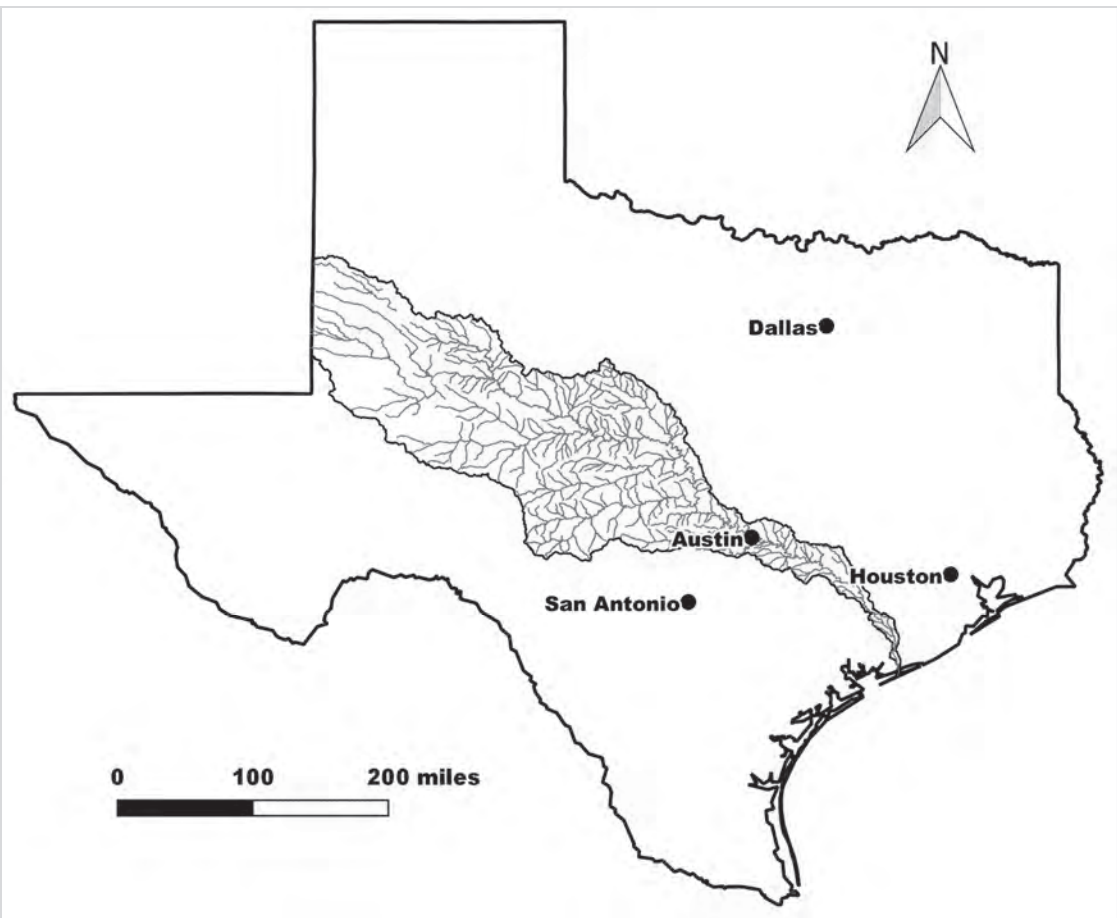

Figure E-3. Colorado River Basin

Physical locations in the river basin network, such as USGS stream gauges, water right diversion points, or reservoirs, are represented with control points. Locations in the river basin network are designated as either primary or secondary control points. Primary control points are typically located at USGS stream gauges or major reservoirs and are associated with naturalized flow inputs. The Colorado WAM uses a monthly naturalized hydrology period of record from January 1940 through December 2016 for the entire river basin. The 43 primary control points where naturalized flows are input in the Colorado WAM are listed in **Table E-1** and illustrated in **Figure E-4**. Secondary control points do not have naturalized flows provided as input. Secondary control points are assigned naturalized flows from nearby primary control points during the simulation. A variety of methods are available in WRAP for distributing naturalized flows from primary to secondary control points, though the drainage area ratio is the generally accepted transfer method in the TCEQ WAMs. There are over 2,100 secondary control points in the Colorado WAM.

Table E-1. Primary Control Points in the Colorado WAM

WAM CP ID	Drainage Area, sq. miles	River Miles to Bay	USGS Gauge No.	USGS Gauge Name
A30000	1,074	868	08119500	Colorado River at Hwy 350 near Ira
A20000	193	858	08120500	Deep Creek near Dunn
A10000	1,575	828	08121000	Colorado River at Colorado City
B40000	176	825	08123600	Champion Creek Reservoir
B30000	1,974	807	08123800	Beals Creek near Westbrook
B20000	4,559	787	08123850	Colorado River above Silver
B10000	5,046	758	08124000	Colorado River at Robert Lee
D40000	6,090	709	08126380	Colorado River near Ballinger
D30000	464	706	08127000	Elm Creek at Ballinger
C30000	258	763	08128000	South Concho River at Chrisoval
C60000	1,613	763	08128400	Middle Concho River above Tankersley
C50000	340	756	08129300	Spring Creek above Tankersley
C40000	164	760	08130500	Dove Creek at Knickerbocker
C70000	1,202	758	08134000	North Concho River near Carlsbad
C20000	4,139	734	08136000	Concho River at San Angelo
C10000	5,185	693	08136500	Concho River at Paint Rock
D20000	12,548	646	08136700	Colorado River near Stacy
D10000	13,788	598	08138000	Colorado River at Winchell
F30000	1,654	595	08143500	Pecan Bayou at Brownwood
F20000	2,074	562	08143600	Pecan Bayou near Mullin
E40000	1,137	632	08144500	San Saba River at Menard
E30000	1,636	584	08144600	San Saba River near Brady
E20000	589	594	08145000	Brady Creek at Brady
E10000	3,048	529	08146000	San Saba River at San Saba
F10000	19,830	506	08147000	Colorado River near San Saba
G50000	897	550	08148500	North Llano River near Junction
G40000	1,859	541	08150000	Llano River near Junction
G30000	3,251	489	08150700	Llano River near Mason
G20000	215	484	08150800	Beaver Creek near Mason
G10000	4,201	444	08151500	Llano River at Llano
I40000	20,521	458	08148000	Lake Buchanan near Burnet
I30000	346	428	08152000	Sandy Creek near Kingsland
H20000	370	471	08152900	Pedernales River near Fredericksburg

WAM CP ID	Drainage Area, sq. miles	River Miles to Bay	USGS Gauge No.	USGS Gauge Name
H10000	901	432	08153500	Pedernales River near Johnson City
I20000	27,357	368	08154500	Lake Travis near Austin
I10000	27,611	311	08158000	Colorado River at Austin
J50000	124	335	08158700	Onion Creek near Driftwood
J40000	324	309	08159000	Onion Creek at US Hwy 183, Austin
J30000	28,580	249	08159200	Colorado River at Bastrop
J20000	29,062	229	08159500	Colorado River at Smithville
J10000	30,244	138	08161000	Colorado River at Columbus
K20000	30,601	65	08162000	Colorado River at Wharton
K10000	30,862	30	08162500	Colorado River near Bay City

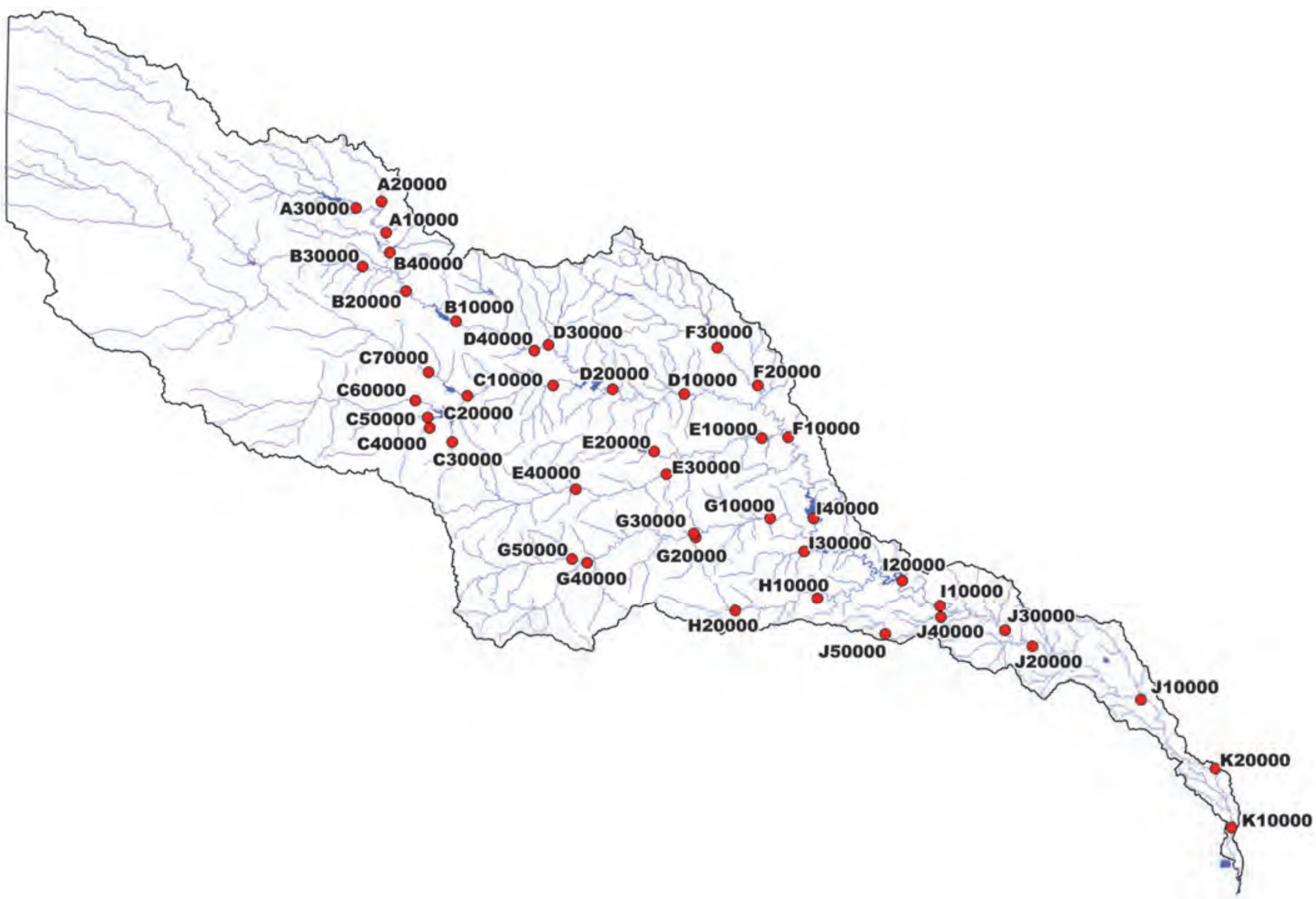

Figure E-4. Primary control points in the Colorado WAM

Control points are also used for the input of net evaporation-precipitation depths at major reservoirs or other pertinent locations in the basin. There are 47 control points in the Colorado WAM that receive input net evaporation-precipitation depths. Like secondary control points that are assigned naturalized flow based on primary control points, net evaporation-precipitation can be distributed to any control point not included in the input file. The net evaporation-precipitation depths are developed from monthly lake evaporation and precipitation quadrangle data maintained by TWDB. The quadrangles are shown in

Figure E-2. Information regarding the calculation of net evaporation-precipitation depths for reservoirs in the Colorado WAM using the TWDB quadrangles can be found in Pauls et al. (2013). A summary of the connectivity of primary control points in the Colorado WAM is shown in **Figure E-5**.

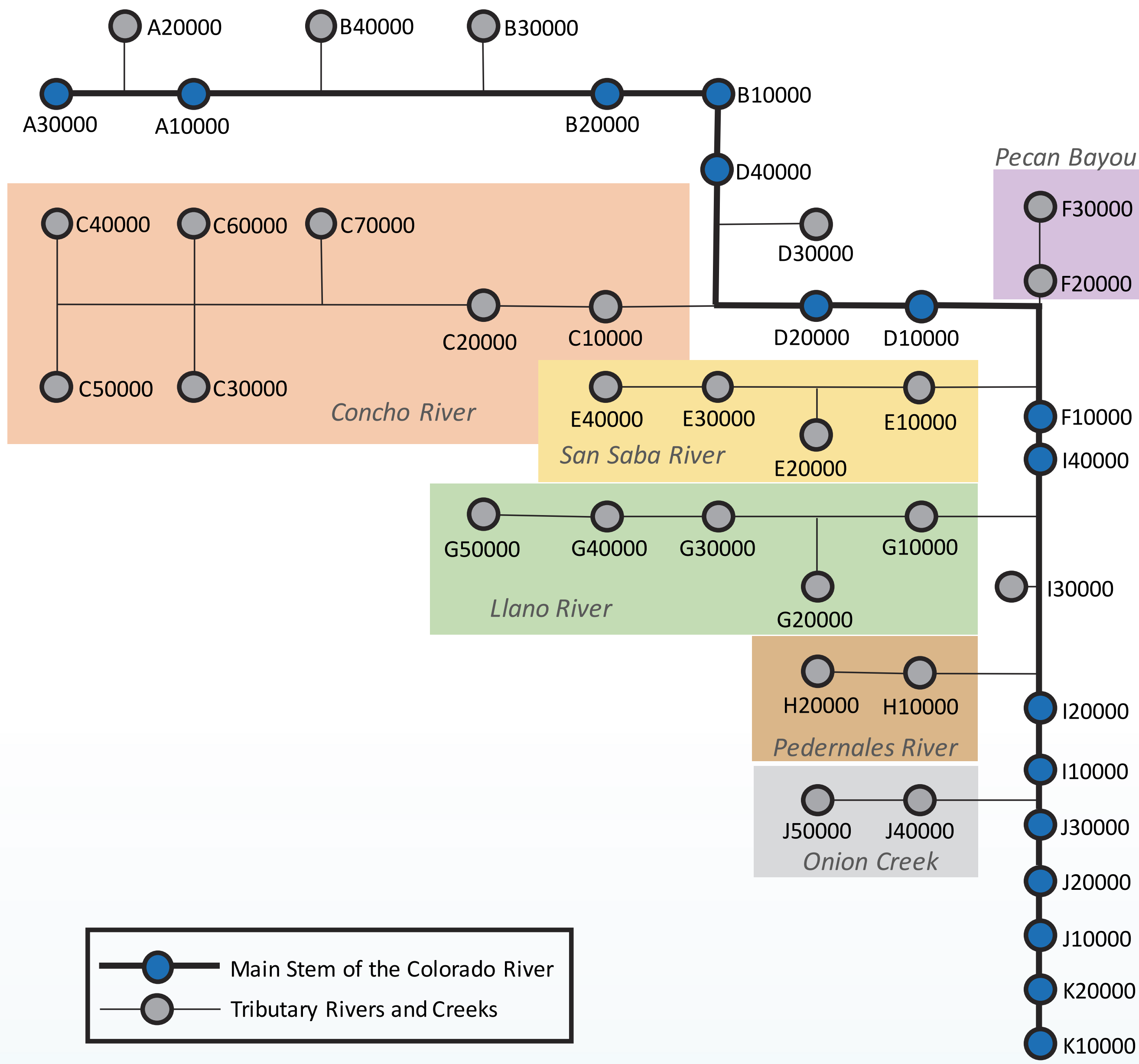

Figure E-5. Connectivity of primary control points in the Colorado WAM

E.1.2 Variants of the Colorado WAM

As mentioned previously, the WAM system is a publicly available computer modeling system and is used by entities other than TCEQ. Other state agencies, river authorities, local governments, or private water right holders use the WAM system and often modify the input water management scenario for specific planning or permitting applications. Modifications are typically made to the input water management scenario to reflect future water demands, explore alternative water right and reservoir system operations, or estimate the size of potential projects to fulfill unmet demands. Modification can also be made to the input hydrology datasets to extend the period of record or to reflect alternative conditions such as those projected with future climate change.

The Lower Colorado Regional Water Planning Area (Region K) is one of 16 regional planning groups supported by TWDB and generally covers the Colorado River Basin that drains into the Highland Lakes and downstream to Matagorda Bay. Each planning group develops a 50-year regional water plan, updated on a 5-year cycle, for submittal to the TWDB. The State Water Plan is developed from the regional water plans. In developing the regional water plans, the planning groups utilize the TCEQ WAM for their respective river basin. Modifications typically include adjustments for surface water demands and return-flow discharges each decade over the 50-year planning horizon, adjustments for future reservoir sedimentation, and extensions to the hydrologic period of record.

Region K employs a major modification to the water rights allocation system in the TCEQ WAM. Instead of all state-granted water rights being simulated with their actual priority dates, water rights at and upstream of lakes O.H. Ivie and Brownwood are modified so that their priority dates are senior to all other water rights downstream. The modification is formally known as the Region K Cutoff Model since it forms a water right seniority disconnect, or *cutoff*, between the upper and lower portion of the Colorado Basin. All water rights included in the upper basin cutoff areas maintain their relative priority dates to each other, and similarly all water rights included in the lower basin area maintain their relative priority dates to each other. The cutoff assumption is intended to reflect current and historical basin operations that have not included priority calls by lower basin senior water rights for the passage of streamflows from the upper basin.

The Lower Colorado River Authority (LCRA) modifies the TCEQ WAM in preparation of amendments to its Water Management Plan (WMP) and for calculation of the combined firm yield of its water supply reservoirs, lakes Buchanan and Travis. A complete description of the modifications for the WMP and combined firm yield models can be found in the Appendix A Technical Papers of the LCRA WMP.[1] Major modifications for the WMP include the Region K priority date cutoff assumption plus additional priority date cutoffs for all water rights not associated with LCRA or LCRA customers, portions of reservoir releases that are not diverted downstream, and reduced streamflow availability for run-of-river water rights downstream of Austin to represent historical baseflow conditions. Water rights associated with LCRA and LCRA customers are assigned near-term future demands. All other water rights in the basin are simulated with their fully authorized water right demands.

The LCRA combined firm yield model utilizes the Region K priority date cutoff assumption for upper basin water rights, though it does not include the additional cutoff assumption for lower basin water rights not associated with LCRA or LCRA customers. Reduced water availability for lower basin baseflow conditions is not considered in the combined firm yield model. All water rights in the basin are simulated with their fully authorized water right demands. Elements of the LCRA WMP are not included, such as storable inflow and stored water allocations for WMP environmental flow maintenance and the availability of interruptible stored water for downstream agricultural purposes.

[1] https://www.lcra.org/water/water-supply/water-management-plan-for-lower-colorado-river-basin/Pages/default.aspx

E.1.3 Baseline Assumptions of the Water Forward WAM

The City of Austin used the Colorado River Basin WAM in the development of its Integrated Water Resources Plan (IWRP) as a part of the Water Forward planning process, and plans to use it to inform the implementation process. The Colorado WAM serves as a key modeling tool to assess baseline future needs and the performance of portfolios of options to address those needs. For the Water Forward IWRP process, the WAM was used to evaluate water available to the City of Austin and the lower Colorado River Basin for the four scenarios (A, B, C, D) illustrated in **Figure E-1**.

Modeling modifications to create the Water Forward WAM mirror those contained in the Region K Cutoff Model and the LCRA WMP WAM. As in the Region K Cutoff Model, priority dates of upper basin water rights at and upstream of lakes O.H. Ivie and Brownwood are made senior to all water rights in the basin. A second seniority cutoff is utilized for lower basin water rights not associated with LCRA or LCRA customers. Water rights in both cutoff assumptions maintain their relative priority dates. In addition, water rights other than LCRA and LCRA customers in both cutoff assumptions are simulated with their fully authorized water right demands. The cutoff and full authorization assumptions provide both a historical operational component (priority cutoff assumptions) and a conservatively high level of streamflow consumption outside of the planning area for Water Forward (full authorization assumption).

The Water Forward WAM incorporates additional operational assumptions contained in the LCRA WMP WAM. Streamflow availability for major run-of-river water rights downstream of the Highland Lakes is limited to estimates of historical baseflow conditions and return-flow discharges. Portions of reservoir releases not diverted by downstream water rights are represented. However, LCRA's Arbuckle Reservoir, located near Lane City, is simulated with the ability to store the undiverted releases according to its water rights. Water rights associated with LCRA and LCRA customers are simulated with future demands that follow and extrapolate Region K demand trends. Future City of Austin demands are set according to the City's disaggregated demand model (see **Appendix C** for more detail on the disaggregated demand model).

Additional information regarding the modeling modifications for the Water Forward WAM is described in the remainder of this report. The modifications include those associated with the development of future hydrologic conditions associated with climate change trends, simulation of droughts worse than the drought of record, and representations of portfolios of demand management and water supply options.

A conceptual roadmap for the work described in this report was presented in **Figure E-1**. City of Austin demands and regional demands in the lower Colorado Basin in the Water Forward WAM were projected and simulated for four planning horizons: 2020, 2040, 2070, and 2115. The 2020 demand set is paired with the historical period of record hydrology as well as an extended hydrologic set constructed from the period of record. The extended hydrologic sets are used for testing water availability under droughts worse than the drought of record. Demand sets for 2040, 2070, and 2115 are paired with all four hydrologic categories shown in **Figure E-1** to simulate water availability under drought of record, droughts worse than the drought of record, and conditions reflective of the historical climate and future climate change trends.

E.2 Extended Hydrologic Data

The historical hydrologic period of record for the Colorado WAM is January 1940 through December 2016. The record contains 77 years, or 924 monthly samples, of naturalized streamflow and net evaporation-precipitation. Within the historical period of record are two major drought periods known as the droughts of the 1950s and 2010s. The drought during the 2010s represents the worst drought from a reservoir water supply perspective and, for the purposes of Water Forward planning, is referred to as the "drought of record" (DOR) because it sets the minimum firm water supply from the Highland Lakes' supply reservoirs, lakes Buchanan and Travis. The drought of the 2010s began in October 2007 and was significantly alleviated, though not completely ended from a reservoir firm water supply perspective, by major rainfall events in the spring of 2016.

A risk factor and source of uncertainty for characterizing water availability to the city of Austin are droughts worse than the drought of record (DWDR). DWDR events are, by definition, droughts that have not yet occurred, and hence are not yet part of the period of record. However, with such a relatively short historical period of record, conservative water supply planning processes should consider the possibility of DWDR events occurring, especially over the 100-year planning horizon of the Water Forward process and against the backdrop of climate change.

The methodology used in Water Forward to create a long sequence of plausible hydrology for modeling DWDR events involves stochastically resequencing the 1940-2016 period of record. The methodology is formally known as Markov Chain Monte Carlo (MCMC) sampling (Brooks et al., 2011). Whole years of hydrology from the period of record are randomly selected and connected back-to-back to build a long sequence of flows. Random sampling of calendar-year sequences of streamflows is conditioned by the observed transition frequencies, such as transitioning from wet to dry years or dry to average years. Modeling the annual flows with a Markov chain ensures the long sequence of randomly sampled calendar-year streamflows matches the same transition frequencies in the period of record and has the same long-term statistical properties of the period of record.

A long sequence of extended synthetic hydrology that preserves the statistical characteristics of the observed period of record is useful for analyses of river and reservoir water availability (Wurbs, 1991). A long sequence of synthetic hydrology allows for the random occurrence of conditions that are both wetter and drier on a short-term basis than contained in the period of record. Multi-year droughts in the extended hydrology can be worse than the drought of the 2010s. For example, the drought of the 2010s is punctuated by high flow events in early 2012 and mid-2015. If random sampling replaced the hydrology of 2012 or 2015 with a drier year in the extended hydrology, then the new drought sequence could be worse than the observed drought of the 2010s.

The hydrology inputs used for Water Forward cover 10,000 years of simulation. The length of this simulation is arbitrary, but it is intended to be long enough for random chance to produce a large number of candidate droughts that are worse than those contained in the period of record. The WAM allows for a maximum of 10,000 years of hydrologic record in a single simulation. Thus, the maximum length was selected even though a shorter extension may be sufficient to produce a large number of candidate droughts. A large number of candidate events is desirable for exploring a range of potential water availability sequences during DWDR conditions. Shiau and Shen (2001) likewise used a 10,000-year sequence of synthetic streamflows for drought recurrence analysis.

These candidate droughts are further ranked by the degree to which they are worse than the drought of the 2010s. Criteria for selecting the ranked candidate droughts for water availability calculations are used to narrow the range of DWDR events for consideration. Further discussion about ranking and selecting candidate droughts is provided in **Section 3** of this appendix. Creating plausible candidate DWDRs in the extended hydrology and ranking their severity allows Water Forward to test water availability in a mathematically sound manner under DWDR conditions.

E.2.1 Transition Frequencies

Creation of an extended synthetic hydrologic record can be accomplished by randomly selecting years from the historical period of record. Serial correlation between calendar-year annual naturalized flow volumes is nearly zero, indicating calendar-year annual flow volumes are likely independent. However, the historical record may reflect persistence of low or moderately low annual naturalized flow volumes, particularly in drought events. Persistence between states of naturalized flows can be quantified by the probability for a year of higher flows to be followed by a year of average flows or a year of lower flows to be followed by another low year of flows, for example. A Markov chain is a type of stochastic modeling process that assigns the probability of an event based on the state of the prior event (Maidment, 1993). In the case of annual naturalized flows, a Markov chain model assigns the probability for a designated state of flow to be followed by the same or different states of flow.

Transition probabilities from the present state to the future state are fundamental to Markov processes. A transition matrix was created that assigns a probability to switch to any possible state in the system based on the prior state. The dependency of the future state based only on the prior state is known as a first-order Markov process. Stochastic streamflow generation is commonly performed as a first-order Markov process (Maidment, 1993; Yeh, 1985).

In the case of annual naturalized flows for the Colorado Basin, a transition matrix was created to designate the probabilities of switching between low, average, and high naturalized streamflow years. Naturalized streamflows at control point I20000, the location of Lake Travis in the WAM, were used for creating the transition matrix. Low, medium, and high flow years were defined by ranking all 77 years in the period of record in ascending order. The lowest one-third of annual flows were classified as low flow. The highest one-third of annual flows were classified as high flow. The remaining one-third of annual flows were classified as medium flows. The historical frequency of switching between low, medium, and high flow years was used as estimates of probability for the transition matrix.

Table E-2 gives the transition matrix calculated for states of lower basin naturalized streamflows at the location of Lake Travis in terms of the number of years and the frequency as a percentage of 76 years of transition. There are only 76 possible transition states in 77 years of record. The transition matrix shown in **Table E-2** corresponds to lower basin naturalized streamflows in the historical period of record. The same process of calculating transition matrices was repeated for the adjusted naturalized streamflow data sets using the quantile mapping methodology described in **Appendix D**. The transition matrix for naturalized streamflows adjusted for the 2080-2100 ensemble is given in **Table E-3**.

Table E-2. Transition matrix for 1940-2016 historical lower basin naturalized streamflows

		Annual Transition State, Number of Years and Frequency		
		Low	Medium	High
Prior Annual State	Low	11 (42.3%)	10 (38.5%)	5 (19.2%)
	Medium	4 (26.9%)	4 (26.9%)	12 (46.2%)
	High	8 (33.3%)	8 (33.3%)	8 (33.3%)

Table E-3. Transition matrix for period of record lower basin naturalized streamflows, adjusted with 2080-2100 Ensemble

		Annual Transition State, Number of Years and Frequency		
		Low	Medium	High
Prior Annual State	Low	9 (34.6%)	7 (26.9%)	10 (38.5%)
	Medium	9 (36.0%)	6 (24.0%)	10 (40.0%)
	High	8 (32.0%)	11 (44.0%)	6 (24.0%)

E.2.2 Random Sampling of Flow States and Years

Stochastic sampling can proceed with the transition matrices defined for the historical period of record and the three adjusted periods of record for climate change conditions. Stochastic sampling involves the use of a (pseudo) random number generator and forms the basis of the Monte Carlo portion of the MCMC methodology. Combined linear congruential generators (L'Ecuyer, 1988) were used to provide the necessary sets of random numbers for each sampling. Two streams of random numbers were used for two samplings as discussed below.

Two samplings were performed. First, the sequence of low, medium, and high states was generated using the transition matrices for the relevant hydrologic dataset. The first 1,000 samples were discarded to allow for a "warm-up" period and the calculation of the distribution of states. Since the low, medium, and high states were created from evenly breaking the ranked years into one-third groupings, the algorithm checks the long-term distribution between low, medium, and high states before selecting a transition state. Transitioning to a new state was allowed based on the probability of maintaining the long-term even distribution of states and the probabilities represented in the transition matrix. The Metropolis algorithm (Kuczera and Parent, 1998) was adapted and used to accept or reject a transition to a different state and to maintain a long-term even distribution between low, medium, and high flows as calculated from the preceding 500 states. Period of record monthly serial correlation was maintained in the extended period from the selection of whole calendar years of hydrologic records with the exception of maintaining serial correlation between December and January.

After the first sampling to establish the sequence of low, medium, and high flow states, a second sampling was conducted to select a year from the 1940-2016 period of record that corresponds to the low, medium, and high states. Sampling of years from the period of record for a given state was random. However, an algorithm was created to ensure that each year from the period of record was selected approximately the same number of times as any other year, i.e., the years of the period of record were evenly sampled. Even sampling of years from the period of record ensures that the long-term annual average naturalized flow of the period of record is the same as calculated for the extended period of record.

E.2.3 Building the Extended Hydrologic Dataset

The extended hydrologic datasets were built after selection of low, medium, and high naturalized flow states and selection of a corresponding year from the period of record. Using the selected year from the period of record, a program was written to select the entire set of naturalized flows from all primary control points and all net evaporation-precipitation control points from the WAM input files. The whole years of input records were added in sequential order to the new extended hydrologic input files. The new extended hydrologic input files span 10,000 years, or 120,000 months of hydrology.

Figure E-6 shows an overview of the steps used in this work to build an extended stochastic hydrologic input dataset using the MCMC methodology. Annual naturalized flow volume was used as a basis for state classification, transition probability based on the prior annual state, and selection of a long sequence of states and years for the period of record. The steps shown in **Figure E-6** were applied to the historical hydrology and the three sets of hydrology, which were adjusted with the ensembles reflecting future climate conditions. Thus, the steps in **Figure E-6** were applied four times total. The final hydrologic input files for the Water Forward WAM consist of 77 years of period of record hydrology, either historical or adjusted for future climate conditions, plus an additional 9,923 years of extended hydrology stochastically sampled from the period of record. The total length of the input hydrologic datasets is 10,000 years.

High, Upper 1/3
Medium, Middle 1/3
Low, Lower 1/3

Step #1 Classify each year in period of record based on annual flow volumes

1940	1950	1960	1970	1980	1990	2000	2010
1941	1951	1961	1971	1981	1991	2001	2011
1942	1952	1962	1972	1982	1992	2002	2012
1943	1953	1963	1973	1983	1993	2003	2013
1944	1954	1964	1974	1984	1994	2004	2014
1945	1955	1965	1975	1985	1995	2005	2015
1946	1956	1966	1976	1986	1996	2006	2016
1947	1957	1967	1977	1987	1997	2007	
1948	1958	1968	1978	1988	1998	2008	
1949	1959	1969	1979	1989	1999	2009	

Step #2 Calculate transition probability between states based on the observed transitions

		Annual Transition State		
		Low	Med	High
Prior	Low	42.3%	38.5%	19.2%
Annual	Med	26.9%	26.9%	46.2%
State	High	33.3%	33.3%	33.3%

Step #3 Select sequence of states	**Step #4** Select specific year
High	2007
Med	1985
Med	1966
Low	2012
Low	1947
Med	1995
Low	2006
Low	1972
Low	1993
High	1957
High	1965
Med	2000
Med	1994
Low	2011
Med	1978
High	1951
High	1989

Step #5 Build extended WAM hydrology input files according to the sequence of selected years

Figure E-6. Steps for building extended WAM hydrology input with MCMC

E.3 Droughts Identification and Selection

The preceding section of this report describes the methodology to extend the Colorado WAM period of record beyond the 77-year historical period of record covering January 1940 through December 2016. Two major drought sequences are contained within the period of record and are conventionally known as the droughts of the 1950's and 2010's. Previously, the 1950's drought was known as the drought of record (DOR) and represented the worst water availability conditions in the lower Colorado River Basin. However, the drought of the 2010s is considered to be the new DOR for Water Forward Planning purposes. Extension of the historical record was selected as the methodology to assess drought conditions that may exceed the DOR.

It is expected that additional major drought sequences will occur within the 100-year planning horizon of Water Forward. One or more of the expected future droughts may produce worse river and reservoir water availability conditions than experienced in either of the droughts of the 1950s or 2010s. Such future drought conditions are designated as droughts worse than the drought of record (DWDR) because the conditions are not yet part of the historical record. It is essential for a long-term water resources plan to anticipate the likelihood of DWDR events occurring within the planning horizon.

The extended hydrology datasets representative of the historical record and those adjusted for future climate change conditions are utilized for detection and characterization of DWDR events. The goal of the work described in this section is to rank major drought events and select a group of candidate or design droughts that can be considered as possible DWDR events relative to the 2010's DOR. Techniques to identify drought sequences and to estimate the return period of major droughts are utilized. Based on estimated return periods, a group of candidate droughts within a range of probability of occurrence in 100 years is proposed for evaluation with the Water Forward portfolios of options.

E.3.1 Definition of Drought

Droughts are prolonged periods of conditions that are lower than normal. Droughts can be defined for many different hydrologic conditions or their associated impacts (Maidment, 1993; Heim, 2002). Meteorological droughts involve the prolonged absence or diminished abundance of precipitation over a given area. Meteorological droughts lead to additional types of drought conditions. Agricultural droughts may be characterized by lower than necessary soil moisture or water availability for crops or livestock. Hydrologic droughts may be characterized by deficits in streamflow or reservoir storage necessary for support of aquatic life or water supply for human activity. Socioeconomic droughts may be characterized by the loss of economic activity as a result of meteorological, agricultural, hydrological, or other deficient physical conditions.

There exists a long history of and abundant methods for characterizing droughts (Heim, 2002; Ward, 2013). In this work, drought detection and characterization are focused on the effects to streamflow in the Colorado River. Thus, the term drought is used synonymously with hydrologic drought and specifically with the characterization of below normal streamflow conditions. Hydrologic droughts can be characterized by duration, magnitude or greatest measurement of deficiency, severity or cumulative deficiency, and frequency of occurrence. Both the duration and severity of the streamflow deficits are considered in this work because both variables impact the water supply to the City of Austin during multi-year droughts, either from direct diversion of available streamflow or from reservoir storage. Frequency of occurrence is derived from analysis of duration and severity.

E.3.2 Standardized Runoff Index

The standardized precipitation index (SPI) was developed by McKee et al. (1993) as a drought characterization tool. The SPI has since gained wide use for communication of precipitation departure from average conditions. The National Climatic Data Center (NCDC) publishes updated SPI coverages for the United States for precipitation aggregation periods of 1 to 24 months to evaluate short- and long-term drought conditions. The SPI is also one of the constituent drought indices incorporated into the U.S. Drought Monitor.

The standardized runoff index (SRI) is calculated in exactly the same manner as the SPI (Shukla and Wood, 2008). Whereas the SPI is calculated using precipitation values, the SRI is calculated using streamflow values. The SPI or SRI are calculated in the following manner. The streamflow values are aggregated over a user-defined accumulation period. Each value in the dataset represents the total flow in the user-defined preceding number of time intervals, which in this case are months. The accumulated flows are fit to a probability distribution to establish a relationship of cumulative probability to accumulated flow. The cumulative probabilities, which have a value range between 0 and 1, are transformed to standard normal (Gaussian) deviates, also known as the Z-scores. The Z-scores are the value of the SRI and have a mean of zero and a standard deviation of 1. The SRI values indicate how many standard deviations the data are away from the mean. Half of the SRI values exceed zero, indicating that the accumulated flows exceed the long-term average. Correspondingly, half of the SRI values are less than zero, indicating accumulated flows are below the long-term average.

The SPI/SRI methodology was selected for this work for several reasons. The methodology has widespread acceptance and is relatively easy to calculate. The user-selected averaging period allows the SRI to be adjusted to reflect an accumulation period that may be relevant to a particular measure of drought conditions. In this work, an 18-month accumulation period of lower basin naturalized flows was found to produce an SRI that best approximates the duration of the drought of the 2010s. The SRI values are standardized and can be compared to differing climatic conditions. This property of the SRI allows it to be compared between historical naturalized flows or the adjusted hydrologic datasets derived from adjustment for future climate conditions.

Drought events are identified from the SRI whenever the value is negative, i.e., the accumulated streamflow value is less than the long-term average. Drought duration can be calculated by counting the number of consecutive SRI values that are either below zero or below a threshold that indicates a qualifying dry state. For this work, a month in which the SRI was less than -0.1 is counted towards the drought category in order to avoid prematurely detecting only slightly below average streamflow conditions. Once a drought duration is established for consecutive months of SRI below the threshold, the drought severity is calculated by summing all of the negative values of the SRI. The drought severity is a unitless number that can be compared between historical- or climate-adjusted naturalized flow datasets.

The monthly lower basin naturalized flows at the location of Lake Travis in the WAM are shown in **Figure E-7** for the period of January 2000 through December 2016. The flows in **Figure E-7** correspond to the historical naturalized flows without adjustment for future climate conditions. From the perspective of the SRI, the drought of the 2010s begins after the high flow event in 2010. Drought relief is provided between high flow events in mid-2015 and mid-2016.

It should be noted that the SRI's streamflow-based calculation of drought starting and ending dates may be different than drought starting and ending dates obtained from a traditional reservoir firm yield analysis. The SRI is an indicator of above or below average streamflow conditions and is independent of factors affecting reservoir water supply. Both the SRI and the traditional firm yield analysis will identify the same general periods of low streamflows. However, drought starting and ending dates identified with a firm yield analysis will reflect a combination of streamflow conditions, reservoir specific storage capacity, and basin-wide water rights utilization assumptions.

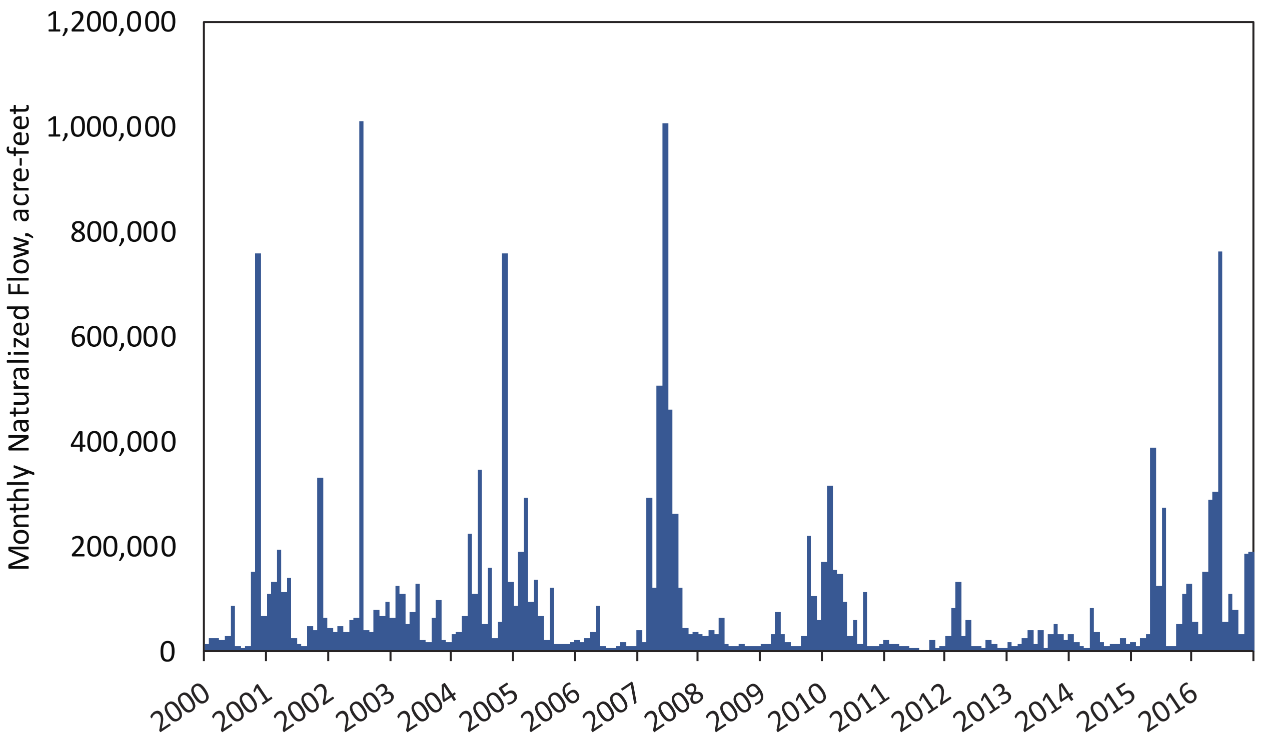

Figure E-7. Lower basin monthly naturalized flow at Lake Travis

An 18-month accumulation period was applied to the monthly naturalized flows and is shown in **Figure E-8**. The accumulation period was iteratively changed based on the outcome of the SRI calculation. The 18-month accumulation period was found to create SRI values that best reflected multi-year river and reservoir water availability in the lower Colorado Basin during drought conditions before and after the elevated flows in late 2009 through mid-2010. Each monthly value in **Figure E-8** represents the total flow in the preceding year-and-a-half period. The monthly accumulation values for the entire 10,000-year extended dataset were found to fit best to a 3-parameter gamma probability distribution to produce cumulative probability values uniformly distributed between 0 and 1.

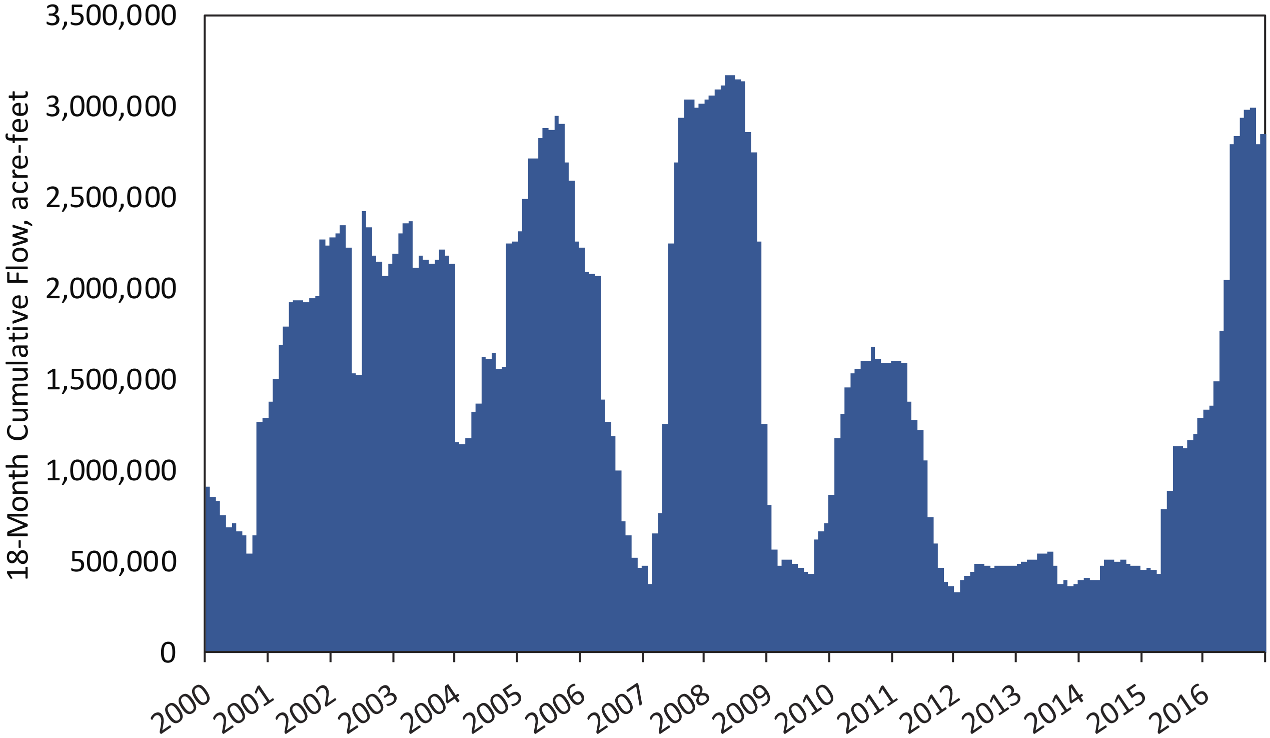

Figure E-8. Monthly lower basin naturalized flow at Lake Travis with an 18-month accumulation period

The cumulative probabilities were transformed to standard normal Z-scores to create the SRI. The SRI values for the 2000-2016 example period are shown in **Figure E-9**, with the drought of the 2010s indicated. As seen in **Figure E-9**, the elevated flow period in late 2009 through mid-2010 created a short period of positive SRI values. This alleviated naturalized flow drought conditions that began to form in 2008. Based on negative SRI values, the 2010s' drought had a duration of 59 months, from April 2011 through February 2016. Individual months of low naturalized flows began prior to April 2011. However, an 18-month accumulation period is being applied, and the elevated flows of late 2009 through mid-2010 were not offset until 2011. The minimum SRI value during the drought is -2.5 in January 2012 and is indicative of extreme drought conditions in the preceding 18 months. The drought severity, as measured by the sum of the absolute values of SRI during the drought period, is 93.

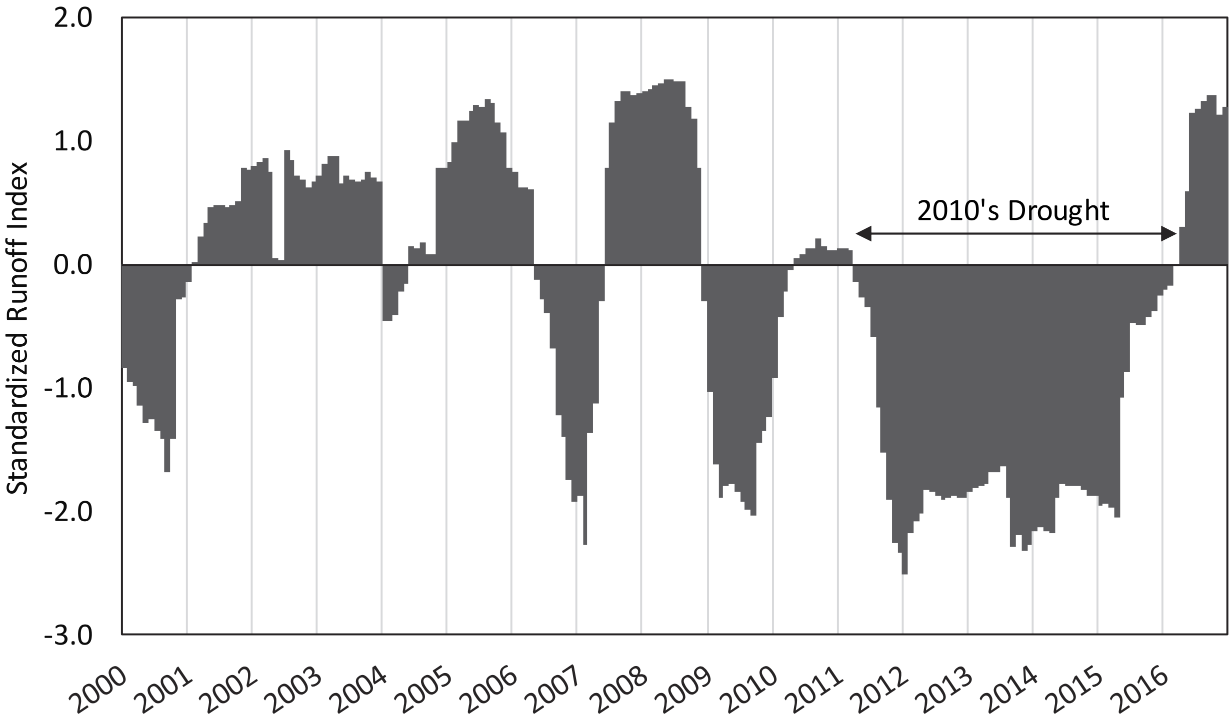

Figure E-9. Monthly SRI values

E.3.3 Drought Return Period

The extended hydrologic dataset covers 10,000 years of monthly values of naturalized flow and net evaporation-precipitation. Extended hydrologic datasets were created for conditions reflecting the historical observation, as well as for the three ensemble periods reflecting modeled future climate conditions. The first 77 years of each extended dataset correspond to the historical period of record. The remaining 9,923 years of monthly values are derived from resampling the first 77 years. An SRI time series was created for each extended naturalized flow time series at Lake Travis, as described above.

Droughts are identified in SRI time series when the value falls below zero. A threshold of -0.1 was applied to avoid detecting conditions that may not be meaningfully below the average of zero. Consecutive months of negative SRI values are counted as contiguous drought events. The drought event durations can be calculated as the number of consecutive months of SRI values below the threshold. Likewise, the severity of drought events can be calculated as the absolute value of the sum of SRI values during the event duration.

Figure E-10 and **Figure E-11** show the distribution of SRI-derived durations and severities of selected drought events for the extended naturalized flows at Lake Travis for the historical hydrologic conditions. The distributions shown in the figures were limited to drought events with at least 12 months of duration. In total, 1,365 drought events were identified. An additional 1,769 events have durations of 1 to 11 months but were excluded for their low duration and severity values and lower relevancy to multi-year river and reservoir water availability.

Recall that half of the SRI values are greater than zero and the other half are less than zero, indicating accumulated flow conditions above or below the long-term mean. There are 120,000 monthly values of

SRI, one for each month in the extended naturalized flow. The identified 1,365 drought events under historical hydrologic conditions have an average duration of 33.7 months. Therefore, approximately 46,000 of the 120,000 months are part of the identified droughts. The remaining 74,000 months have SRI values above zero or are part of periods with minor or short-term below average flows. The average interarrival time between the 1,365 identified droughts is 87.9 months, or 7.3 years, and will be used to calculate return period, as discussed below.

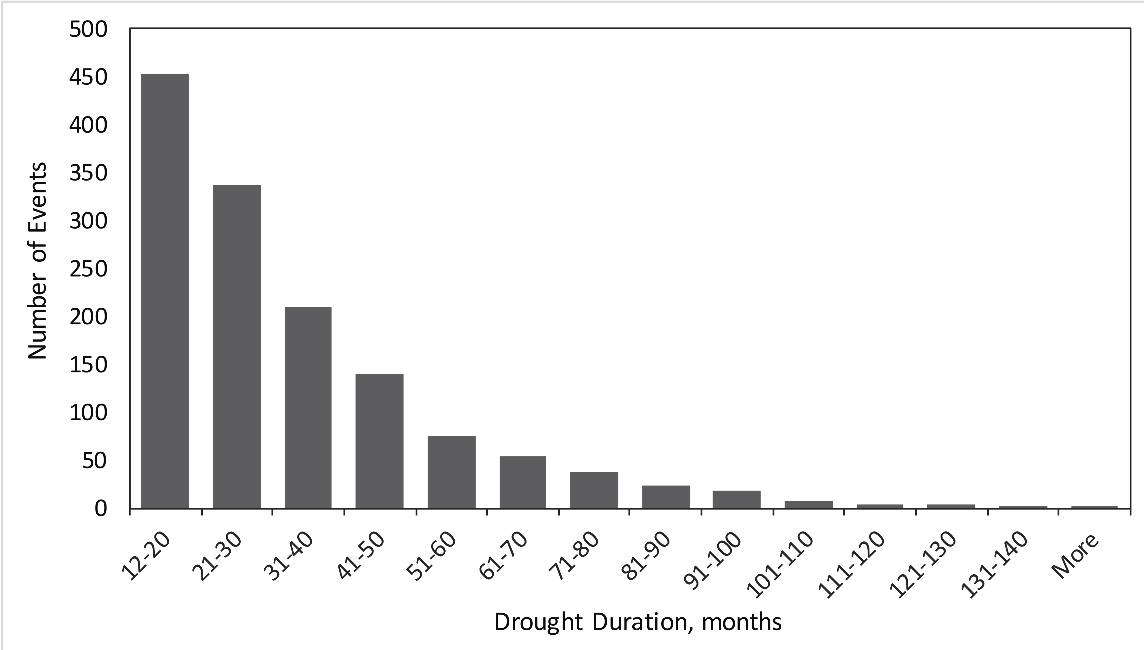

Figure E-10. Distribution of drought duration

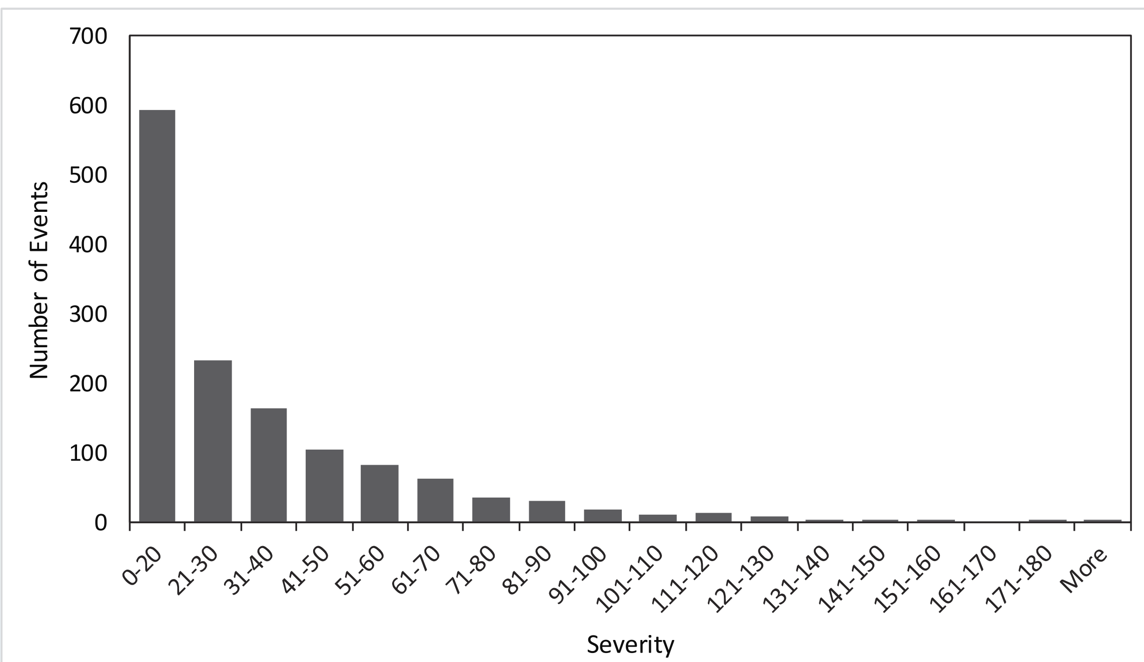

Figure E-11. Distribution of drought severity

Duration and severity are two common measures to characterize drought events. A large amount of research exists on the relationship of either duration or severity for characterizing drought event probabilities (Shiau, 2006). However, duration and severity are related measures. Consideration of the two measures jointly provides more information about the probability of droughts occurring than consideration of a single measure alone. A scatter plot of drought severity and duration is shown in **Figure E-12** to illustrate the close relationship between the two measures. The linear correlation of the measures shown in the figure is 0.93.

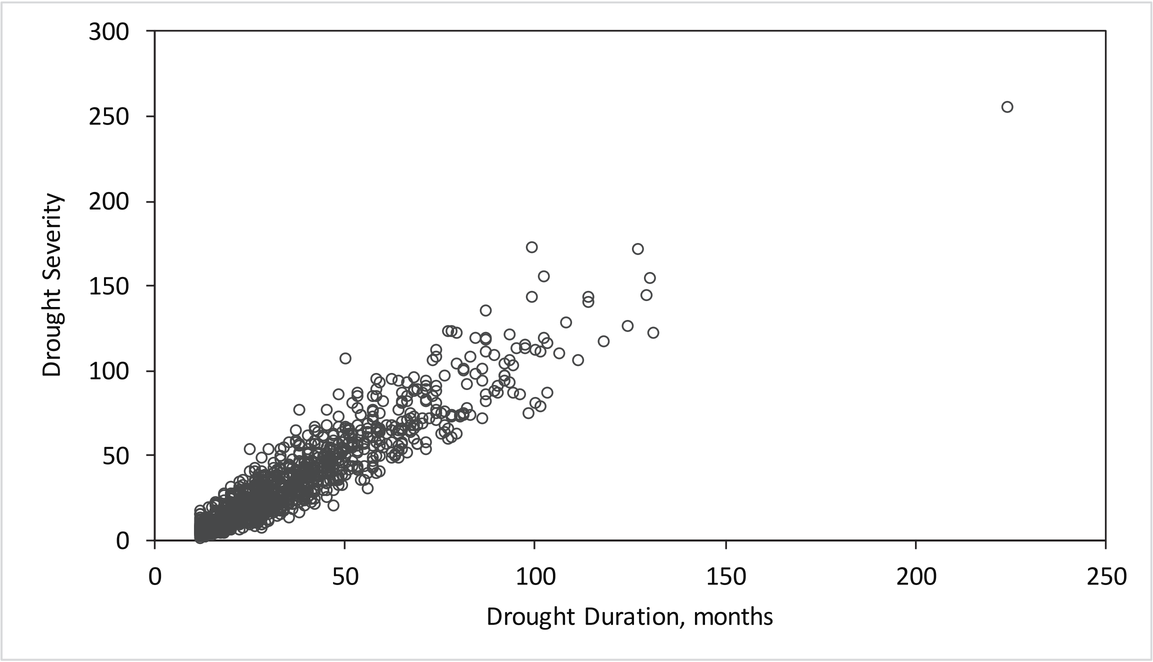

Figure E-12. Drought severity versus duration

To estimate the joint probability of drought duration and severity, the probabilities of the two individual variables are first estimated. Probability distributions are fit to both the duration and severity distributions shown in **Figure E-10** and **Figure E-11**. The probability distributions may be the same, but that is not required. For the examples shown in **Figure E-10** and **Figure E-11**, the best fits were found to be the Weibull and Inverse Gaussians distributions, respectively.

With duration and severity fit to probability distributions, the joint probability of the two variables can be assessed with a function known as a *copula* (Genest and Favre, 2007). Copulas are functions that relate the dependence between two or more variables without requiring the individual variables to be derived from the same probability distributions. A copula from the Archimedean family was fit to relate the joint probability of duration and severity.

Drought event return period can be estimated using the univariate distributions for duration and severity and the joint distribution of the two variables (Shiau, 2006). The return period of drought events in the historical extended datasets, in which duration and severity both exceed certain thresholds, is mapped to contour plots shown in **Figure E-13**. The same return period contour map for drought events in the extended dataset as adjusted for the year 2100 climate change ensemble is shown in **Figure E-14**. The 2010s' drought event is plotted with a black square. The 1950s' drought event is plotted with a black triangle. Drought events that exceed the return period of the 2010s' drought but have a return period of less than 450 years are plotted with red circles. The meaning of the red circles is explained in the next section. All other drought events are plotted with gray circles. The gray circles in the bottom left of the plots have return periods equal to the average interarrival time between droughts, which equal 7.3 and 6.5 years for **Figure E-13** and **Figure E-14**, respectively.

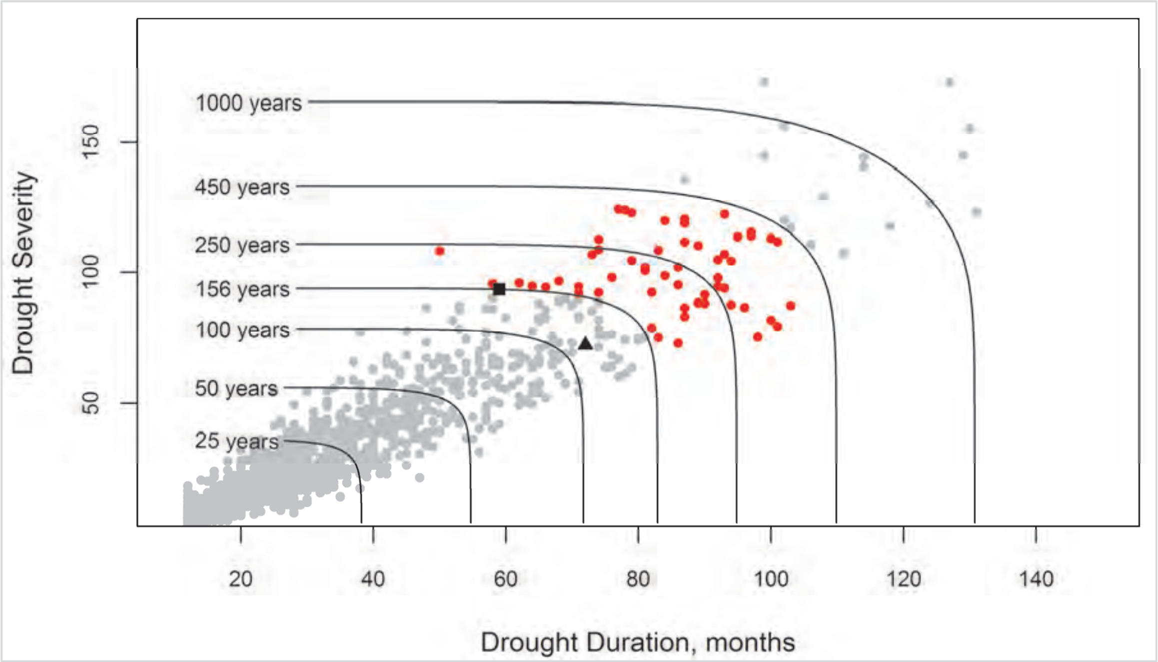

Figure E-13. Joint drought duration and severity return period, historical extended hydrology

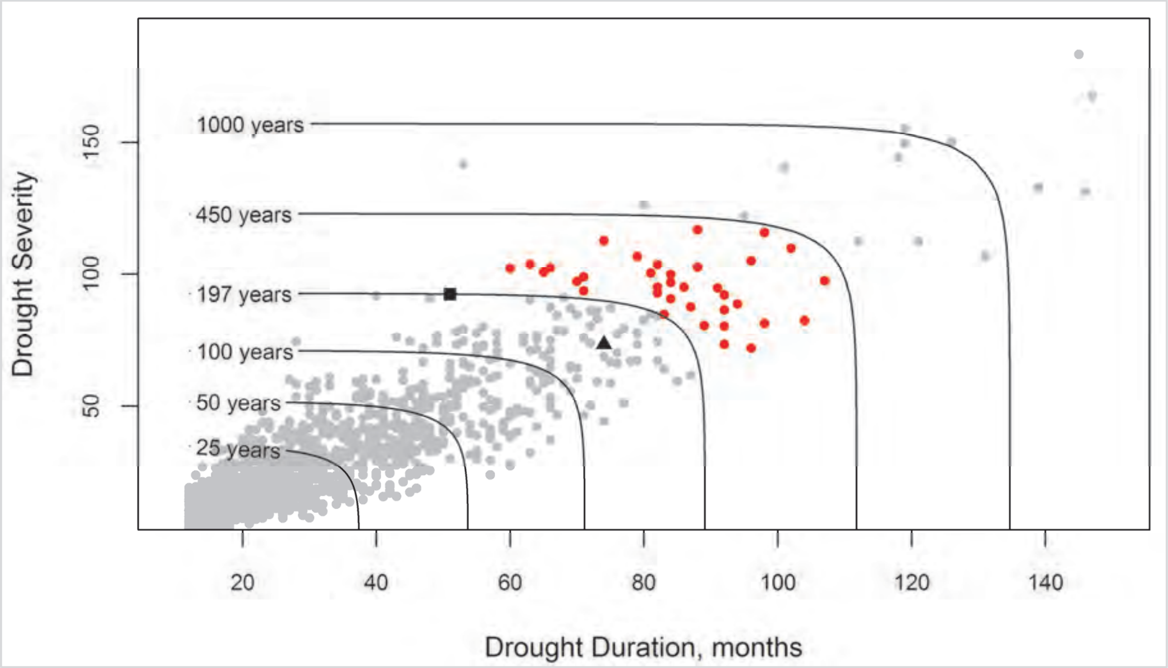

Figure E-14. Joint drought duration and severity return period, extended hydrology with 2080-2100 climate change ensemble adjustment

E.3.4 Candidate Droughts

The two major droughts in the historical record are the droughts of the 1950s and 2010s, with the latter representing the DOR. As shown in **Figure E-13** and **Figure E-14**, the DOR status is confirmed by the higher return period for the 2010s' drought. The extended hydrologic datasets contain a large number of drought events with varying return periods representing frequent short-term drought events to infrequent and extreme droughts. The number of droughts to be considered as potential DWDR events was narrowed based on return period and the corresponding risk of occurrence.

Return period does not indicate that a given event has 100% certainty of occurring in a given interval of time. For example, an event assigned a 100-year return period has a probability of 1 in 100 in any given year. Over the course of 100 years, an event with a 100-year return period can be expected to occur at least once, with a probability of approximately 63%. Over the course of a theoretically very long observational period, an event with a 100-year return period would tend to occur on average every 100 years.

The associated probability or risk of at least one event occurring in a given number of years of observation for a given or greater return period is calculated by subtracting the probability of non-occurrence from 1. The following equation provides a calculation for the occurrence risk:

$$Occurrence\ Risk = 1 - \left(1 - \frac{1}{T}\right)^N$$

where *T* is the return period expressed in years and *N* is the number of year of observation. The equation is presented graphically in **Figure E-15** for various return periods and observation years.

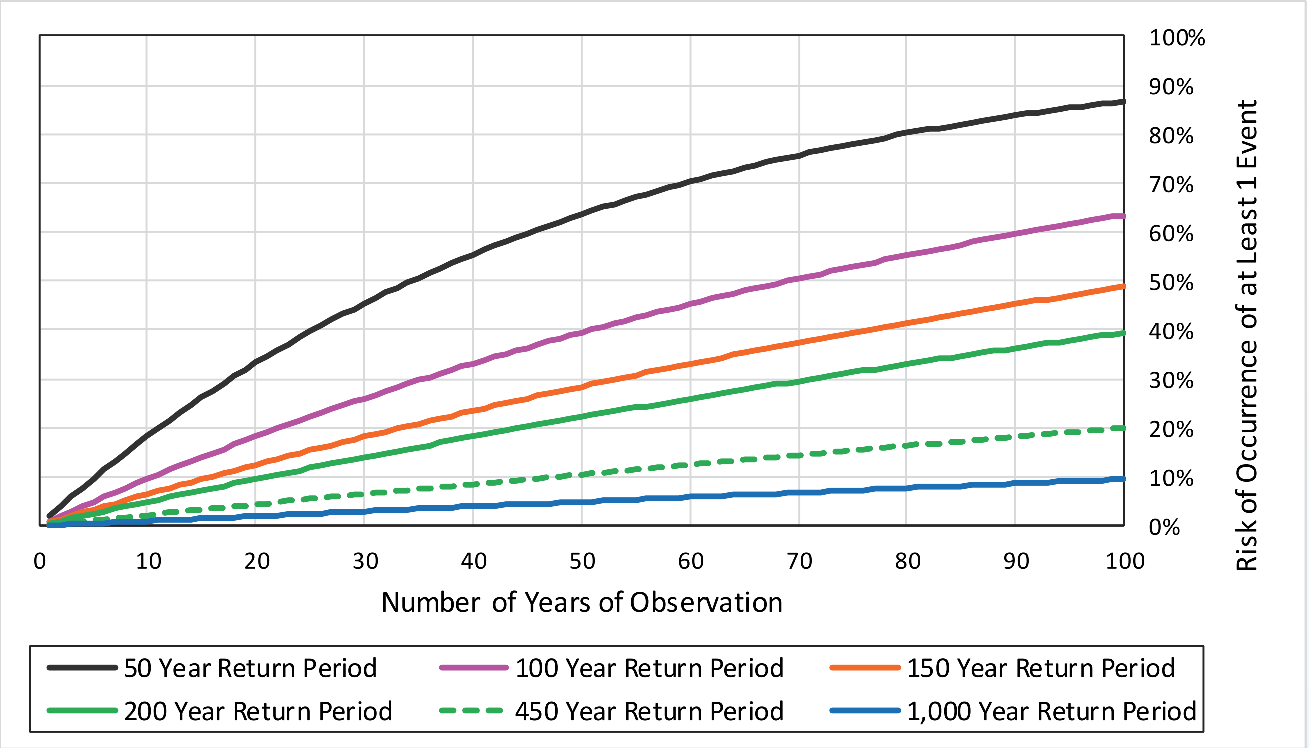

Figure E-15. Risk of occurrence versus years of observation

Selection of candidate DWDR events for evaluating water availability was based on risk of occurrence. Selecting all drought events in the extended hydrologic dataset would include events with a very low risk of occurrence in the 100-year planning horizon. Conversely, selecting drought events only slightly worse than the DOR would not provide an adequate level of assurance that the recommended strategies in the Water Forward plan could perform as necessary during DWDR conditions. Based on judgement and conservative planning, the candidate DWDR events were selected that had up to a 20% risk of occurrence within the 100-year planning horizon. This is equivalent to approximately at 450-year return interval.

Candidate DWDR events are plotted with red circles in **Figure E-13** and **Figure E-14**. The candidate events have a return period greater than the drought of the 2010s and less than 450 years. The candidate droughts represent a range of durations and severities that is important for performance evaluation of the water management strategies. For the historical extended hydrologic dataset, there are 56 candidate droughts. Under the future climate change conditions represented in **Figure E-14**, the DOR increased in estimated return period. This reduced the number of candidate droughts to 35.

The use of a return period methodology that incorporates two variables, duration and severity, provides a greater diversity of candidate droughts. In both **Figure E-13** and **Figure E-14**, it can be seen that the 2010s' DOR has a shorter duration than most droughts of a similar or greater return period. The 2010s' drought severity is high for droughts of similar duration. By incorporating both duration and severity, candidate DWDR events can be selected that have lower severity but greater duration than the 2010s' DOR. This provides a greater breadth of planning information than if candidate droughts had been selected based on either duration or severity as the only selection criterion.

Tables E-4 and **E-5** provide a selection of drought events from the historical and future climate change adjusted extended datasets. The ending year and month in the dataset are indicated in the two leftmost columns. The years in the extended dataset begin with zero. However, the first 77 years of the dataset correspond to 1940 through 2016. Therefore, the drought of the 1950s has an ending year of 12, which corresponds to 1952, and the drought of the 2010s has an ending year of 75 or 76, which corresponds to 2015 or 2016. Extended hydrology beyond 1940-2016 are indicated by simulation years 77 through 9,999.

The bottom two rows of each table contain information for the droughts of the 1950s and 2010s. The remaining rows of each table are a small selection of DWDR events in the extended hydrology. The DWDR events in both tables have equivalent risks of occurrence in 100 years. The far right column of each table indicates if the DWDR was designated as a candidate DWDR event for evaluation in Water Forward.

The drought severity measure is a summation of all SRI values during the drought duration. Severity is a standardized measure and is comparable across climatic conditions. The drought events in **Table E-4** and **Table E-5** have a similar range of severity. However, the average annual naturalized flow volume is significantly different between the historical and climate change adjusted datasets. For example, the naturalized flow during the drought of the 2010s under the future climate change condition is only 43% of the historical annual average.

Table E-4. Selected drought events, historical extended hydrology

End Year	End Month	Duration, Months	Severity, Unitless	Annual Average Nat. Flow, ac-ft/yr	Return Period, Years	Risk of at Least 1 Occurrence in 100 Years	Candidate DWDR, Yes/No
6472	5	131	123	630,000	1,207	8%	No
1021	12	99	145	580,000	716	13%	No
761	2	102	120	600,000	471	19%	No
1976	10	100	113	590,000	403	22%	Yes
2911	4	84	120	540,000	346	25%	Yes
8594	7	92	105	595,000	292	29%	Yes
577	11	94	88	630,000	260	32%	Yes
593	1	50	108	430,000	233	35%	Yes
76	2	59	93	595,000	156	47%	No
12	8	72	72	605,000	114	59%	No

Table E-5. Selected drought events, extended hydrology w/ 2080-2100 climate change ensemble adjustment

End Year	End Month	Duration, Months	Severity, Unitless	Annual Average Nat. Flow, ac-ft/yr	Return Period, Years	Risk of at Least 1 Occurrence in 100 Years	Candidate DWDR, Yes/No
1522	6	139	133	260,000	1,213	8%	No
3455	3	53	142	110,000	708	13%	No
4737	12	95	122	210,000	468	19%	No
1716	7	107	98	235,000	409	22%	Yes
422	12	96	105	225,000	343	25%	Yes
3555	2	88	103	250,000	296	29%	Yes
7439	8	66	102	130,000	265	32%	Yes
2178	3	70	97	185,000	233	35%	Yes
75	6	51	92	255,000	197	40%	No
12	8	74	73	245,000	141	51%	No

E.3.5 Uncertainty

The goal of the work described in this section is to select a group of candidate or design droughts based on a relative ranking. The candidate droughts can be considered as possible DWDR events relative to the 2010s' DOR. Techniques to identify drought sequences and to estimate the return period of major droughts are utilized. Based on estimated return periods, a group of candidate droughts within a range of probability of occurrence in 100 years is proposed for evaluation with the Water Forward portfolios of options.

The methodology applied requires fitting of probability distributions calculations of the SRI, probability of duration and severity, and a copula model for the joint probability of duration and severity. As such, the methodology is sensitive to the goodness-of-fit of the distributions. Many probability distributions and copula were tested at each step of the methodology, and the best fits were chosen. Creating the extended hydrology sequences also required calculation of transition probabilities between states of high, medium, and low annual flows. Therefore, there is inherent uncertainty because of the necessary model-upon-model approach to arrive at drought return period.

The historical record, 77 years, is relatively short for characterization of the return period of major multi-year droughts such as the droughts of the 1950s and 2010s. The short length of the historical record and the uncertainty described above should be considered with respect to the estimated drought return periods of those specific droughts. Additional years of hydrologic observation will improve drought return period estimation. However, the goal of the work was not to accurately estimate the drought return periods of those two events. Instead, the goal was to select candidate drought events that are worse than the 2010s' DOR. To this end, the methodology was successful, and groups of DWDR events were selected for the historical hydrologic condition and the climate change adjusted hydrology datasets.

E.4 Water Management Scenario Modeling Assumptions

The TCEQ WAM System is introduced and described in Section 1 of this appendix. The WAM system is comprised of two components: generalized computer modeling software known as the WRAP and a set of basin specific input files and supporting GIS coverages. The WAM uses naturalized streamflow, net lake evaporation minus precipitation, and a water management scenario as its three main inputs for every river basin. The WAM simulates surface water availability to basin water rights under the specified water management scenario through a repeat of the input hydrologic conditions. TCEQ, other state agencies, planners, and permit holders use the WAM for a variety of applications ranging from permitting to short-term and long-term planning.

Appendix D focus on modeling assumptions for the hydrologic inputs of the Water Forward WAM. Climate change adjustments, extension of the hydrologic period of simulation, and drought analysis are addressed. This section of the report focuses on the WAM modeling assumptions for water management scenarios. The assumptions cover basin-wide water management as well as those specific to the City of Austin and the Water Forward planning process.

E.4.1 Baseline Assumptions of the Water Forward WAM

Modified versions of the TCEQ WAM are created to suit specific permitting and planning applications. Modifications to the Colorado WAM used by Region K and LCRA, as well as the baseline modifications for the Water Forward WAM, are described in **Appendix D**. The baseline modification for the Water Forward WAM mirror those contained in the Region K Cutoff Model and the LCRA WMP WAM.

The Water Forward WAM baseline assumptions include the following:

- Austin and other lower basin firm customers demand projections for 2020, 2040, 2070, and 2115.
- Weather-variable lower basin agricultural demands for 2020, 2040, 2070, and 2115.
- Demand increases of 2%, 4%, and 6% for firm customers as estimates of future climate change impact on demand in 2040, 2070, and 2115 for hydrologic scenarios modelled with climate change.
- Demand increases for lower basin agricultural demand for future climate change in 2040, 2070, and 2115 calculated with weather variable-demand equations that consider precipitation and evaporation.
- Interruptible stored water availability for lower basin agriculture maintained according to the 2015 LCRA WMP through 2040 with conversion to lower basin supplies only between 2040 and 2070.
- Conservation capacity for lakes Buchanan and Travis adjusted for future sedimentation estimates through 2100.

- 2015 LCRA WMP instream flow targets and bay and estuary inflow targets, including lake-level triggering levels, are maintained through 2115, but with proportional adjustment of the lake-level triggering levels to account for future sedimentation of lakes Buchanan and Travis.

- Firm and interruptible demands downstream of the Longhorn Dam are provided run-of-river availability according to estimates of reliable baseflow supplies.

- The amended LCRA Garwood water right is utilized for delivery of run-of-river water to LCRA customers after first meeting agricultural irrigation demands.

- LCRA Arbuckle off-channel reservoir operational and providing for agricultural and firm demands, and Matagorda Bay threshold needs in all time horizons.

- Drought contingency curtailment of firm customer demands at 900,000 acre-feet or less of combined storage in lakes Buchanan and Travis.

- Pro-rata curtailment of firm customer demands begins at 600,000 acre-feet of combined storage with a second level of increased pro-rata curtailment at 450,000 acre-feet.

- City of Austin municipal demand curtailment is implemented according to levels in the city's drought contingency plan according to the following combined storage schedule:

  - Full to 1.4M acre-feet: Conservation Stage.

  - 1.39M to 900k acre-feet: Stage 1.

  - 899k to 600k acre-feet: Stage 2.

  - 599k to 450k acre-feet: Stage 3.

  - 449k or less: Stage 4 (trigger level assumed; actual implementation at the discretion of city management).

- Upper basin water rights, defined as all water rights upstream of lakes O.H. Ivie and Brownwood, are assigned a senior priority to all downstream water rights (priority "cutoff" assumption) while maintaining their relative upper basin priority order; the priority cutoff is consistent with Region K and LCRA planning assumptions.

- Other lower basin water rights, defined as all water rights not included the upper basin priority cutoff and not associated with LCRA or LCRA customers, are assigned a priority senior to all water rights associated with LCRA or LCRA customers but junior to all upper basin water rights. This second-tier priority cutoff is consistent with LCRA WMP modeling.

- All water rights not associated with LCRA or LCRA customers are modeled with demands according to the fully authorized water rights.

- Additional operational modeling assumptions for lakes Buchanan and Travis, such as "ordered but not diverted" deliveries of stored water, as contained in 2015 LCRA WMP Appendix A.

Demand projections for the City of Austin, other lower basin firm customers served by LCRA, and lower basin agricultural are presented in **Table E-6**. The City of Austin municipal demands shown in the table are for the baseline condition that does not include the advanced additional demand management, conservation, and non-potable reuse options considered in the Water Forward portfolios. City of Austin municipal demands were developed by the City's detailed disaggregated demand model (see **Appendix C**) for an average use case. The disaggregated demand model was also used to estimate return flow discharge to the Colorado River after accounting for direct reuse needs.

Table E-6. Lower Colorado River Basin demand projections

		Non-Climate Adjusted Demands				Climate Adjusted Demands		
	DEMAND CATEGORY All Demands in units of acre-feet per year	**Year 2020**	**Year 2040**	**Year 2070**	**Year 2115**	**Year 2040**	**Year 2070**	**Year 2115**
[1]	**Firm Demands**					***2.0%***	***4.0%***	***6.0%***
[2]	City of Austin Municipal Baseline Demand (Avg Year)	153,853	207,453	296,992	467,392	211,602	308,872	495,436
[3]	City of Austin Municipal Direct Reuse (Avg Year)	3,816	3,816	3,816	3,816	3,816	3,816	3,816
[4]	City of Austin Parks and LBL Evap	1,415	1,415	1,415	1,415	1,443	1,472	1,500
[5]	**City of Austin Baseline, Rows 2+3+4**	**159,084**	**212,684**	**302,223**	**472,623**	**216,862**	**314,159**	**500,752**
[6]	Fayette County (Downstream of lakes)	20,000	20,000	20,000	20,000	20,000	20,000	20,000
[7]	Sim Gideon / Lost Pines Demand	0	0	0	0	0	0	0
[8]	Llano County (Near/upstream of lakes)	5,500	11,300	20,000	20,000	11,300	20,000	20,000
[9]	**LCRA - Power Plant Demand**	**25,500**	**31,300**	**40,000**	**40,000**	**31,300**	**40,000**	**40,000**
[10]	Fayette County	9,000	9,000	9,000	9,000	9,000	9,000	9,000
[11]	Travis County	9,000	9,500	9,500	9,500	9,500	9,500	9,500
[12]	**City of Austin - Power Plant Demand**	18,000	18,500	18,500	18,500	18,500	18,500	18,500
[13]	Municipal Firm Contract Demand	65,684	97,170	143,046	169,000	99,113	148,768	179,140
[14]	LCRA New Contracts (2016 Region K Table 5-19)	2,877	19,154	33,654	45,000	19,537	35,000	47,700
[15]	Domestic lakeside use	5,000	5,000	5,000	5,000	5,000	5,000	5,000
[16]	LCRA Firm Irrigation	4,800	7,400	10,000	10,000	7,548	10,000	10,000
[17]	BRA - HB 1437 Demand	6,386	25,000	25,000	25,000	25,000	25,000	25,000
[18]	Manufacturing and Mining Demand	16,253	18,277	20,300	24,000	18,642	21,112	25,440
[19]	Other (Conveyance and Emergency Release)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
[20]	**Other Firm Demands**	**106,000**	**177,000**	**242,000**	**283,000**	**179,840**	**249,880**	**297,280**
[21]	**Total Firm Demand, Rows 5+9+12+20**	**308,584**	**439,484**	**602,723**	**814,123**	**446,502**	**622,540**	**856,532**
[22]	STPNOC ROR + LCRA Backup (Rolling Average)	102,000	102,000	102,000	102,000	102,000	102,000	102,000
[23]	Corpus Christi Garwood Water Rights	35,000	35,000	35,000	35,000	35,000	35,000	35,000
	Interruptible Agricultural Demand							
[24]	Garwood Demand (Dry - 90th Percentile)	89,700	85,300	79,200	69,300	90,369	86,546	77,258
[25]	Gulf Coast Demand (Dry - 90th Percentile)	147,400	113,400	103,900	88,600	136,928	127,371	111,875
[26]	Lakeside Demand (Dry - 90th Percentile)	135,500	128,100	119,300	106,700	137,464	131,580	121,074
[27]	Pierce Ranch Demand (Dry - 90th Percentile)	27,000	25,600	24,100	22,300	26,091	25,608	24,390
[28]	**Total Interruptible Agricultural Demand, Rows 24+25+26+27**	**399,600**	**352,400**	**326,500**	**286,900**	**390,852**	**371,106**	**334,597**

Firm customer demands, excluding the City of Austin municipal demands, were developed from information in the 2016 Region K Water Plan. Region K uses a 50-year planning horizon that currently extends through 2070. Demands beyond 2070 were extrapolated from the trend. Region K planning assumptions use demands for hot-dry conditions as could be expected during severe drought. Some firm customer demands have contractual limits and are represented in the table with a capped constant demand over time. The power generation demand in Bastrop County, Row 7 in the table, are almost entirely supplied from groundwater and thus are not represented as having a demand on the river and reservoir system.

Lower basin agricultural demand projections were taken from a technical paper contained in the 2015 WMP. The demands were provided in the technical paper on a decadal basis through 2060. The demand trend of the 2040-2060 decadal projections were extended to estimate agricultural demands for the 2070 and 2115 planning years. Seasonal weather variability of agricultural demands was developed from regression equations provided by LCRA to account for precipitation and evaporation conditions over the agricultural divisions.

The Water Forward planning horizon extends through 2115. Changes to demand projections, especially beyond the Region K planning horizon of 2070, can be expected as new information regarding population projections and per capita water use is developed. Regular updates in the Water Forward planning process will take new information into consideration, and the demands as presented in **Table E-6** will be adjusted accordingly. In addition to demand updates, the LCRA WMP will be updated over time to account for new demand projections and new hydrologic data. Interruptible stored water availability under updated WMPs will be incorporated into the modeling for Water Forward. The LCRA WMP also includes water for instream and bay and estuary inflow needs according to operational levels in lakes Buchanan and Travis. Updates to the Water Forward WAM will reflect changes in the WMP.

E.4.2 Source Assumptions for Water Supply Strategies

Demand management and water supply options to meet future City of Austin municipal needs were grouped into portfolios. Within the context of the Water Forward WAM, the portfolios were evaluated for their water supply benefits, particularly during periods of extreme drought. Definitions of water supply needs were developed for periods of extreme low storage conditions in lakes Buchanan and Travis and for long-term needs above the 1999 water supply contract between the City and LCRA. The 1999 Contract provides water from Colorado River sources to the City of Austin for municipal purposes up to an amount of 325,000 acre-feet per year.

Water supply and water conservation and demand management strategies are described in the main plan document. The definitions of Types 1, 2, and 3 water supply needs are described further in **Appendix F**. For reference, the definitions of Types 1, 2, and 3 water supply needs are given below:

Type 1—Water need in an amount equal to the estimated savings from the City's Stage 4 Drought Contingency Plan (DCP) implementation.

Type 2—Fifty percent of the amount of water the City expects to receive from LCRA supply when combined storage in lakes Buchanan and Travis is extremely low; for modeling purposes, this is assumed to be 450,000 acre-feet. Type 2 needs are calculated each month during the simulation and only when the City's existing run-of-river rights cannot fulfill the monthly municipal demand during extreme low lake levels.

Type 3—Amount of water above Austin's current LCRA contract for municipal supply of 325,000 acre-feet per year.

Water conservation and demand management strategies were indirectly modeled in the Water Forward WAM. For example, a portfolio's water conservation, demand management, and reuse strategies were applied toward reducing the total demand from the disaggregated demand model to calculate an adjusted total demand for physical water diversion. The total demands were distributed to each stage in the City's DCP plan. The DCP varying demands to be met from river and reservoir supplies were used as inputs for the Water Forward WAM.

Some water supply strategies are explicitly modeled in the Water Forward WAM. Based on the water source and intended water supply need to be addressed, the water supply strategies were entered as WRAP input record modeling code in the Water Forward WAM. Approximations were necessary since not all aspects of daily operation for water supply strategies can be represented in a monthly water availability model. The water supply strategies were modeled for conjunctive use with the City's existing run-of-river water rights and LCRA stored water supplies under the 1999 Contract. Water supply strategies were generally modeled as secondary sources to maximize utilization of the City's existing water rights and LCRA stored water supply.

E.4.2.1 Sources of Water Supply for Aquifer Storage and Recovery (ASR) and Off-Channel Reservoir (OCR)

Five authorizations contained in the City of Austin's water rights were considered as sources for the water supply strategies. The five authorizations were assumed to be applicable in a multi-use and system operations manner consistent with the principle of fully utilizing the City's water rights to meet demands under the 1999 Contract (see **Section 2** of the full plan report for more detail). It is acknowledged that the multi-use and system operations assumptions will require amendments to the City's water rights and cannot presently be implemented as modeled. The Water Forward Plan has a 100-year planning horizon, and it is expected that, if the recommended water supply strategies are pursued, water right amendments will be required over time.

The five authorizations used as sources for the water supply strategies are the following:

- 250,000 acre-feet per year for municipal use with a 1913 priority.
- 21,403 acre-feet per year for municipal use with a 1914 priority.
- 24,000 acre-feet per year for industrial cooling with a 1914 priority.
- 20,300 acre-feet per year for municipal use with a 1945 priority.
- 16,156 acre-feet per year for industrial cooling with a 1945 priority.

In total, the five authorizations provide 331,859 acre-feet per year of run-of-river water, although seldom, if ever, is there sufficient Colorado River streamflow across an entire year to divert the entire amount. Run-of-river diversions are subject to the prior appropriation system and hydrologic conditions, the latter of which is highly variable and frequently results in uneven distribution during the year. The five authorizations were modeled as first being utilized for their intended purposes. For example, the three municipal authorizations were modeled as first providing water for municipal demands. Unutilized portions of the authorizations on an annual basis were made available to water supply strategies.

Two water supply strategies that make use of unutilized portions of the five authorizations are aquifer storage and recover (ASR) and an off-channel reservoir (OCR). Since both strategies derive water from the City's existing water rights, water supplies from ASR and OCR are only applied to meeting Type 1 and Type 2 needs. Demands in excess of 325,000 acre-feet per year are considered Type 3 needs and are beyond the scope of the 1999 Contract. Alternate sources of water not derived from the City's water rights are used for meeting Type 3 needs.

Water to be stored in the ASR facility is modeled as being diverted at Lake Austin from existing water treatment plant infrastructure. In any month, if there is vacant storage capacity in the ASR and if there are unused portions of any of the five authorizations, then run-of-river water is diverted for injection into the ASR. If vacant storage capacity still exists after use of the five authorizations, and if there is remaining injection rate capacity, unused amounts of the 1999 Contract for stored water are diverted. If a portfolio has a Type 3 need, then there is no unused amount under the 1999 Contract, as an assumption. Stored water under the 1999 Contract is only modeled for ASR injection if combined storage in lakes Buchanan and Travis is 1.4M acre-feet or greater to minimize any impacts to lake levels.

Water to be stored in the OCR facility is modeled as being diverted into the river reach downstream of Longhorn Dam and upstream of discharge points of any Austin wastewater treatment plant. No diversion point presently exists for the five authorizations in this reach. The location is for modeling purposes only. Diversion from the Colorado River with the five authorizations for storage in the OCR is modeled with the junior-most priority in the basin. Because the OCR could have a high pumping rate, all LCRA WMP instream flow conditions and bay and estuary inflows are checked prior to diversion. Senate Bill 3 environmental instream flow standards at the Bastrop stream gauge are also modeled. The location, junior priority, and multiple environmental flow considerations are intended to provide a conservative estimate of water availability and to avoid impacts to all existing needs for streamflow.

E.4.2.2 Source of Water Supply for Indirect and Direct Potable Reuse

Indirect potable reuse (IPR) is modeled as a strategy for meeting needs under extremely low combined storage levels. If combined storage is below 450,000 acre-feet, a fraction of Austin's return flow is modeled as discharged into Lady Bird Lake for indirect reuse purposes. Although IPR was modeled as coming online if combined storage is below 450,000 AF, in actual operation Austin Water would plan to utilize this strategy only if combined storage is below 400,000 AF. Diversion from Lady Bird Lake occurs in an amount equivalent to the return flow discharge. IPR is only utilized to meet Type 1 and Type 2 needs.

Direct potable reuse (DPR) is modeled as a supply source derived from the City's wastewater treatment plant's effluent stream prior to discharge to the Colorado River as return flow. A fraction of the effluent stream is modeled as directly recycled to the water treatment plant facilities. DPR is utilized to meet Type 1 and Type 2 needs during extremely low lake-level conditions. It is also utilized to meet Type 3 needs for portfolio scenarios with demands in excess of the 1999 Contract.

E.4.2.3 Source of Water Supply for Other Strategies

The portfolio scenarios may contain three additional water supply strategies not derived from the Colorado River Basin. All three strategies are modeled with alternative water sources provided in the model but unrelated to naturalized inflows or return flows. Brackish groundwater desalination, seawater desalination, and imported groundwater are modeled as strategies to meet Types 1, 2, and 3 needs. Seawater desalination and imported groundwater were not modeled together based on the portfolio compositions.

E.4.3 Order of Water Supply Strategy Utilization

Under the 1999 Contract, the City's municipal run-of-river water rights are utilized to meet municipal demands as streamflow is available. The demands are input to the model with adjustments for conservation and demand management strategies included in the respective portfolios. The monthly demands are lowered from Conservation Stage down to Stage 4 as combined storage in lakes Buchanan and Travis decrease. Any unmet monthly municipal demand is met from either the portfolio's water supply strategies or LCRA sources. When in Conservation Stage, the overall municipal demand that is eligible to be met from LCRA sources cannot exceed 325,000 acre-feet per year (1999 LCRA contract amount).

The order in which the City's municipal demands are met under the 1999 contract, from Conservation Stage to Stage 4, is as follows:

1. Austin's municipal run-of-river water rights.
2. If the City's river demands are lowered to Stage 4, then portfolio water supply strategies are used to satisfy the Type 1 need, which is calculated in the model as the difference between Stage 3 and Stage 4 demands. Type 1 needs are met from water supply strategies in the following order:
    a. Aquifer storage and recovery.
    b. Off-channel reservoir.
    c. Brackish groundwater desalination.
    d. Direct potable reuse.
    e. Seawater desalination or imported groundwater.
    f. Indirect potable reuse.
3. If the City's run-of-river water rights have not fully satisfied the monthly municipal demand, and Stage 4 demands are in effect, the Type 2 need is calculated. Water supply strategies are used to meet the Type 2 need in the following order:
    a. Aquifer storage and Recovery.
    b. Off-channel reservoir.
    c. Brackish groundwater desalination.
    d. Direct potable reuse.
    e. Seawater desalination or imported groundwater.
    f. Indirect potable reuse.
4. The remaining unmet monthly municipal demand is met from LCRA sources. If Stage 4 demands are not in effect, Steps 2 and 3 above are skipped.

Storage content in the ASR and OCR facilities is derived from the City's five water right authorizations. The ASR facility is not modeled as diverting water for injection during times when Stage 3 or Stage 4 demands are in effect. The OCR is modeled with the ability to divert and store water at any time that streamflow is available and there is vacant storage capacity in the reservoir. However, there may be little to no available water for many months during extreme drought conditions. The ASR and OCR can be viewed as finite resources during extreme drought and utilized in a manner to extend their storage content to the greatest degree. Though the ASR and OCR are listed as the first two options for meeting Type 1 and Type 2 needs, the model attempts to reserve their utilization if the other four water supply strategies are included in the portfolio and if the four strategies have remaining monthly yield to divert.

Water Forward has a 100-year planning horizon. Firm demands for municipal, industrial, and manufacturing customers are projected to grow to a level that reaches the full LCRA system yield during this horizon. Agricultural demands are also projected to be present over the planning horizon, but with lower demands over time. Climate change conditions are also modeled, which adds to water availability scarcity, especially in 2070 and 2115, through the effects of reduced streamflow during drought and higher evaporation levels. There are periods during extreme droughts in which the combined storage of lakes Buchanan and Travis are simulated as empty. The Water Forward WAM includes existing triggering levels for firm customer voluntary and mandatory curtailment levels, as well as assumptions for the degree of potential mandatory curtailment under never before seen storage conditions.

When the combined storage of lakes Buchanan and Travis is simulated as empty, no water is available in the model to meet the demands under the 1999 Contract as listed in Step 4 above. During such months, the model simulates a diversion from an alternative source. The alternative source diversion is recorded in the model output and represents a potential regional supply shortage. These potential shortages appear in the simulations for 2070 and 2115.

When demands exceed the 1999 Contract, new sources of water supply must be used. The City's water right authorizations cannot provide for Type 3 needs by definition. DCP Stage demand reductions are also applied to Type 3 needs. The order in which the City's Type 3 municipal needs, from Conservation Stage to Stage 4, are met in the model is as follows:

1. New contract supply from LCRA.
2. Direct potable reuse.
3. Brackish groundwater desalination.
4. Seawater desalination or imported groundwater.

E.5 Shortage Metrics

Water availability models, such as the Water Forward WAM, simulate a water management scenario through a repeat of a hydrologic sequence. With most simulations, reproduction of the historical past performance of the water management scenario is not of interest. Development of water availability simulations is generally motivated by estimating or predicting how the water management scenario will behave under future conditions. Future conditions may involve near-term or long-term demands as well as future hydrologic conditions. Time series of water availability can be generated from simulation outputs once the appropriate future demand and hydrologic conditions of interest are assembled. The time series may be directly analyzed and/or summary measures may be generated to describe performance in terms of meeting or failing to meet certain criteria.

The preceding sections of this work introduce the Water Forward WAM and describe the methodologies to develop hydrologic and water management scenario inputs. The hydrologic inputs include consideration of future climate change conditions and identification and selection of candidate droughts. The water management scenario inputs include future basin-wide demands and demands for the City of Austin. The water management scenario also includes options that make up the Water Forward portfolios of future water supply options. The work described in this section brings together the hydrologic and water management scenario inputs for summarization in the form of shortage metrics developed from the simulation outputs.

E.5.1 Reliability, Resilience, and Vulnerability

Hashimoto *et al.* (1982) introduced the concepts of reliability, resilience, and vulnerability – collectively known as RRV – as measures for evaluating satisfactory performance of a water resources system. Measuring the performance of a water resources system is important during droughts or periods of high demands. Since the introduction of RRV, the concepts have been widely applied in water resources evaluations. Defining satisfactory and unsatisfactory states of performance is central to the definitions of reliability, resilience, and vulnerability. For this work, a *satisfactory state* is a period in which water supply is able to fully meet demands above DCP Stage 4. An *unsatisfactory state* is therefore a period of water shortage. The period used for this work is a month. Satisfactory months, unsatisfactory months, and monthly shortage volumes are conceptually illustrated in **Figure E-16**.

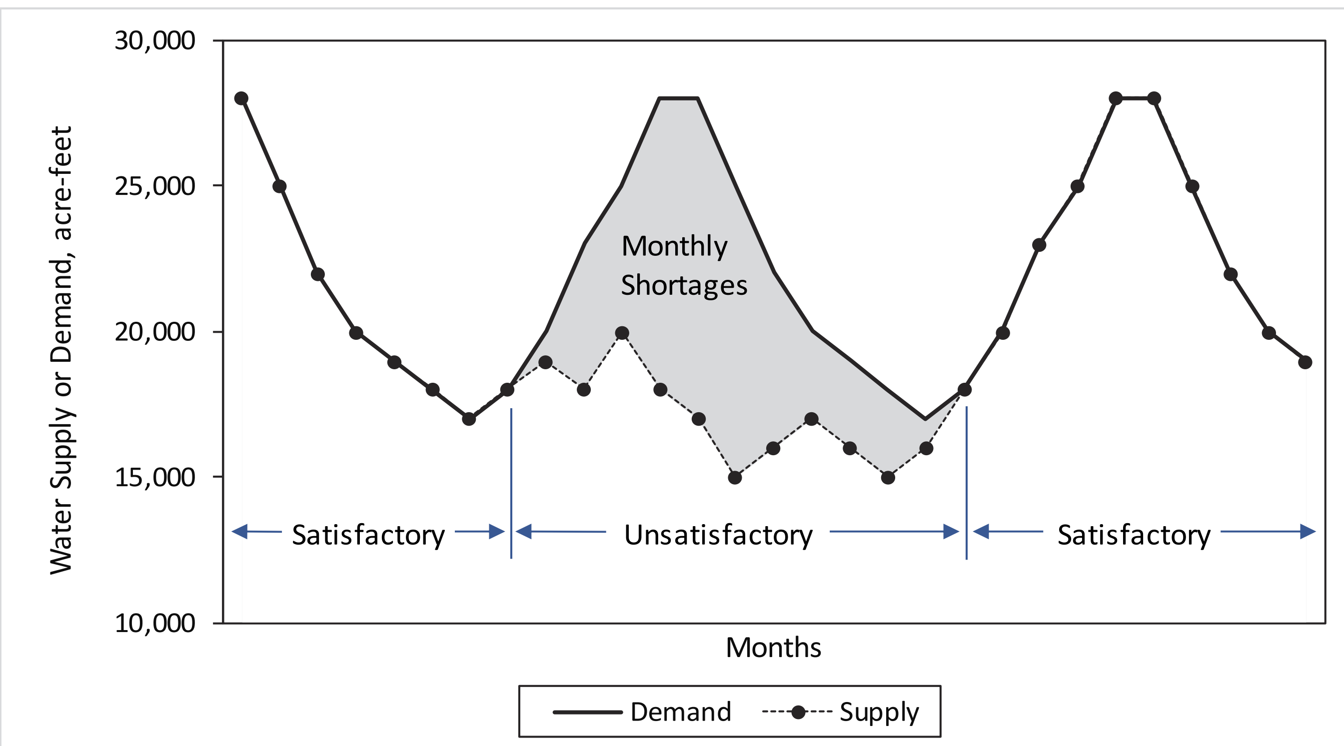

Figure E-16. Conceptual illustration of satisfactory and unsatisfactory states around a shortage event

Satisfactory and unsatisfactory states and shortage volumes are measured each month from the simulation outputs, and the metrics of reliability, resilience, and vulnerability can be calculated using the following definitions.

Reliability is the probability that the water resources system is in a satisfactory state throughout the simulation. In other words, reliability is measure of how frequently the supply fully meets demand. Reliability is calculated as the number of satisfactory months divided by the total number of simulated months.

Resilience is the probability that a satisfactory month will follow an unsatisfactory month, or in other words, how likely it is that supplies will be able to fully meet demands again once a shortage has occurred. Resilience can be calculated as 1 divided by the average duration of all periods of unsatisfactory performance.

Vulnerability is a measure of the magnitude of shortage volume if a shortage occurs. Vulnerability can be calculated in a variety of ways. A few possible methods to calculate vulnerability include: (1) averaging the maximum shortage month all unsatisfactory periods, (2) averaging the cumulative shortages measured during all unsatisfactory period, (3) calculating the largest cumulative 12-month period of shortage of the entire modeling period.

The objective of calculating shortage metrics for Water Forward is to ultimately rank portfolios with a relative scoring system. Time series of demands and supplies were output from the simulations for needs analysis evaluations and for understanding the performance of portfolios of options being considered in Water Forward. In addition to the time series, reliability and vulnerability were calculated as shortage metrics for scoring the portfolios and ranking their relative performance. *Resiliency was not considered in the Water Forward shortage metrics since it is correlated with vulnerability*. The cumulative volume of shortage events is related to duration of the event. Thus, the informational value of resiliency is somewhat captured in vulnerability.

E.5.2 Combining Shortage Metrics

Values of reliability have a range of 0 to 1 to indicate complete failure or no shortages observed, respectively. However, the definition of vulnerability results in a metric with units of volume. So that vulnerability can be compared to reliability in a range of 0 to 1, a relative vulnerability metric can be calculated by dividing by another quantity with volumetric units (ASCE, 1998). For Water Forward, relative vulnerability was calculated as 1 minus the maximum 12-month total shortage volume divided by the Stage 4 demands during the same period. A relative vulnerability of 0 indicates no water was provided during the worst 12 months of drought, whereas a relative vulnerability of 1 indicates there were no shortages during the worst 12 months of drought.

Shortage metrics can be combined into a single measure, or index, to compare the relative performance of different water resource system configurations (ASCE, 1998; Sandoval-Solis et al., 2011). Individual metrics reflect performance in different manners. Reliability considers all months of the simulation and only counts “yes” or “no” for satisfying demands through any hydrologic condition. Vulnerability, on the other hand, focuses only on shortage volumes during times of drought. Combining shortage metrics into a single index is useful for combining disparate measures and comparing alternative water management scenarios in a relative ranking or scoring process.

For Water Forward, the geometric means of reliability and relative vulnerability were calculated for the 2020, 2040, 2070, and 2115 planning horizons for historical hydrologic conditions and climate change adjusted hydrology (for 2040, 2070, and 2115). An index, or score, was created from the weighted arithmetic mean (average) of the geometric means. The geometric mean was used to normalize, or scale, the metrics. This was done because demands increase, and climate change-adjusted hydrologic conditions tend to worsen over the planning horizons. This combination causes a tendency for reliability and relative vulnerability to decrease over time and skew performance comparisons towards later planning horizons. Performance of earlier planning horizons are essential. Normalizing the reliability and vulnerability metrics with the geometric mean improved the weighting of earlier planning horizons in the final index.

E.5.3 Scoring Summary for Overall Performance

Portfolio water supply scoring brings together all of the elements of modeling described in this appendix. The work documented in this appendix covers the steps taken to develop WAM inputs: hydrology, water demands, and water management scenarios. The inputs were developed for four planning horizons: 2020, 2040, 2070, and 2115. Reliability and vulnerability metrics indicate the performance of the portfolios for each planning horizon over a wide range of hydrology including wet, average, DOR, and DWDR conditions. A final score for each portfolio combines the reliability and vulnerability metrics into a single number that is used for ranking the portfolios on a relative basis.

Section E.3 of this report describes the methodology to identify and rank droughts worse than the drought of record (DWDR). The selection of candidate DWDR events is based on risk of occurrence within the 100-year planning horizon of Water Forward. Reliability was calculated for all months of the period of record and also for the extended simulation. Reliability for the extended simulation excludes months falling within periods of drought that exceed the risk of occurrence of the candidate droughts. Relative vulnerability was calculated for the drought of record (DOR) and all candidate DWDR's. For scoring purposes, relative vulnerability metrics were calculated for the worst 12-month period of the DOR and the worst 12-month period of any of the candidate droughts. Portfolio water supply scores for the four planning horizons and hydrologic conditions can be found in **Appendix L**.

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APPENDIX F: WATER NEEDS IDENTIFICATION

F.1 Introduction

The City of Austin has taken significant steps towards securing its long-term water supply. The City has substantial run-of-river water rights in addition to long-term contracts with the Lower Colorado River Authority (LCRA) for firm water. However, the 2008-2016 recent historic drought has highlighted the importance of the City taking steps to enhance the reliability of its water supply. In response to the drought, the Austin community answered calls to decrease water use through lawn watering restrictions and participate in other water use efficiency programs. The Water Forward plan seeks to develop a sustainable, resilient, diversified water supply and demand management portfolio to achieve our desired water future.

All water plans require an assessment of future water needs that determine the timing and sizing of new potential demand-side management and water supply options. Austin's core water supply includes run of river rights to water from the Colorado River backed up by a contract with the Lower Colorado River Authority for stored water primarily from the Highland Lakes. Analysis of this core water supply provides the basis from which the Water Forward needs assessment was developed. In times of drought, lake storage levels can drop significantly. When storage volumes in the Highland Lakes reach certain triggers, customers who have firm water[1] contracts such as the City of Austin implement drought contingency plans, which include mandatory restrictions on certain types of water usage. For example, in the City of Austin Drought Contingency Plan, Stage 1 water restrictions are imposed when combined storage levels in Lakes Travis and Buchanan are below 1,400,000 acre-feet, Stage 2 water restrictions are imposed when combined storage levels are below 900,000 acre-feet, Stage 3 is triggered below 600,000 acre-feet, and Stage 4 is triggered at the discretion of the City Manager.

These City of Austin and other firm customer water restrictions are implemented to stretch out water supplies and help to mitigate falling storage levels during droughts. Even with drought contingency plan implementation on the part of many firm customers, combined lake levels can still drop. In modeling for Water Forward, considering long-term future demand and climate change impacts, all of the water in the lakes is used in certain modeled scenarios such that no stored water would be available. This occurs as early as 2070 in some hydrologic scenarios. While Austin Water (AW) would still have access to run of the river water if available, without stored water there would be drastic impacts to AW's customers in terms of health and safety, economy and overall quality of life. While both the Lower Colorado River Authority and the City are looking at ways to address future water supply issues, one of the goals of the Water Forward plan is to manage this type of risk.

For the purposes of developing Austin's Integrated Water Resource Plan, it was necessary to conduct an analysis to define and quantify the identified water needs. A preliminary needs analysis was conducted to develop an initial understanding the magnitude of the needs. This preliminary needs analysis provided valuable information to ensure that, when combined into portfolios, the magnitude of selected demand

[1] Firm water is defined as a supply that can be provided through a repeat of the drought of record. Prior to the recent historic drought, the drought of record was a drought that occurred from 1947 to 1957. In light of the severity of the late 2007-2016 drought, the Lower Colorado River Authority is in the process of updating assumptions related to the drought of record.

management and water supply options would be sufficient to meet the identified needs. Through the process of developing and evaluating portfolios, the preliminary needs analysis was later refined to categorize water need quantities, referred to as Type 1, 2, and 3 needs, in various portfolio configurations.

F.2 Preliminary Water Needs Identification

Unlike traditional water planning, the integrated water resource plan is a dynamic process that considers planning for needs under a range of possible future conditions. In traditional water planning, one demand projection line is plotted against one supply line and the identified need is the amount of water in the highlighted area above where those two lines cross, as depicted in **Figure F-1**, below. This assumes that there is only one set of conditions to plan for and that future weather and climate will replicate past weather and climate.

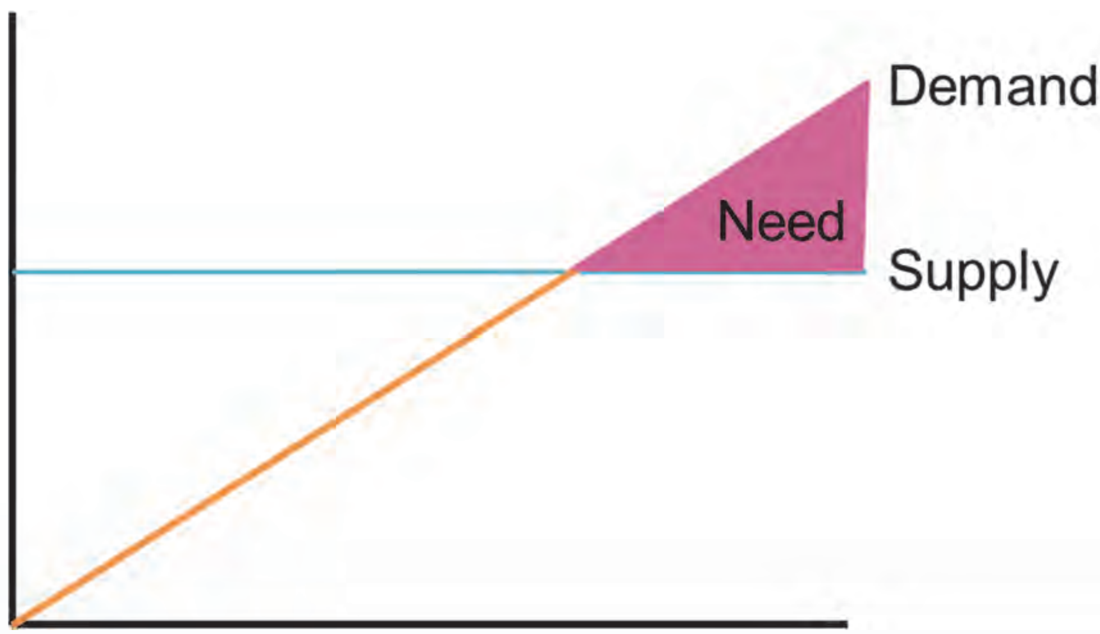

Figure F-1. Traditional water planning paradigm

As depicted in **Figure F-2**, the Water Forward integrated water resource plan process analyzed needs considering four different hydrologic scenarios at four different planning horizons. By evaluating the potential impacts of various hydrologic conditions over time, the integrated water resource plan considered options that can provide reliability and sustainability benefits across multiple future conditions. As described in **Section 5** of the main report, the hydrologic conditions evaluated included A) a repeat of the historical hydrology during the period of record, B) the period of record hydrology adjusted to reflect the effects of climate change, C) droughts worse than the late 2007-2016 drought that were selected from a 10,000 year sequence developed by resequencing years from the period of record hydrology , and D) droughts worse than the late 2007-2016 drought that were selected from a 10,000 year sequence developed by resequencing years from the period of record hydrology adjusted to reflect the effects of climate change.

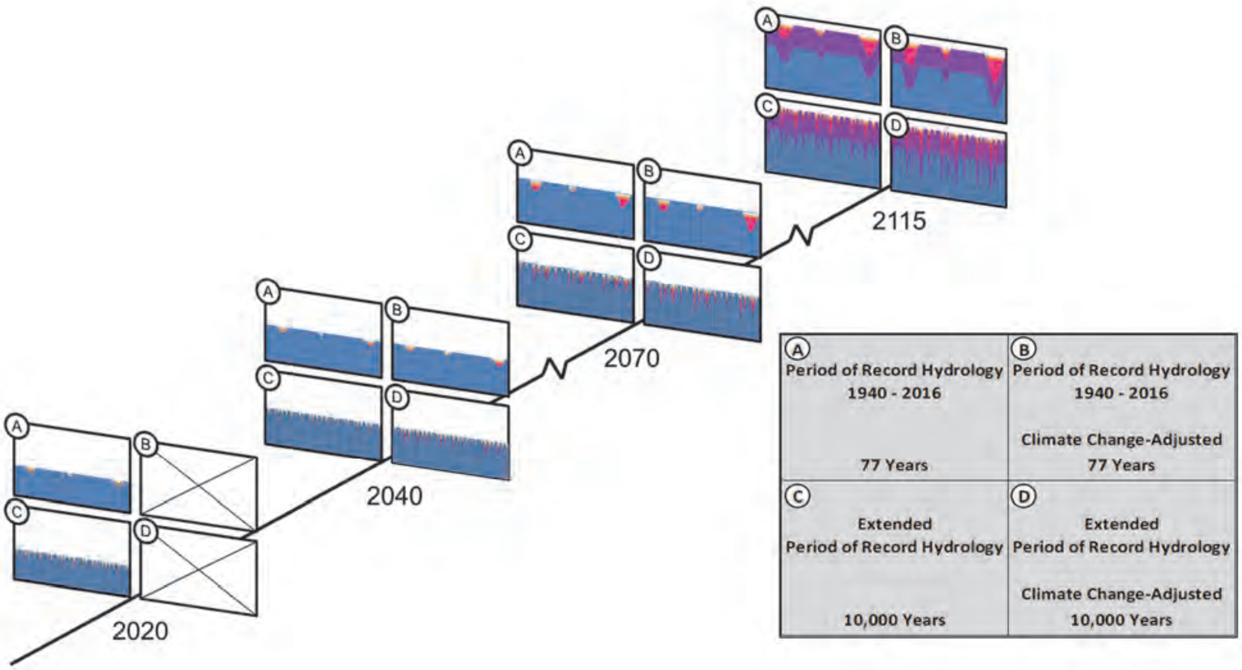

Figure F-2. Water Forward Integrated Water Resource Plan planning horizons and hydrology scenarios

Preliminarily needs were identified in three main categories:

- Austin's needs during drought associated with managing risk of low combined storage levels in Lakes Travis and Buchanan including prolonged implementation of drought contingency plan stages,
- Austin's needs above current 325,000 acre-feet per year contract with Lower Colorado River Authority,
- Regional needs including periods when combined storage levels in Lakes Travis and Buchanan may dip below emergency levels. It was anticipated that future hydrologic scenarios may identify regional water needs. Despite assumed cutbacks on the part of AW and others, reservoir levels may still go below emergency levels under some future drought scenarios.

F.3 Water Needs Refinement

After development of preliminary water needs, three types of water needs were further refined and quantified. These three types of water needs were used to develop the magnitude of portfolios of demand management and supply options to be evaluated. Two of the types of needs are associated with the need to increase supply and reliability in extreme drought conditions, such as droughts worse that the historic drought of record and droughts that incorporate the projected effects of climate change. The third type is more akin to a traditional needs assessment. This third type of need quantifies needs above the City's current Lower Colorado River Authority contract amount. Each type of water need is discussed in more detail in the following sub-sections.

F.3.1 Type 1 Needs

Type 1 needs were identified in an attempt to avoid the numerous potential negative impacts anticipated as a result of being in Stage 4 Drought Contingency Plan measures for a prolonged period in times of severe drought. For reference, Stage 4 Drought Contingency Plan measures would restrict all outdoor water use, such as irrigation, car washing, pools, foundation watering, or washing any outdoor surface. Strategies identified in Water Forward would provide demand management and new supply options so that Austin Water customers could continue to use water outdoors at Stage 3 Drought Contingency Plan levels in a sustainable fashion through a multi-year drought scenario. While customers would still be able to use outdoor water, Water Forward strategies would allow the City to reduce its demand on the river as if the City were enacting Stage 4 restrictions during prolonged drought. Both demand management and water supply options can fill this need. Type 1 needs were established to mitigate societal, environmental, habitat, and economic impacts of staying in Stage 4 drought restrictions.

To quantify Type 1 needs, the needs were defined to be equal to the estimated reduction in water demand from Austin's Colorado River supplies that would occur from implementation of the City's Stage 4 Drought Contingency Plan. Strategies meeting Type 1 needs would then be used to meet that estimated reduction amount. For the purposes of Water Forward Water Availability Modeling (discussed in more detail in **Appendix E**), Stage 4 restrictions were set to begin when the combined storage of Lakes Travis and Buchanan was at or below 450,000 acre-feet (or approximately 22% full) in the model scenario. In an actual prolonged drought scenario, Stage 4 restrictions would begin at the discretion of the City Manager.

Taking climate change into account, the Type 1 need was calculated in the model for the various planning horizons. For the Water Forward baseline demand projection with climate change effects included, the maximum 12-month Type 1 needs recorded when modeling under hydrologic scenario B (period of record with climate change) are shown in **Table F-1**, should a triggering drought event occur. These projections are the estimated outdoor water use savings amounts, using the baseline demands with climate change effects, associated with going from Stage 3 to Stage 4 restrictions in the drought contingency plan.

Table F-1. Baseline Type 1 needs under hydrologic scenario B (period of record with climate change)[1]

Year	2020[1]	2040	2070	2115
Type 1 Needs	3,000 AFY	10,600 AFY	15,400 AFY	24,800 AFY

[1]Because climate change effects were not included for 2020, Type 1 needs were defined by modeling under hydrologic scenario C (extended hydrology without climate change).

In the portfolio evaluation process, water conservation and reuse options combine to reduce the overall potable water demand. Therefore, in every portfolio a portion of the Type 1 baseline amount is met through conservation and reuse. The remaining Type 1 needs after conservation and reuse options are considered is targeted to be met by new water supply options. Note that Stage 4 restrictions may still need to be implemented for short-term emergency situations in the future, but the Water Forward goal for meeting Type 1 needs is to avoid going into Stage 4 for prolonged periods during sustained extreme droughts.

F.3.2 Type 2 Needs

This is a potable supply target developed to manage the risk of Austin having very little or no Colorado River supply due to severe drought, including droughts that may be worse than what the region has seen in the past, and potential climate change effects. Strategies to meet Type 2 needs are readily accessible potable supplies that could be relied upon by the City in the event that combined storage levels drop to extremely low levels during a prolonged drought. This type of need can be thought of as a backup supply or an insurance policy for risk mitigation in extreme drought conditions. Defining this type of need was important in addressing the Water Forward goal of increasing water supply reliability. During the 2008-2016 drought lake levels dropped sharply, causing community impacts and concerns, and new supply options were proving challenging to prepare for implementation in the necessary timeframe. With this in mind, Type 2 needs were developed as part of the Water Forward process to manage similar or possibly more severe impacts and concerns associated with extremely low lake levels in the future as climate change effects are anticipated to increase.

Water availability modeling results were used to quantify Type 2 needs amounts. To increase the reliability of Austin's access to potable water supplies in a severe drought, the Type 2 target was set to equal 50% of the amount of water Austin would expect to receive from Lower Colorado River Authority stored water at extremely low lake levels. To define extremely low lake levels in the Water Forward Water Availability Model, Type 2 needs were set to trigger in the model only when combined storage in Lakes Travis and Buchanan was less than 450,000 acre-feet, or about 22% full. If combined storage in the lakes was modeled to empty, Type 2 needs were still calculated as 50% of the water expected from Austin's Lower Colorado River Authority contract had there been available storage. This is further explained in the sections below. The remaining 50% of the water expected from Austin's Lower Colorado River Authority contract was categorized as a regional need and Water Forward strategies were not specifically identified to meet this regional need. Since this Type 2 need targets development of strategies that provide Austin access to a substantial supply of potable water during severe drought, only options that can readily provide potable water could fill this need (not conservation or non-potable reuse options).

F.3.2.1 Type 2 Needs Illustration

To illustrate the Type 2 needs concept and how those volumes are quantified, the following sequence of figures (**Figure F-3** through **Figure F-7**) show a progression of graphs which are based on a combination of water availability modeling results and Water Forward inputs. The left-side axis in this graph sequence shows monthly water volumes from various supplies and demand management options for meeting the City of Austin's municipal water demands. The top line in thick green represents the total water demand of the City, which is met by the combination of expected supplies and demand management strategies shown in the layers below the top line. The peaks and valleys in the top line represent annual seasonal change in water use—demand tends to go up in the summer as water use for irrigation and other seasonal uses increases.

The graph sequence presented below represents a combination of Austin's projected demands and expected supplies in 2115 as well as modeling results from the recent historic drought from 2008-2016, based on 2115 projected demands with the effects of climate change. The volume of supplies shown in the graphs vary over the drought depending on the combined storage volume. The graphs shown in **Figures F-3 through F-7** are all based on the Hybrid 1 portfolio modeled under Scenario B hydrologic conditions (period of record with climate change). **Figure F-3** is presented to show the starting point demands for calculating the Type 2 needs. The blue area in the graph represents the amount of Austin's demand expected to be met by water from Austin's Lower Colorado River Authority contract. Note that the blue demand for total Colorado River supply is a significant portion of the total demand.

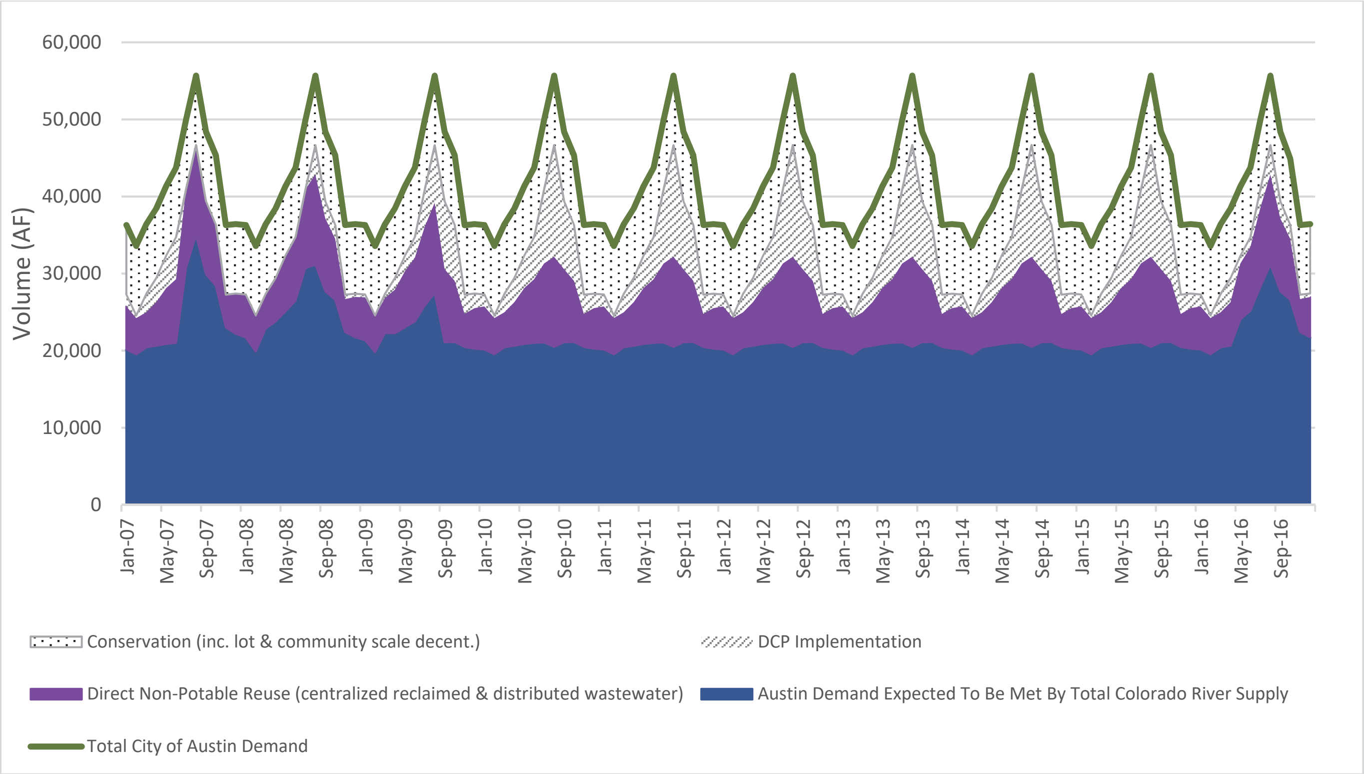

Figure F-3. Hypothetical supply scenario during critical drought sequence

In some model conditions, particularly when modeling climate change impacts and droughts worse than the drought of record, water from the Colorado River supply is not available in the simulation. The next figure shows the first step of determining a Type 2 needs volume for development of supply to provide water for supply augmentation in extreme low lake level conditions. This first step is to determine the maximum Colorado River demand during the critical drought period, with all drought contingency plan measures engaged. In **Figure F-4**, a black line representing the combined storage of Lakes Travis and Buchanan has been added to the graph. The combined storage line is associated with the y-axis on the right side of the graph. Additionally, a grey line indicating 450,000 acre-feet of combined storage has been added. Type 2 needs are amounts calculated only when the model-simulated combined storage volume drops below the gray line. In **Figure F-4**, a gold box has been drawn around the total Colorado River demand when combined storage drops below 450,000 acre-feet. The gold box represents the theoretical maximum demand on Colorado River supplies during the critical drought period. The Type 2 needs are a function of this theoretical maximum demand and how much run-or-river water supply is available, as illustrated in the next figure.

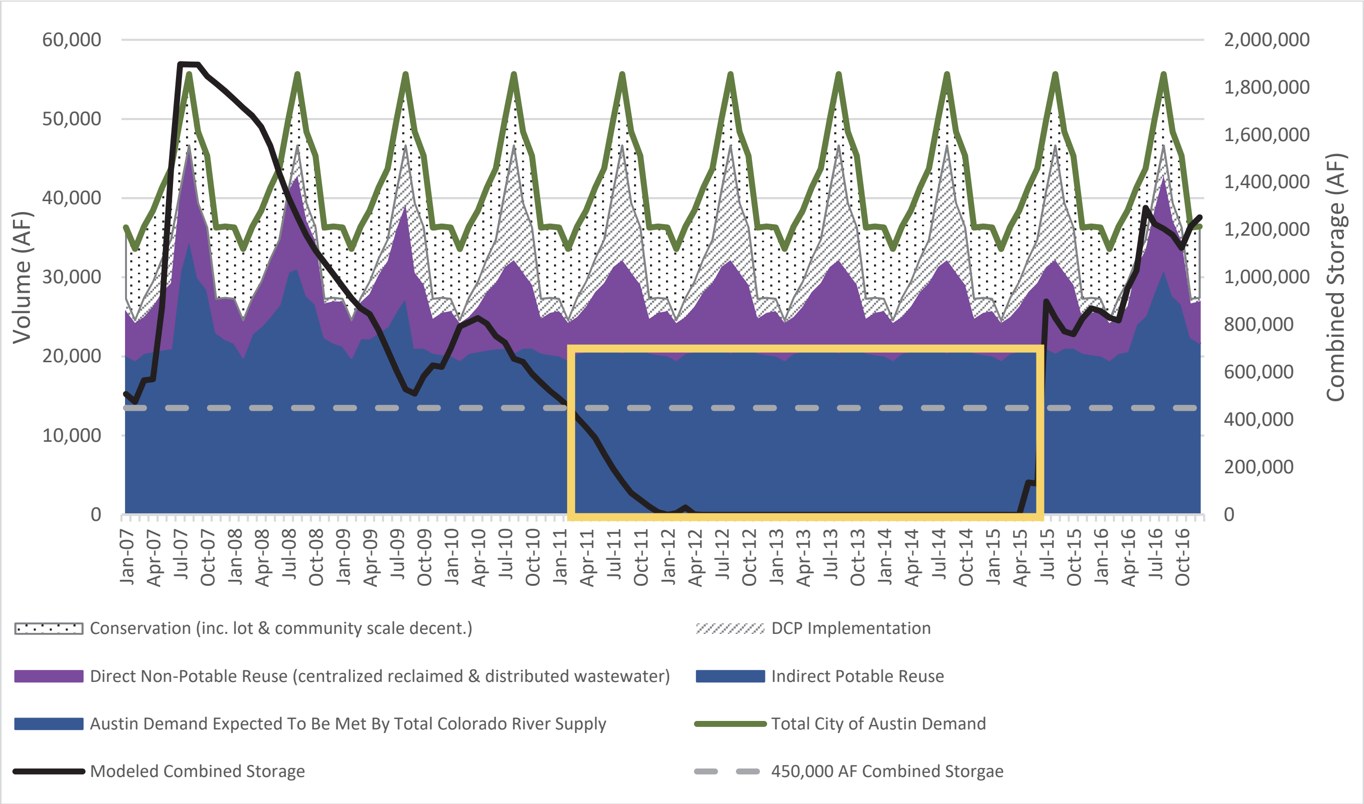

Figure F-4. Hypothetical supply scenario during critical drought sequence with Type 2 Box Shown

In the next step of Type 2 needs determination, the model was used to determine how much supply is available to meet the total demand for Colorado River water from both Lower Colorado River Authority stored water supplies and City of Austin run-of-river supplies. These two supplies make up Austin's current core contractual water supply. **Figure F-5** shows the breakout of these two supplies in the context of meeting Austin's water demand in this simulation sequence. Both Austin's run-of-river supply and the amount expected to be available from Lower Colorado River Authority stored water supply are used in the calculation of Type 2 need, as discussed next.

As in the previous figure, once the black combined storage line drops down below the gray line at 450,000 acre-feet, a Type 2 needs volume was calculated. For the purposes of Water Forward, this volume was set to be 50% of the supply Austin would expect to receive from Lower Colorado River Authority stored water for each month that combined storage is below 450,000 acre-feet. This is calculated by determining Austin's total demand for Colorado River water, subtracting the City of Austin run-of-river available in the model, and dividing by 2 to get 50% of the total Lower Colorado River Authority stored water Austin would expect to receive (shown in the equation below). An example of this calculation is presented for April 2013 Type 2 need, as shown in **Figure F-5** and the example equation below.

$$Monthly\ Type\ 2\ Need = \frac{Austin\ Demand\ for\ Colorado\ River\ supply - Available\ City\ of\ Austin\ ROR}{2}$$

$$April\ 2013\ Type\ 2\ Need = \frac{20{,}657\ AF - 11{,}385\ AF}{2} = 4{,}636\ AF$$

To calculate the maximum 12-month Type 2 needs over a whole simulation period (which was the metric used for portfolio evaluation), the twelve greatest continuous monthly Type 2 need volumes were summed. The results of this calculation for the baseline model under hydrologic scenario B are shown in **Table F-2**.

Table F-2. Baseline Type 2 needs under hydrologic scenario B (period of record with climate change)[1]

Year	2020[1]	2040	2070	2115
Type 2 Needs	6,000 AFY	20,400 AFY	77,000 AFY	93,600 AFY

[1]Because climate change effects were not included for 2020, Type 2 needs were defined by modeling under hydrologic scenario C (extended hydrology without climate change).

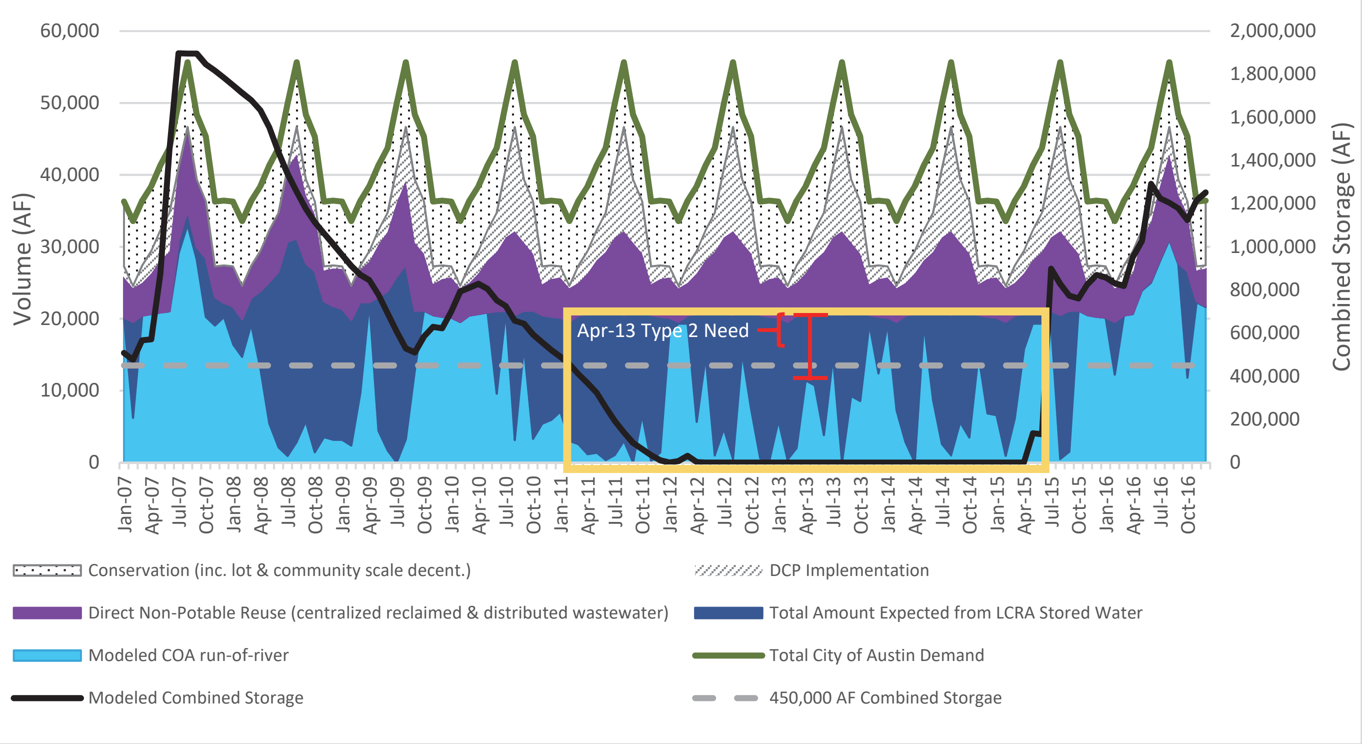

Figure F-5. Hypothetical supply scenario during critical drought sequence with total amount Austin would expect to receive from Lower Colorado River Authority stored water identified.

Type 2 needs were defined as 50% of the amount of water that Austin would expect to receive from Lower Colorado River Authority stored water because it represents the middle of two extremes. On one hand, 100% could have been selected, meaning that the Type 2 needs could have been set at 100% of expected Lower Colorado River Authority stored water, whether or not it was available in the model. Another option would have been to pick 0%, and to, in effect, not have targeted an amount of water to develop as an additional back-up supply to Austin's Colorado River firm supplies. However, this selection would not have helped to address one of the key goals of the integrated water resource plan process, which is to ensure a diversified, sustainable, and resilient water future for Austin. The 50% was selected to be in the middle as a reasonable amount to develop to meet this need.

F.3.2.2 Portfolio Supply Interaction with Type 2 Needs

After identifying Type 2 needs, the next step was to determine supplies that could meet them. Applicable Water Forward options were used to meet Type 2 needs, whereas any available Lower Colorado River

Authority stored water was only modeled to meet the other 50% of Austin's total Colorado River demand. Supplies were modeled this way to help manage uncertainty associated with extremely low lake levels. **Figure F-6** shows that the model simulates that Austin may still get some amount of Colorado River system water from Lower Colorado River Authority stored water supplies and City of Austin run-of-river water when modeled combined storage is less than 450,000 acre-feet, as shown in the two blue-shaded areas of the graph (City of Austin run-of-river water is in light blue and Lower Colorado River Authority stored water is in dark blue).

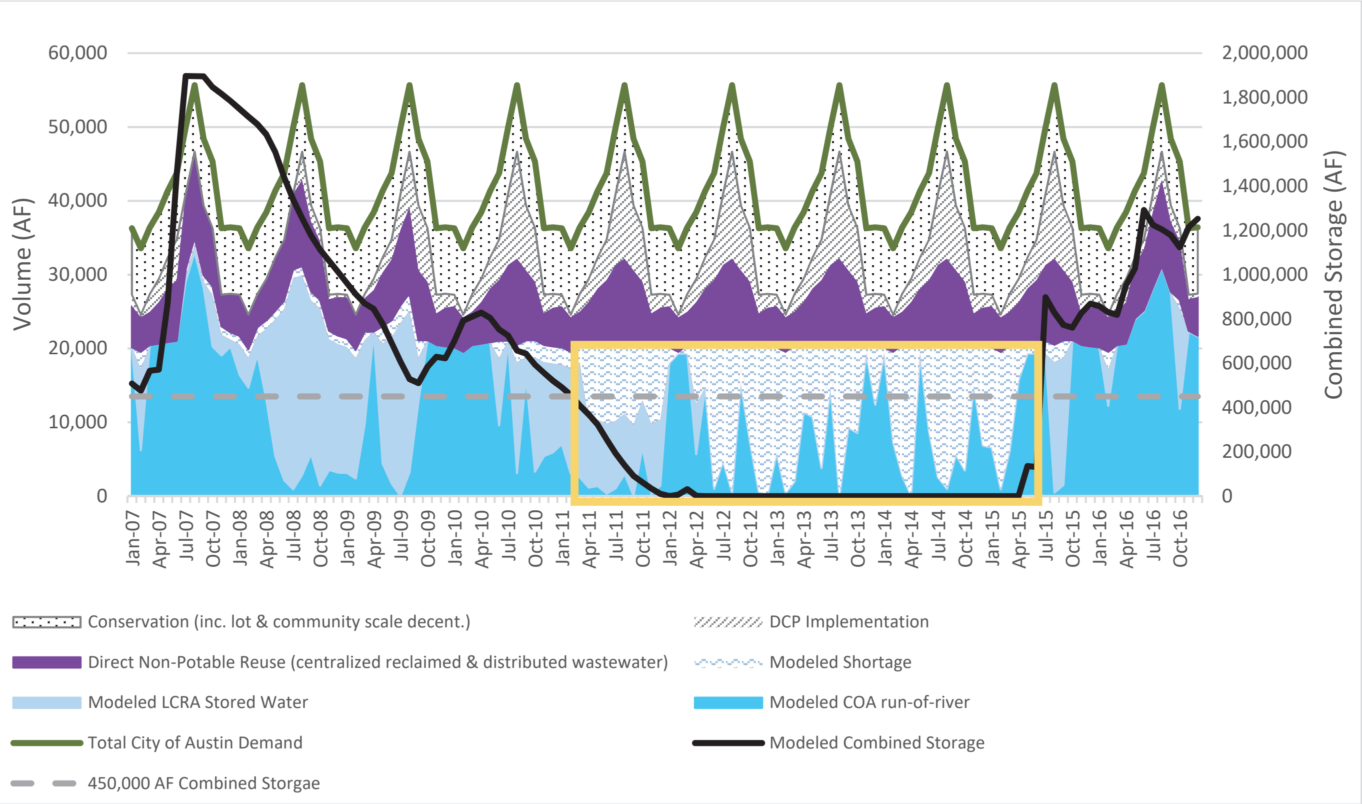

Figure F-6. Hypothetical supply scenario during critical drought sequence with shortages identified

The next step in modeling portfolio supplies to meet Type 2 needs was to model the volume of portfolio supplies available and the remaining regional shortages. **Figure F-7** shows the addition of simulated portfolio supplies in green, which are needed to fill the wavy hatched area in **Figure F-6**. This wavy hatched area represents the simulated shortages in meeting the modeled demand. As shown in the next graph, the portfolio supplies represented in green are able to completely fill the Type 2 needs portion of the wavy hatched area, leaving the pink area associated with regional shortages. These regional shortages are the remainder of Austin's total Colorado River demand and represent the other 50% of the Type 2 needs quantification. Regional shortages will need to be addressed in the future as Austin works with other regional partners in the basin and as others in the basin may develop additional supplies that may address this need.

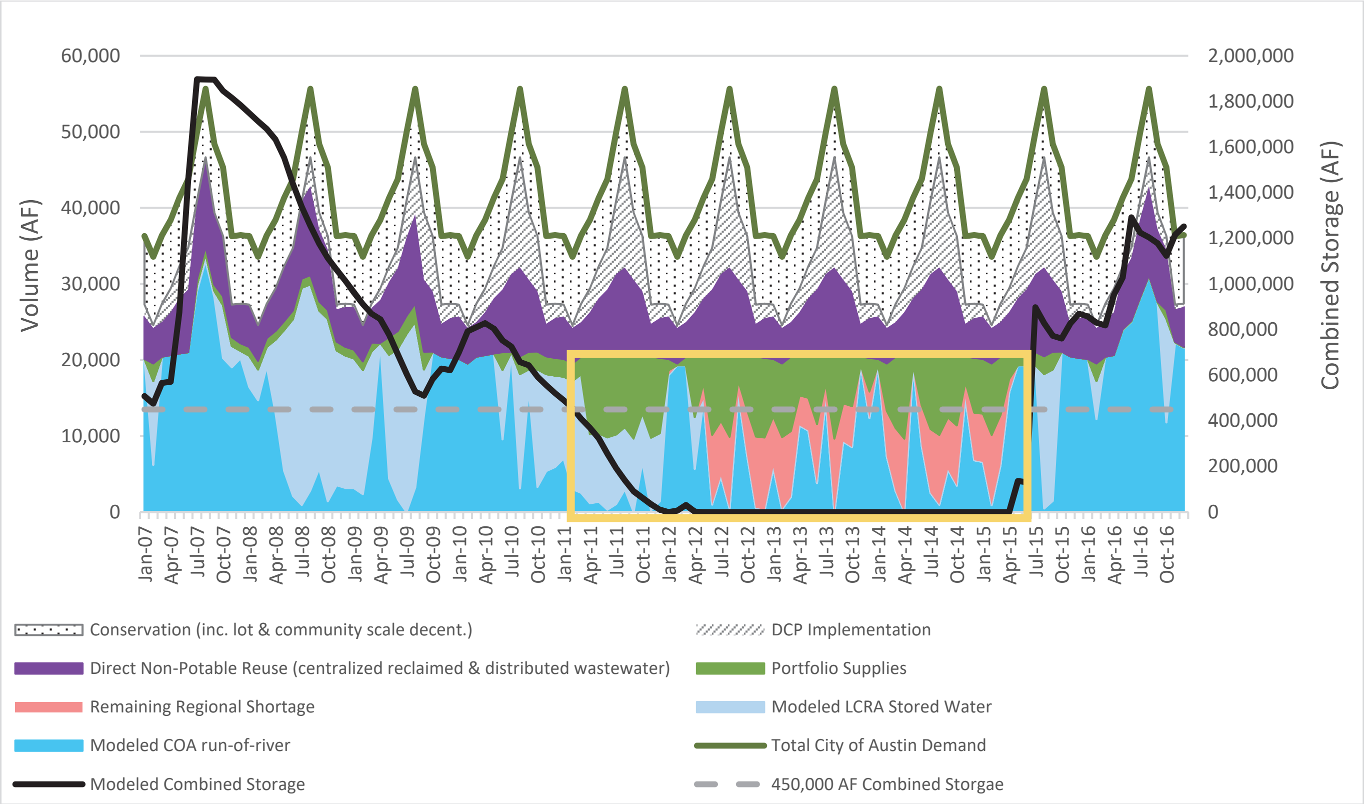

Figure F-7. Hypothetical supply scenario during critical drought sequence with Portfolio Supplies added

F.3.3 Type 3 Needs

Type 3 needs represent an amount of water to meet projected demands above Austin's current 325,000 acre-feet firm water supply contract with Lower Colorado River Authority. From the baseline demand projection with climate change effects on water demands incorporated, the Type 3 need shown in **Table F-3**. It should be noted that Type 3 needs are largely met or are considerably reduced through demand reductions from portfolio demand management and conservation options in the portfolio development and evaluation process. Both demand management and water supply options can fill this need.

Table F-3. Baseline Type 3 needs under hydrologic scenario B (period of record with climate change)[1]

Year	2020[1]	2040[1]	2070[1]	2115
Type 2 Needs	0 AFY	0 AFY	0 AFY	170,400 AFY

[1]There are no Type 3 needs in 2020, 2040, or 2070 because baseline projected demands are expected to remain below Austin's 325,000 acre-feet Lower Colorado River Authority contract.

F.4 Summary of Refined Baseline Identified Water Needs

Table F-4 is a summary table of baseline Type 1, 2, and 3 needs. It should be noted that beyond the Type 1, 2, and 3 needs identified through the integrated water resource plan process, there are also regional needs that will need to be addressed over time. As outlined in the Type 2 section, above, Austin will need to continue to work with other regional partners across the basin as conditions and planning assumptions change over time.

Table F-4. Baseline 12-month identified water needs for the period of record with climate change[1]

Water Need Type	2020 (AFY)[2]	2040 (AFY)	2070 (AFY)	2115 (AFY)
Type 1: Met by New Demand Management or Supply Options	3,000	10,600	15,400	24,800
Type 2: Met by New Potable Supply Options	6,000	20,400	77,000	93,600
Type 3: Met by New Demand Management or Supply Options	0	0	0	170,400
Total Identified Water Needs	**9,000**	**31,000**	**92,400**	**288,800**

[1]Because climate change effects were not included for 2020, needs were defined by modeling under hydrologic scenario C (extended hydrology without climate change).
[2]AFY = acre-feet per year

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APPENDIX G: WATER CONSERVATION SUMMARY

This appendix summarizes the history of the City of Austin's watering restrictions and other water conservation measures. A more high-level summary is provided in the main report in **Section 6**.

G.1 History of the City of Austin's Watering Restrictions

During the summer months of 1984-1986, the City limited landscape irrigation to a five-day schedule during the drought based on the 1983 Emergency Water Conservation Ordinance; the ordinance was enforced by issuing fines of up to $500 per watering violation. Restrictions were imposed again during the summer months in 1984-1986 to reduce outdoor watering. However, the City experienced explosive population growth that impacted the capacity of the water treatment infrastructure towards the late 1990s. As a result, the drought in the summer of 2000 caused the City to impose watering restrictions for the first time since 1986.

During the following years, the City enforced watering restrictions from 2000-2016. The watering schedules during 2000 were implemented on both a voluntary and mandatory basis due to water treatment capacity concerns. The watering restrictions implemented during 2007 through 2016 were in response to severe drought conditions. A chronology of the City's annual watering requirements is provided below:

- **Early June – July 15, 2000**: Stage 1 – Voluntary basis; all sectors requested to water once every five days (time restrictions only for commercial irrigation between 12am-10am or 7pm-12am). The drought in the summer of 2000 caused the City to call for voluntary compliance with watering schedules due to water treatment capacity concerns.
- **July 16 – September 21, 2000**: Stage 2 – Mandatory; all sectors allowed to water once every five days (no watering between 10am-7pm); restrictions on car washes, pools and fountains. The drought in the summer of 2000 caused the City to impose watering restrictions due to water treatment capacity concerns.
- **September 22 – October 1, 2000:** Stage 1 – Voluntary basis; all sectors requested to water once every five days (time restrictions only for commercial irrigation between 12am-10am or 7pm-12am). The drought in the summer of 2000 caused the City to call for voluntary compliance with watering schedules due to water treatment capacity concerns.
- **Year 2001 – 2006:** None – Watering restrictions lifted.
- **October 1, 2007 – April 30, 2008:** Permanent; Mandatory for commercial and multi-family – allowed to water twice a week (watering prohibited with automatic sprinklers during 10am-7pm; no water waste) & voluntary for residential.
- **May 1 – September 30, 2008:** Stage 1 – Mandatory restrictions per code; all sectors allowed to water twice a week (watering by hand permitted during 10am-7pm; no water waste).

- **October 1, 2008 – April 30, 2009:** Permanent; Mandatory for commercial and multi-family – allowed to water twice a week (watering prohibited with automatic sprinklers during 10am-7pm; no water waste) & voluntary for residential.
- **May 1 – August 23, 2009:** Stage 1 – Mandatory restrictions per code; all sectors allowed to water twice a week (watering by hand permitted during 10am-7pm; no water waste).
- **August 24 – November 20, 2009**: Stage 2 – Mandatory; all sectors allowed to water one day per week (no automatic or hose-end watering between 10am-7pm/hand watering allowed any time); efficiency restrictions on car washes, no warnings for fines, no fountains, pressure washing of surfaces, or auto-fill valves on pools, water served only by request in restaurants.
- **November 21, 2009 – September 5, 2011:** Stage 1 – Mandatory restrictions per code; all sectors allowed to water twice a week (watering by hand permitted during 10am-7pm; no water waste).
- **September 6, 2011 – July 15, 2012:** Stage 2 – Mandatory; all sectors allowed to water one day per week (no watering between 10am-7pm except with a hand-held hose or bucket); efficiency restrictions on car washes, no warnings for fines, no fountains or auto-fill valves on pools, water served only by request in restaurants.
- **July 16 – September 3, 2012:** Stage 1 – Mandatory restrictions per code; all sectors allowed to water twice a week (time restrictions for automatic sprinklers between 12am-5am or 7pm-12am; watering by hand permitted during 10am-7pm).
- **September 4, 2012 – May 17, 2016:** Stage 2 – Mandatory; all sectors allowed to water one day per week (time restrictions for automatic sprinklers between 12am-5am or 7pm-12am; hose-end sprinklers permitted during 12am-10am or 7pm-12am); efficiency restrictions on car washes, no warnings for fines, no fountains or auto-fill valves on pools, water served only by request in restaurants.

On May 18, 2016, the City lifted drought conditions but established a Conservation Stage containing year-round water conservation measures that apply to its retail water customers. These measures include a schedule that gives more efficient irrigation methods more time to water. During Conservation Stage, the following requirements are in place:

- Residential and commercial facilities may irrigate either before 10:00 a.m. or after 7:00 p.m. only on a designated outdoor water use day;
- Automatic irrigation systems are limited to no more than one designated outdoor water use day per week, which allows up to fifteen hours of irrigation;
- Hose-end sprinklers are allowed up to two designated outdoor water use days per week, for a total of thirty hours of irrigation; and,
- Car washing is allowed with the use of a bucket and/or hose containing a manual shut-off nozzle or at a car wash facility that has completed an annual efficiency inspection.

Additional requirements under Conservation Stage include:

1. Charity car washes are only allowed at a commercial carwash;
2. Outdoor fountains must recirculate the water;

3. Restaurants may not serve water unless requested by a customer;
4. Commercial properties (including restaurants and bars) may only operate patio misters between 4 p.m. and midnight; and,
5. Wasting water is prohibited.

Failure to follow the water restrictions may result in an enforcement action, including fines of up to $500 per violation. The following are allowed at any time on any day of the week:

1. Watering with drip irrigation, a hand-held hose or a refillable container;
2. Watering trees with a Treegator, soaker hose or automatic tree bubbler;
3. Watering vegetable gardens with a soaker hose; and,
4. Pressure washing sidewalk/driveway/deck/patio/paved areas/home siding/fence.

G.2 Current Water Rates and Fee Structure

For more than 100 years, Austin Water has provided water services in a cost-effective manner to its customers. Austin Water generally uses rate revenues to fund its water conservation programs. Since strict rules apply under state cost-of-service requirements for public utilities (reference Texas Water Code §§13.182, 13.183, and 13.184), Austin Water uses the utility cost-benefit approach when issuing rebates from customer revenues to private individuals; these rebate amounts are based on a quantifiable and comparable benefit to rate payers of the utility.

Due largely to significant impacts of the historic drought and necessary water use cutbacks, in September 2012, a five percent system average water rate increase and updated rate structure was approved by City Council, which became effective in February 2013. At that time, the Council also directed the City Manager to create a Joint Committee of three City Commissions, with input from the public, to develop recommendations for short and long-term financial plans to strengthen the financial stability of Austin Water. After an extensive six-month process, the Council adopted the following recommendations of the Joint Committee:

1. Achieve a goal of 20 percent of total water revenue collected from fixed minimum charges. This will be accomplished by eliminating the current Revenue Stability Fee, and replacing it with:
    a. Residential volume-based tiered minimum charge
    b. Multifamily & Commercial meter-based fixed charge
    c. Large Volume fixed charge
    d. New Residential volumetric rate block intervals
2. Implement a volume-based Reserve Fund Surcharge for all customers to build a reserve to offset revenue losses caused by extreme weather patterns, both wet and dry.
3. Overall impact of new Residential rates and structure
    a. The meter-based Revenue Stability Fee ($4.40 with 5/8-inch meter) was replaced by the new volume-based Tiered Minimum Charge.

b. Volumetric water tiers were modified to better reflect residential usage patterns (see **Table G-1**).

Table G-1. Volumetric tier structure for residential water customers

Rate Tiers	Previous (Gallons)	New (Gallons)
1	0 – 2,000	0 – 2,000
2	2,001 – 9,000	2,001 – 6,000
3	9,001 – 15,000	6,001 – 11,000
4	15,001 – 25,000	11,001 – 20,000
5	25,001 – Over	20,001 – Over

c. In 2013, a new volume-based Reserve Fund Surcharge was adopted at $0.12 per 1,000 gallons but was subsequently changed to $0.19 per 1,000 gallons for retail customers and $0.12 per 1,000 gallons for wholesale customers. Once the goal of the reserve fund has been met over a period of five (5) years, the surcharge might be reduced to maintain this goal unless the reserve is needed to offset revenue losses.

4. Overall impact of new Multifamily & Commercial rates and structure

   a. The rate increase impact varied significantly depending on the meter size and water volume registered.

   b. The monthly customer charge structure did not change and included rate changes.

   c. The meter-based Revenue Stability Fee was replaced by a new meter-based fixed charge to achieve the fixed revenue goals set by the Joint Committee.

   d. The volume rate structure remained unchanged with the rates changing to only maintain each customer class' cost of service.

The City Council voted in March 2018 to approve a mid-year water and wastewater rate decrease. All retail customers, including residential, multifamily, commercial and large volume customers of Austin Water experienced rate decreases, which took effect on May 1, 2018; the average residential customer will see a $2.40 reduction to their monthly utility bill. Initiatives that helped keep rates from increasing include: (1) reducing scheduled debt service expenses by over $70 million between 2016-2018; and (2) cost containment including a budget reduction of $30 million from 2014-2015. Austin Water's efforts over the last few years to contain costs and restructure debt allowed the utility to recommend a zero percent rate increase in 2018 for all water and wastewater customers and a mid-year rate decrease for all retail customers.

A key component of Austin Water's debt management plan has been the use of revenues collected from the Capital Recovery Fee to pay down debt. Capital Recovery Fees are charged to developers to pay for new connections to Austin Water's system. In 2014, Capital Recovery Fee rates increased significantly to ensure that new development pays for its fair share of system growth. Revenues collected from the water and wastewater capital recovery fees, or impact fees, increased from approximately $8 million in fiscal year 2013 to approximately $30 million in fiscal year 2018.

G.3 Current Water Conservation Incentive Programs for Residential Customers

Traditional residential water conservation programs, such as rebates for plumbing fixtures and appliances or more efficient irrigation systems and landscapes, have been implemented by most public water utilities, including Austin, for many years. More and more of these programs are beginning to be phased out by Austin Water due to federal manufacturing standards, market saturation, and state/local requirements.

A summary of the City's water conservation incentive programs currently in place for residential customers is provided below. Austin Water's wholesale water customers are also eligible for most of the City's water conservation programs.

The Austin City Council must approve rebates of more than $58,000. In addition, rebate funds are committed for payment during the fiscal year in which they are to be dispersed.

G.3.1 Free Water Conservation Tools

The City offers a variety of free indoor and outdoor conservation tools to help customers save water. A summary of each tool is provided below; there is a limit of one item each per residential customer.

G.3.1.1 Indoor Tools

- Water-efficient showerhead – available in either regular or soap-up valve models (1.5 gpm)
- Kitchen & Bathroom Faucet Aerator – available for bathrooms (0.5 gpm) and kitchens (1.5 gpm)

G.3.1.2 5.1.2 Outdoor Tools

- Soil Moisture Meter - available in ladybug or frog design
- Treegator – available in 15-gallon size or tree seedlings/small shrubs and 20-gallon size for trees at least 2-3 inches in diameter with branches at least 25 inches from the ground
- Water Saver Hose Meter - digital meter attachment for garden hoses and hose-end sprinklers; available for check-out at the Austin Public Library
- Sunlight Calculator – used to measure the amount of light each area of your yard receives; available through check-out at the Austin Public Library

G.3.2 Irrigation System Evaluations and Rebates

Residential customers of Austin Water or a qualifying water provider may schedule a free Irrigation System Evaluation by a licensed irrigator from Austin Water if they have an in-ground sprinkler system and have used either more than 25,000 gallons in one month or more than 20,000 gallons in two consecutive months.

Each audit varies depending on specific conditions but generally includes the following:

- Documenting current controller settings;
- Checking for leaks by verifying with the residential meter;
- Obtaining a current meter reading;
- Operating each station on the sprinkler system to determine flow rates and quantify the current schedule on the controller;
- Testing the system and noting deficiencies and opportunities for improvement or equipment upgrades;

- Providing a recommended watering schedule;
- Reviewing audit results with the customer;
- Reviewing controller functions and settings with the customer; and,
- Resetting controller to recommended settings if needed.

Eligible residential customers may also receive up to $400 in rebates for improving the water efficiency of their irrigation system. Installations of new irrigation systems and/or expansions to existing systems are not eligible for the rebate.

G.3.3 Pool Cover Rebate

To help reduce the amount of water lost to evaporation, residents can receive half of the purchase price up to (1) $50 for a new manual pool cover or solar rings; or (2) $200 for a new permanent, mechanical pool cover.

G.3.4 Pressure Regulating Valve (PRV) Rebate

The City offers a rebate of up to $100 to residential customers for the purchase and installation of a PRV. PRVs are inserted into a customer's plumbing to prevent misting and evaporation losses in irrigation systems.

G.3.5 Rainwater Harvesting Rebate

The City's Rainwater Harvesting Rebate provides residential, multi-family, and commercial customers of Austin Water or a qualifying water provider up to $5,000 for purchasing equipment to capture rainwater.

G.3.6 Watering Timer Rebate

Austin Water residential customers can receive 50 percent of the cost (tax not included) of purchasing up to two hose timers with a maximum rebate of $40 per service account.

G.3.7 WaterWise Landscape Rebate

The City's WaterWise Landscape Rebate Program helps customers convert turf grass to native plant beds. Residents may receive $35 for every 100 sq. ft. (minimum 500 sq. ft.) of converted landscape with a rebate up to $1,750.

G.3.8 WaterWise Rainscape Rebate

Homeowners and schools can receive up to $500 ($0.30/sq. ft. -- 100 sq. ft. minimum) for installing landscape features such as berms, terraces, swales, rain gardens, porous pavement, and infiltration trenches that direct and retain rainwater/runoff on the property. A rainwater harvesting system may also be connected to the rainscape.

In order to be eligible to apply for the WaterWise Rainscape Rebate, applicants must be customers of Austin Water or a qualifying water provider (reference list at beginning of section). Participants are allowed to apply for the program more than once if they have multiple eligible areas of landscape to convert. Applications are accepted two times per year (December-March for spring installation/June- September for fall installation).

This rebate program targets an existing, developed residential or school property, and does not require a site plan submission or other authorization under the City's Land Development Code. Plant materials must be installed between March 15 and May 15 (spring) and September 15 and November 15 (fall); gravel or rock rainscape must not extend over 3-feet in width.

G.4 Current Water Conservation Incentive Programs for Businesses

The City continued to expand the water conservation programs over the years to gain additional water savings by offering monetary incentives, equipment giveaways, and subsidized sales. A summary of the City's water conservation incentive programs currently in place for residential customers is provided below. Austin Water's wholesale water customers are also eligible for most of the City's water conservation programs.

The Austin City Council must approve rebates of more than $58,000. In addition, rebate funds are committed for payment during the fiscal year in which they are to be dispersed.

G.4.1 Commercial Vehicle Wash Facility Efficiency Assessments

According to Rule Number R161-13.16, the City requires commercial, multi-family, and municipal facilities with vehicle wash equipment that uses potable water from Austin Water to submit an annual efficiency evaluation report. A plumber licensed by the State of Texas must perform the evaluation. Submittal deadlines are determined by the zone with the ZIP code for a facility's physical address. Based on the zone's submittal schedule, facilities must submit either a passing Vehicle Wash Equipment Assessment Form or a Compliance Plan. A facility may complete the evaluation up to 90 days before the official due date; however, the penalty for not submitting the required form by the deadline will result in a $200 late fee plus a daily accrual fine of $25 until Austin Water receives the form.

G.4.2 3C Business Challenge

The City is offering the 3C Business Challenge to allow businesses the opportunity to gain information about ways to reduce water usage and to show their commitment to saving water. Water Conservation staff works closely with the businesses participating in the program to recommend steps for improving water efficiency and to determine their eligibility for rebates.

The 3C Business Challenge also allows businesses to earn points toward qualifying for Austin Green Business Leaders. This program provides businesses with tools and information to help them incorporate sustainable practices, including protecting the environment, practicing community stewardship, and maintaining a healthy workplace. The City also publicly recognizes businesses that implement green practices.

To help with making water-saving changes, Austin Water offers rebates of up to $100,000 to businesses that replace old equipment with new water-efficient models. Projects must be pre-approved before any equipment is purchased. The City also provides a number of online water and energy efficiency assessment tools and guides for the commercial sector that include automated water, energy and cost savings calculators based on nationally recognized water and energy efficiency assumptions.

G.4.3 "Bucks for Business" Commercial Rebate

The City offers rebates of up to $100,000 for equipment and process upgrades that save water and exceed city water efficiency requirements.

Examples of eligible upgrades include, but are not limited to:

- Reuse of high quality rinse water used in the high-tech industry;
- New equipment and processes that reduce the amount of potable water used for cooling towers including those that maximize cycles of concentration for cooling towers above five cycles;
- Capturing on-site sources of water such as air conditioner condensate or foundation drain water to use for landscape irrigation, cooling tower water makeup, and other non-potable water uses;
- Laundry water use reduction measures such as ozone treatment and water reuse systems;
- New equipment that reduces water used in boilers to heat commercial and multi-family facilities including condensate return systems, automated conductivity controllers, make-up and blow down meters, and water quality treatment systems that treat corrosion and remove scaling to reduce make-up water demand; and,
- Health care equipment including steam sterilizers, vacuum pumps, air compressors, pure water stills, and analytical equipment.

The incentive available for each project is $0.50 for every 1,000 gallons saved over a ten-year lifetime of the rebated equipment or 50 percent of the cost, whichever is less, not to exceed $100,000. All projects must be approved prior to purchasing or installing any equipment. Some projects may also qualify for property or sales tax exemptions or other incentives.

G.4.4 Commercial Kitchen Rebates

Austin Water is providing rebates to commercial and institutional customers to replace their food service equipment with more efficient, cost-saving models. Eligible equipment and their rebate amounts are summarized in the specific rebate application included in Attachment G of this memo. The qualifying replacement equipment criteria are based on the Energy Star (Version 2.0) Program Requirements, effective February 1, 2013.

Rebates are available for both purchased and leased equipment. The equipment must be operational for at least a consecutive ten-year period. If replaced within the ten-year period, the replacement equipment must meet or exceed the efficiency standards under the rebate program for the remainder of the ten-year period.

Funding is limited and available on a first-come, first-served basis. The City also notes that the offerings, program guidelines, and rebate levels are subject to change without notice.

G.4.5 Industrial, Commercial, Institutional (ICI) Audit Rebate

Austin Water offers a rebate that pays customers up to $5,000 for an independent water efficiency audit of their industrial, commercial, or institutional facility. To qualify for the rebate, customers must commit to fixing any leaks and making any equipment or system setting adjustments recommended by the auditor. The City offers rebates of 75 percent of the cost of the audit or up to $5,000, whichever is less to retail water customers of Austin Water or a qualifying water provider (reference list in Attachment E). A rebate is available for each individually metered facility that meets the minimum water usage of 100,000 gallons per year.

G.4.6 Irrigation System Improvement Rebate

Commercial and multi-family customers of Austin Water or a qualifying water provider may receive rebates for installing the following irrigation system improvements:

- Central computer irrigation controller system ($50 per station, or 50 percent of cost, not to exceed $5,000);
- Master valves ($100 each on systems installed before Jan. 1, 2009);
- Flow sensors ($300 each); and,
- Converting entire stations from spray to multi-stream, multi-trajectory rotor nozzles ($4 per nozzle).

Central computer irrigation system controllers are typically used for larger areas, such as golf courses, park systems, school districts, university campuses, commonly owned or managed multi-family facilities, and large commercial complexes. They include a master controller (which can be a computer or mobile device) that allows users to remotely schedule and manage the irrigation system.

This rebate program targets existing irrigation systems; the installation of new irrigation systems and/or expansions to existing systems are not eligible for this rebate. Irrigation systems must comply with all applicable city codes, ordinances, and rules, including the Commercial Facility Irrigation Assessment Program.

G.4.7 Multi-family HOA WaterWise Landscape Rebate

The City's WaterWise Landscape Rebate Program helps customers convert turf grass to native plant beds. Multi-family Home Owners Associations (HOAs) that share one water or irrigation meter may receive $25 for every 100 sq.ft. (minimum 1,000 sq. ft.) of converted landscape with a rebate up to $5,000.

G.4.8 Multi-family Pressure Regulating Valve (PRV) Rebate

The City of Austin offers a $100 per unit rebate up to a maximum of $500 per property (parts and labor) for the purchase and installation of a PRV for multi-family water customers. To be eligible for the rebate, a property must have water pressure over 80 psi and not have an existing PRV already installed.

G.4.9 Rainwater Harvesting Rebate

The City's Rainwater Harvesting Rebate provides residential, multi-family, and commercial customers of Austin Water or a qualifying water provider up to $5,000 for purchasing equipment to capture rainwater.

G.4.10 WaterWise Rainscape Rebate

Homeowners and schools can receive up to $500 ($0.30/sq. ft. -- 100 sq. ft. minimum) for installing landscape features such as berms, terraces, swales, rain gardens, porous pavement, and infiltration trenches that direct and retain rainwater/runoff on the property. A rainwater harvesting system may also be connected to the rainscape.

In order to be eligible to apply for the WaterWise Rainscape Rebate, applicants must be customers of Austin Water or a qualifying water provider. Participants are allowed to apply for the program more than once if they have multiple eligible areas of landscape to convert. Applications are accepted two times per year (December-March for spring installation/June- September for fall installation).

This rebate program targets an existing, developed residential or school property, and does not require a site plan submission or other authorization under the City's Land Development Code. Plant materials must be installed between March 15 and May 15 (spring) and September 15 and November 15 (fall); gravel or rock rainscape must not extend over 3-feet in width.

G.5 Previous Water Conservation Incentive Programs

In 1985, the Texas Water Commission (renamed as the Texas Commission on Environmental Quality) issued an enforcement order to the City for water quality violations and required the City to implement water conservation programs to retrofit and replace inefficient plumbing fixtures. As a result, Austin Water's Water Conservation Division established the first conservation program for the City during that same year. The Water Conservation Division teamed with Austin Energy in the Residential Energy Efficiency Audit Program from 1985-1990 and installed low-flow showerheads, faucet aerators and toilet dams in existing toilet tanks for residential customers. An overview of the City's water conservation incentive programs during the early years are summarized in the subsections below, and on **Table G-2**.

Table G-2. Summary of previous Austin Water conservation incentive programs

Water Conservation Program	Equipment or Service Issued	Implementation Date/End Date
Landscape Irrigation Audits	Free audit & hose timers	1985/since modified & still in effect
Toilet Rebate Program	Rebate for HETs[1]	1991/June 2010
Free Toilet Program	Free HETs*	1994/Dec. 2011
High-Efficiency Washing Machine Rebate Program	Rebate for HE Washing Machines	1998/2013
ICI Rebate	Free audit	1996/since modified & still in effect
Rainwater Harvesting Rebate	Rebate for rain barrels	2000/since modified & still in effect
Xeriscape Program	Rebate for using native plants & turf grasses	1984/1998
Residential Landscape Conversion Incentive – Lawn Remodel Option	Rebate to replace turf w/ Bermuda or Buffalo grasses	Oct. 2011/Sept. 2013
Restaurant Water Waste Program	Free audit & 1.6 gpm spray valves	2004/Jan. 2006

[1]High-efficiency (HE) toilets (HETs) that used 1.28 gallons per flush.

A summary of the rebate activity for the current and previous water conservation incentive programs is included in Attachment C.

G.5.1 Landscape Irrigation Audits

The City offered free landscape irrigation audits performed by a licensed irrigator from Austin Water to both residential and commercial customers who watered excessively outdoors; this was the City's first water conservation program established in 1985. The audits were voluntary and provided free advice to customers on best practices to reduce outdoor landscape watering. The irrigation audit program during the early years was available exclusively to high water users using a minimum of 25,000 gallons per month. In 1997, the City offered free hose timers to customers who irrigated with hose-end sprinklers. This program was modified in October 2016 and is still in effect.

G.5.2 Toilet Rebate Program

In 1991, the City offered the Toilet Rebate Program to residential customers to encourage them to change-out old toilets with ultra-low flush (ULF) toilets that used 1.6 gallons per flush. This program initially offered a rebate of $60-80 per toilet and then increased to $200 per toilet depending on the model purchased.

Beginning in 1993, Austin Water offered two options, the Free Toilet Program and the Toilet Rebate Program, to customers wanting to replace inefficient toilets using 3.5 gallons per flush or more with higher efficiency models. The Free Toilet Program provided vouchers for a specific toilet that could be redeemed at a local plumbing supply company under contract with the City while the Toilet Rebate Program gave rebates for the purchase of toilets meeting specified efficiency criteria. In these programs, single-family customers could receive up to three toilets per home, multi-family customers could receive up to three toilets per dwelling unit, and commercial customers could replace all eligible toilets in a building.

Both programs proved to be very popular and resulted in accelerating replacement of more than 166,000 inefficient toilets: 93,077 single-family (61,769 Free/31,308 Rebate), 62,753 multi-family (26,346 Free/36,407 Rebate), and 10,537 commercial (3,963 Free/6,574 Rebate). In their final years, the programs experienced unprecedented participation, especially in the multi-family sector. The Toilet Rebate Program ended for multi-family/commercial customers in December 2009 and for residential customers in June 2010. The Free Toilet Program ended for all customers on August 31, 2011.

Austin Water ended these programs after data indicated they had reached a high degree of saturation. The Texas Water Development Board's Water Conservation Best Management Practices Guide states that utilities should aim to retrofit at least 50 percent of eligible toilets. Based on national replacement rates and end use data combined with program participation, Austin Water estimates that 75 percent of commercial, 88 percent of multi-family, and 80 percent of residential toilets had been replaced by the end of fiscal year 2010. Additionally, plumbing code changes that became effective in October 2010 required all toilets installed in new construction or to replace existing toilets to use no more than 1.28 gallons per flush.

G.5.3 Free Toilet Program

In 1994, the City offered the Free Toilet Program to encourage the replacement of older, less efficient models for low-income homeowners. This retrofit program was a high-efficiency toilet (HET) give-away, in which AWU purchased a single HET model in large quantities for volume discounts; free HETs were limited to three per residential customer. This program was initially limited to low-income residential customer, but it was expanded to all residential customers in 1996 and multifamily and commercial customers in 1998. The City provided vouchers for free toilets to customers who were eligible and willing to pick up the HETs; these vouchers could be redeemed at several vendors who contracted with the City. The City ended this program by the end of 2011.

G.5.4 High-Efficiency Washing Machine Rebate (WashWise Washer Rebate)

In 1998, the City established the High-Efficiency Washing Machine Rebate for water- and energy-efficient washing machines identified on a list published by the Consortium for Energy Efficiency. This rebate program also included an energy rebate from Austin Energy or Texas Gas Service for residential and multi-family customers. The City lowered its rebate amount from $100 to $50 in July 2010 to make the program more cost-effective; however, the program ended in 2013 when the new federal standards were adopted.

G.5.5 ICI (Industrial, Commercial, Institutional) Rebate / Bucks for Business

In 1996, the City initiated a free service to commercial customers, where Water Conservation Division staff auditors would evaluate a business' water consumption to determine how the company used water. These auditors would then suggest ways to reduce water use and explore potential eligibility for special commercial rebates to industrial, commercial, and institutional customers for installing new water conservation equipment and processes at existing facilities. The City initially offered rebates of up to $40,000 per project with the amount of the rebate limited to half the cost of the improvement up to $1/gallon saved per day and have since increased the amount of the rebate to $100,000. Manufacturers such as Motorola, AMD and Samsung previously participated in the program.

G.5.6 Rainwater Harvesting Rebate / Rain Barrel Sales

In 2000, the City offered rebates for rainwater harvesting, which included a $30 rebate for purchasing approved rain barrels. The City also offered a rebate of up to $500 for implementing higher-volume pressurized rainwater systems; the amount of the rebate depended on the storage capacity and overall cost of the system. In April 2001, the Water Conservation Division decided to supply barrels to its customers at a reduced and subsidized price of $60 per barrel. Since the program's inception, the City has sold more than 6,000 rain barrels. The Rain Barrel Sales Program ended in 2009. In July 2010, AWU increased rebate levels at a lifetime limit of $5000 per site to encourage more rainwater systems; this program is still in effect. This rebate program includes costs (materials and labor) for tank, pad, screens, filters, first-flush, and selected piping installation; gutters, irrigation system, shipping or delivery, and auxiliary water source requirements are not eligible costs. For tanks 500 gallons and up, customers must get pre-approval from Austin Water before purchasing and installing any equipment for this program. Details regarding the rebate amount are the following:

- Non-pressurized (no pump): $0.50 per gallon up to half of the equipment cost;
- Pressurized (has a pump): $1.00 per gallon up to half of the equipment cost; and,
- May apply every 12 months for system expansions until you reach $5,000.

G.5.7 Xeriscape Program

In 1984, the City initially launched an education program to promote the principles of Xeriscaping in an effort to emphasize the practice of using plants that were native or adapted to the climate in order to reduce or even eliminate the need for irrigation. By 1994, the Xeriscape program was modified, and a residential rebate for the program was initiated to encourage the installation of plants and turf grasses that were better adapted to Austin's climate. The program was later revised to emphasize only trees and shrubs in order to promote a hardier group of plants demonstrating a long-lasting water savings and to reduce the evapotranspiration from the surrounding area. The initiatives of this program were met with mixed success since it attracted customers already heavily conserving water; the program was in effect for a number of years and was eventually phased out in 1998.

G.5.8 Residential Landscape Conversion Incentive – Lawn Remodel Option

In response to the severe drought in 2011, Austin Water offered residential customers a one-time opportunity to replace water-thirsty turf with Bermuda or Buffalo grasses, which are more likely to survive future droughts. This program was implemented on October 31, 2011 and phased out by the end of September 2013. Rebate amounts for this program ranged from $10 to $30 for every 100 square feet of turf converted. Approximately 800 participants committed to stop watering stressed turf until the drought ended and a sustained recovery was projected. Once Stage 2 Restrictions were lifted, Austin Water asked these participants to submit a design plan that may include selected turf varieties, native plants, and non-irrigated areas.

G.5.9 Restaurant Water Waste Program

In 2004, the City identified an area for additional water savings with the restaurant industry. Austin Water Conservation staff members performed water audits for restaurants in the Austin area and replaced old spray valves with new 1.6 gpm valves since most restaurants used 3-6 gpm spray valves to rinse dishes. The program was phased out in January 2006 when the Texas Legislature passed HB 2428 that required only spray valves with a flow rate of 1.6 gpm or less could be sold or distributed throughout the state.

G.6 Current Water Conservation Ordinances

The City of Austin water conservation ordinance applies to commercial businesses as well as residences throughout Austin. In the city ordinance, commercial buildings and a wide range of businesses are defined as facilities that must utilize water-conserving plumbing fixtures. These regulations also apply to schools, day care centers, hotels, motels, and shopping centers. Facility owners must install and maintain toilets equipped with a flush tank water saver that serves as a dam to withhold part of the flush tank water that would otherwise drain into the toilet bowl on flushing. The toilet must also be equipped with a flush valve water saver that shortens the flush cycle and further reduces the volume of water flow during a flush to not more than 3.0 gallons for each toilet flush and 1.0 gallon for each urinal flush.

Every lavatory or kitchen faucet must also utilize water-conserving measures with an aerator that reduces flow by introducing air bubbles into the water stream and a flow restrictor that reduces the opening through which water passes, or a spray tap that delivers water in a broad pattern of droplets. The ordinance specifies that the water flow of a lavatory or kitchen faucet may not exceed 2.75 gallons per minute with an inlet water pressure between 20 and 80 pounds per square inch, when measured with both hot and cold water supply valves in the fully open position.

In addition to utilizing water conserving toilets and faucets, any business or facility in Austin providing showers – from apartment complexes with five or more rental units to health or fitness centers – must be equipped with water-conserving showerheads that are designed to provide dispersed and reduced water flow and automatically clean debris from its water channels or pores. Showerheads must have an adjustable spray that produces a water cone that is not more than 42 inches wide in a size and half foot vertical drop. The showerhead is required to have a maximum flow rate of three gallons per minute in an inlet water pressure of between 20 and 80 pounds per square inch when measured with the adjustable spray in the fully opened position. These same requirements apply to hotels and motels in Austin.

In 2000, the City required that all new two-, three- and four-dwelling properties have a dedicated water meter for each unit. The City also required that all new commercial properties over a minimum size install a meter to register irrigation use. Enhanced irrigation standards were implemented in January 2008 for residential and commercial landscapes. These require more precise distribution of irrigation water applied to landscapes to increase efficiency of plant uptake, decrease run-off to hardscapes, and reduce application to non-irrigated areas.

Changes for new equipment, including vacuum pumps and garbage grinders, were made effective in the plumbing code in January 2008. New home construction has been required to use Pressure Regulating Valves (PRVs) since January 2008. Toilet standards for new buildings were made effective in May 2010.

A chronology of the City's water conservation ordinances adopted during 2007 through 2017 is provided below:

2007

- Automatic irrigation systems prohibited from watering between 10:00 a.m. and 7:00 p.m. year-round (effective October 2007)
- No more than 2 times per week residential watering May thru September; commercial year-round (effective October 2007)

2008

- Submeters required in new multi-family and mixed-use facilities (effective January 1, 2008)
- HET urinals (0.5 gpf) required for new construction and retrofits (effective January 1, 2008)
- Commercial food waste and garbage disposal units prohibited (effective January 1, 2008)
- Liquid ring surgical and dental vacuum pumps prohibited (effective January 1, 2008)
- New or replacement cooling towers must achieve at least 5 cycles of concentration and have conductivity controllers, makeup and blowdown meters, overflow alarms, drift eliminators (effective January 1, 2008)
- Car wash equipment efficiency and facility certification requirements (effective January 1, 2008)
- Automatic irrigation system design standards for new commercial and multi-family residential properties (effective January 1, 2008)
- Commercial landscape soil depth and plant requirements adopted

2009

- 5th tier residential water rate for use above 25,000 gallons per month (effective November 2008)

2010

- HET 1.28 gpf toilets required for facilities built or renovated on or after October 1, 2010; waterless urinals allowed
- Innovative Commercial Landscape Ordinance requiring new commercial developments to capture storm water to prevent runoff and for landscape irrigation.

2011

- Stormwater retention and irrigation required for new commercial properties (effective January 2011)

2012

- Year round two times per week watering schedule for all customers (effective September 2012)
- Morning automatic irrigation system watering reduced midnight to 5:00 a.m.
- Mandatory reclaimed water hook-up (effective October 2012; implemented May 2015)

2013

- Revised rate structure to compress residential rate tiers including 5th Tier to now apply to residential use above 20,000 gallons per month (effective February 1, 2013)

- Mandatory irrigation system audits every two years for commercial/multi-family/city properties over one acre (effective 2013)
- Mandatory annual vehicle wash facility efficiency assessment for commercial, multi-family and city facilities (effective 2013)
- Administrative enforcement process/penalties for water use violations (effective 2013)
- Water may be served only by customer request at restaurants (effective 2013)
- Hotels must have towel/linen exchange programs (effective January 2013)

2016

- Year-round watering one time per week for automatic irrigation systems

2017

On June 8, 2017, a mandatory annual cooling tower water efficiency registration and inspection program was approved by the City Council as part of the adoption of local amendments to the 2015 Uniform Mechanical Code, effective September 6, 2017. The purpose of the program is to assist Austin Water customers in meeting cooling tower water use efficiency standards and equipment requirements, identify rebate opportunities, and save customers money on their water and wastewater bills.

The inspection must occur within the preceding 90 days prior to the March 1st deadline, and it must be completed and signed by an independent third party (Texas licensed mechanical or chemical engineer or a person holding a Class A - TDLR Texas Air Conditioning and Refrigeration License with a combined endorsement for process cooling and refrigeration).

First adopted by the City Council on October 18, 2007 and effective January 1, 2008 and currently codified under the city's local amendments to the 2015 Uniform Mechanical Code and 2015 Uniform Plumbing Code, cooling towers installed after December 31, 2007 using Austin Water potable water must include the following:

- make-up and blow down sub-meters;
- a conductivity controller;
- a drift eliminator with a drift rate of not more than 0.005% of the circulated water flow rate for cross-flow towers and 0.002% for counter flow towers;
- an overflow alarm; and
- achieve a minimum of five cycles of concentration.

In addition, the owner must maintain a written log on-site that contains the monthly make-up and blow down meter reads, conductivity values, and cycles of concentration; this information needs to be available to City inspectors upon request.

For new cooling towers (effective September 6, 2017) of 100 tons or greater combined cooling tower capacity, the make-up and blow down meters and overflow alarm must be connected to the building's Central Energy Management System or Utility Monitoring Dashboard. In addition, the facility must either have a water storage tank, plumbing and treatment system to utilize blow down water for wash down, cleaning, toilet flushing, subsurface irrigation and other authorized purposes; or offset a minimum of 10 percent of the make-up water with reclaimed or on-site alternative water sources.

In June 2017, the City Council approved the adoption of the 2015 Uniform Mechanical Code including local amendments requiring new commercial and multi-family facilities with a combined cooling capacity of 200 tons or greater to have air conditioning (AC) condensate recovery systems. Although there are many variables in calculating cooling capacity, 200 tons would generally be the amount needed for approximately 100,000 to 120,000 square feet of cooled space.

G.7 Water Loss Programs

Austin Water has a 544 square mile service area boundary with approximately 232,000 connections, more than one million retail and wholesale customers, and approximately 3,900 miles of transmission and distribution water lines. A primary conservation goal of the utility is to continue to manage water loss due to leaks in the distribution system.

G.7.1 Leak Response and Repair

Austin Water uses acoustic technology to inspect more than 1,500 miles of water lines for leaks. In 2013, the utility completed a five-year program of inspecting the distribution system. That information is now being used to enhance Austin Water's active leak detection program. Austin Water has an accelerated leak response and repair program that has proven highly successful, with most leaks now repaired in one day or less and almost 90 percent of emergency leaks responded to within three hours. During the recent historic drought Austin Water experienced a record number of water leaks because of extreme drought conditions.

Based on the American Water Works Association's Infrastructure Leakage Index (ILI), Austin Water performs well in a national group of utilities that have active water loss programs, typically either exceeding its goal of an ILI of 3.0 or less or falling in the range of 3.0 – 5.0 being recommended by the Texas Water Development Board as the target range for utilities with demand management interventions (leakage management and water conservation) included in the long-term plan. The ILI is calculated by taking the real losses (water lost due to leaks) and dividing them by the unavoidable real losses.

G.7.2 Renewing Austin

Austin Water has launched Renewing Austin, an on-going program which invests $125 million in a five-year program to replace and upgrade aging water lines and keep pace with the infrastructure demands of a growing city; this program will continue to prioritize the list of water lines on the Capital Improvement Program on an annual basis. A summary of Austin Water's performance measures related to linear feet of pipe replaced per year is presented in **Table G-3**.

Table G-3. Renewing Austin program summary

	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016
Number of LF of water main rehabilitated w/ CIP	0	0	0	0	0	0	0
Number of LF of water main rehabilitated w/ Pipe Bursting	8,113	903	0	0	0	0	0
Number of LF of Water main replaced w/ CIP Project Rehab	10,654	25,321	55,574	47,127	40,018	12,097	26,273
Number of LF of Water main replaced w/CIP Project Relocation	0	13,838	40,153	3,595	10,946	34,085	22,397

	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016
Number of LF of Water main replaced by Utility Crews	1,589	6,533	7,124	5,874	6,571	6,341	7,627
Total Linear Feet of Deteriorated Water Mains Replaced or Relocated	**20,356**	**46,595**	**102,851**	**56,596**	**57,535**	**52,523**	**56,297**
Total Capital Cost	**$19.1M**	**$19.6M**	**$17.3M**	**$30.7M**	**$20.8M**	**$16.0M**	**$18.6M**

G.8 Dropcountr Pilot Project

In April 2015, Austin Water contracted with Dropcountr, Inc. to provide 10,000 residential customers with free home water use reports on a pilot basis. Dropcountr's mobile application ('app') was selected to allow Austin Water the ability to quickly provide customers with information and alerts, as well as give customers the necessary ease in accessing the information.

Dropcountr calculated the water use goal by using the household characteristics affecting water use (provided by customer) along with lot size information from the Travis County Tax Appraisal District; indoor and outdoor water efficiency metrics were also applied based on local and national studies. If the proposed goal was lower than the monthly water use, then the customer was asked to consider water saving tips and rebate programs to conserve water. If the goal was higher than the monthly water use, this indicated the household may already be efficient with their water usage. However, the customer had the option to determine and adjust the goal by identifying additional water savings to keep water use and monthly bills low.

To recruit participation in this pilot study, Dropcountr emailed approximately 121,000 Austin Water customers from their contact information on file in Austin Water's billing system. Afterwards, approximately 8,500 participants were randomly selected based on those who expressed interest in participating in the pilot program. Those selected were notified with instructions on how to download the application or access their report online. This randomization process was intended to help provide a statistically valid analysis of behavior changes prompted by use of the application. In addition, three control groups of 500 customers each were randomly selected based on individual high water usage and geographic location within the City. The customized home water use reports were designed to help customers identify potential water savings and ideas on how to save water and money on their water bills.

Based on an independent analysis performed by researchers at the University of Kentucky, Dropcountr had a statistically and economically significant conserving effect on water consumption. The introduction of the Dropcountr services for the population of households participating in Dropcountr resulted in a 9 percent reduction in water usage with a significant variation in the effect across households' dependent on baseline consumption quintile. Households in the highest quintile of baseline consumption reduced consumption by an estimated 17 percent in response to the Dropcountr services.

Based on the results of the pilot program, Austin Water has contracted with Dropcountr and now offers free, digital home water use reports to all of their residential customers. The reports can help customers save both water and money. Reports are available by mobile app and/or by internet and include the following:

- Customized household water use profile;

- Information about a customer's past water use compared to similar households, utility bill rate tiers and water efficiency standards;
- The customer's water saving goals;
- Suggestions for ways to save water and links to Austin Water conservation programs; and,
- Utility alerts and announcements about new conservation programs.

Dropcountr's home water use reports have resulted in significant water savings. The reports also helped customers better understand their water use, address high water bill complaints, and communicate a wide range of services and programs offered by Austin Water. The mobile app platform was the most preferred delivery method and was the most cost-effective and quickest method to communicate alerts and other information to customers. Mailed written reports, on the other hand, were more costly, less interactive, and less effective in reaching the customer.

G.9 Advanced Metering Infrastructure (AMI)

Austin Water has been recently studying the cost and feasibility of implementing Advanced Metering Infrastructure (AMI), which involves including 'smart' meters that automatically report daily, hourly or water usage more frequently to the utility and the customer. This study includes evaluating advanced analytics to provide precise water budget calculations for each customer to help identify those with the largest potential to conserve water. These calculations are based on climate, parcel size, vegetation coverage and other information derived from aerial imaging surveys and provide individual water conservation recommendations directly to customers through their home water use reports. Current pilot studies are underway studying savings from residential customer engagement via mobile and web-based application.

G.10 Water/Energy Partnerships

Energy and water are intertwined, and many sources of energy require water in their production processes. In turn, energy is necessary for the production and delivery of water, including irrigation and potable water uses. As a result, Austin Water is promoting water conservation by connecting water and energy consumption through the following programs.

G.10.1 Home Efficiency Assistance Program

Since 2012, Austin Water has partnered with Austin Energy and Texas Gas to provide low income residential customers holistic water and energy efficiency evaluations, free high efficiency water and energy fixtures and plumbing repairs, and other assistance to save water and energy and their associated costs. By partnering together, the utilities have been able to:

- Reduce water and energy costs for low income residents, older facilities, and renters;
- Increase compliance with water and energy efficiency ordinances;
- Provide customers a one-stop-shop approach to utility efficiency programs;
- Leverage program resources and widen their reach and effectiveness; and
- Overcome split incentives imbedded in rented and low income building spaces.

G.10.2 Multi-Family Efficiency Program

Austin Water continues to partner with Austin Energy and Texas Gas Service to provide 'one touch' energy and water efficiency evaluations, upgrades and retrofits to low income multi-family facilities with consistently higher than average water and energy use. The program was initiated in late 2011 as a result of a competitively awarded federal stimulus grant from the U. S. Department of Energy.

G.10.3 Green Building Program

The City of Austin created the nation’s first green building program in 1990. Austin Energy Green Building is now the nation's most successful sustainable building program. AEGB encourages the design and construction of more sustainable homes and buildings by using an Austin-specific rating systems for energy and water efficiency above the baseline code requirements. Certain scores above the baseline code are required through zoning ordinances for new development in high growth areas.

G.11 Water Conservation Public Education Programs

An expanded focus on customer engagement using electronic technology has shown to increase customer awareness of water usage and leaks, as well as promoting water efficiency measures and the City’s conservation incentive programs. A summary of Austin Water’s water conservation public education programs is provided below.

G.11.1 Water IQ

EnviroMedia created Water IQ, an official State of Texas public awareness water conservation program campaign that has been implemented with varying funding levels across the state. The Water IQ brand is based on statewide quantitative and qualitative research conducted by EnviroMedia on behalf of the governor's Water Conservation Implementation Task Force.

Specifically in Central Texas, EnviroMedia has worked extensively with the Lower Colorado River Authority, the City of Cedar Park, and the City of Austin on Water IQ water conservation campaigns, helping to promote a regional approach to conservation. In 2006, EnviroMedia assisted with media relations promoting a new partnership between the Lower Colorado River Authority and the City of Austin to help people extend and protect the region's water supply. An interactive news conference was held on at a resident’s home, where influential local and state officials lined up to demonstrate their support for the new water awareness campaign, ‘Water IQ: Know Your Water.’ Experts from the Lower Colorado River Authority and City of Austin offered hands-on demonstrations of water-saving tips. The press conference was a great success, as six local news organizations attended the event. Similar Central Texas Water IQ partnership press conferences with the Lower Colorado River Authority and other regional water providers were held again in both 2008 and 2010.

EnviroMedia developed a Water IQ campaign designed specifically to meet the City of Austin’s needs. The campaign was comprehensive, featuring advertising, media relations, and outreach; creative messages that resonated with the Austin community; and a media buy that geotargeted Austin’s residents.

Objectives of the Water IQ Campaign:

- Reduce peak-day consumption;
- Raise awareness of water as a finite resource;
- Educate residential and commercial consumers about their natural water source;
- Encourage all local Austin stakeholders to consider the impact their everyday lifestyle choices have on the current and future water supply by providing ideas and information that guide proactive decision-making; and,

- Educate consumers and businesses on the reasoning behind the regional water conservation measures adopted by Austin and encourage them to support the local watering schedule.

EnviroMedia combined efforts and/or budgets as requested for all three Central Texas Water IQ entities (Austin Water, LCRA, and Cedar Park) to enable messages and media budgets to stretch further. This collaboration resulted in two successful and well-covered regional press conferences during the drought in 2009, in addition to shared advertising, shared media buys, and shared outreach setups and events.

In early 2010, Austin Water hired EnviroMedia to conduct an assessment of the utility's water conservation marketing efforts. They conducted quantitative and qualitative research in March 2010 to gauge awareness and attitudes about the utility, its conservation programs, and water use in general. In addition to a public online and phone survey, EnviroMedia conducted in-depth interviews with key stakeholders of Austin Water. This research provided the foundation of the strategies and recommendations presented to City Council in June 2010.

As part of this project, EnviroMedia developed a Positioning and Awareness Plan for Austin Water, along with a 10-year blueprint to assist Austin Water with marketing its conservation efforts in order to achieve its goal of 140 GPCD by 2020. The Positioning and Awareness Plan provided the tools for Austin Water to raise its brand awareness in the community and establish the utility as a leader in developing a "culture of conservation" in the region. EnviroMedia also identified key Austin Water stakeholders and opportunities to engage them, and they devised a methodology for the City to effectively and consistently communicate with them. At this time, Austin Water is no longer participating in Water IQ.

G.11.2 WaterWise Partner Program

Through the WaterWise Partner program, Austin Water recognizes commercial customers that have made comprehensive water-efficiency upgrades in their facilities or incorporated efficiency measures into the design of new properties. Austin Water launched the WaterWise Hotel Partner program at the end of FY 2011. Participants receive a certificate to display publicly from Austin Water regarding their achievement, as well as table tents, coasters, door hangers and other water conservation signage.

G.11.3 Dowser Dan Show

The Dowser Dan Show is a popular program that educates children and teachers about water conservation. The City of Austin first designed the program in 1992 and has modified and updated it on an annual basis. Targeting kindergarten through fourth grade students, the Dowser Dan Show reaches approximately 18,000 students each school year. In addition, students receive promotional items, such as calendars, magnets, stickers, and bookmarks containing water conservation tips and lessons.

G.11.4 Mobile Classroom

In partnership with the Colorado River Alliance (CRA), Austin Independent School District (AISD), and other local entities, Austin Water expanded its current youth education programs to include the Texas Colorado River Mobile Learning Experience. Since 2015, the mobile exhibit functions as a traveling, interactive science museum, utilizing interactive exhibits and hands-on activities housed inside a 40-foot trailer. Students enter a world where science and technology merge to encounter critical thinking about water. The exhibit currently brings the field trip experience to more than 5,000 seventh grade students in AISD. In addition, CRA and Austin Water are targeting to reach an additional 3,000 to 5,000 middle school students through community events and expanded partnerships with surrounding area schools.

G.11.5 Speakers' Bureau

Since 1999, Austin Water has offered presentations on water conservation techniques and available programs to a variety of interest groups including homeowners associations, garden clubs, professional organizations and other community groups. Austin Water also participates in festivals, school events and informational fairs by providing staff and materials to promote water conservation. In 2009, it developed a Water Conservation Speakers' Bureau, allowing area groups to schedule speakers on topics of interest. Staff members are available to speak on topics that include conservation measures, irrigation, leak detection, and water waste; Austin Water annually participates in more than 100 events and programs.

G.11.6 WaterWise Irrigation Professional Seminar

Since 1997, Austin Water has offered seminars to licensed professional irrigators in the area in order to provide continuing education credits toward their license renewal. These seminars include information on water-efficient irrigation systems, water conservation programs, and the mandatory watering schedule and watering hours. Additional topics include electrical troubleshooting, irrigation auditing, and turf grass watering requirements.

Austin Water periodically hosts 'Irrigation Controllers 101' classes each year. In this hands-on workshop, customers review how controllers work and find out about hidden features and options that can help them save water and money. Participants also practice programming a controller similar to the one in their yard and learn efficient scheduling strategies.

G.11.7 Annual Austin Water/Lower Colorado River Authority Industrial, Commercial, and Institutional Water Conservation Technical Workshop

Austin Water and the Lower Colorado River Authority jointly hold an annual free water conservation technical workshop in September with industrial, commercial and institutional customers, facility managers and engineers on water saving measures, technologies, and rebate programs. This program is still ongoing and was initiated in 2013.

G.11.8 Online Information, Electronic Newsletters and Social Networking

Since 1998, Austin Water has provided conservation information, policies, and program offerings to customers through online postings on *www.WaterWiseAustin.org*. Communication efforts have also been expanded by providing updates on conservation-related topics through Facebook, Twitter, NextDoor and YouTube. Since March 2004, Austin Water has offered the WaterWise e-Newsletter to increase communications with customers, as well as participation in water conservation initiatives. The e-newsletter is distributed electronically to a database of approximately 30,000 customers and made available on the Water Conservation website. A quarterly Commercial Conservation e-newsletter is also published.

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APPENDIX H: DEMAND MANAGEMENT SCREENING PROCESS

Water conservation programs (i.e., demand management) have been and will continue to be a critical element in Austin's management of water resources. Accordingly, Austin Water (AW) and the Water Forward Task Force have established water conservation as a major focal point for the Integrated Water Resource Plan (IWRP). Thus, an important task of the IWRP is to describe existing conservation measures implemented by AW, identify potential new options for future implementation, screen the potential new options to a list of those best analyzed as potential components of the IWRP, and characterize and quantify those measures. This memorandum summarizes the demand management options screening effort and results. The outcome of this process will be a list of the ten demand management measures to be fully evaluated for cost and benefits and thereby carried forth into the subsequent task of portfolio development.

H.1 Screening Criteria and Weight

The screening process for assessing the potential demand management options under consideration for the IWRP focused on a total of four broad qualitative criteria:

- Incremental Water Savings Potential: This criterion provides a qualitative, comparative assessment of the incremental water savings potential for a given measure. Each measure is scored numerically from a 0 to 5, with 0 indicating very little water savings potential and 5 indicating significant water savings potential. The water savings potential for each measure is determined based on consideration of current or historical programs that have targeted the same end use, additional savings that can be achieved by that measure given the extent of the sector/end use demand currently, new versus existing development, the 100-year planning horizon that projects an addition of roughly 3 million additional people to be serviced, and success that other utilities have had implementing a similar program.
- Incremental Utility Cost of Implementation: This criterion characterizes the incremental utility cost of implementing a measure. Each measure is scored numerically from 1 to 5, with 1 indicating significant expense and 5 indicating minimal costs. The utility cost of implementation scoring takes into consideration whether the measure requires rebate investments, staff time and resources, potential for requiring capital expenditures, and the complexity of designing an ordinance or code, and considers how these costs might change over time.
- Ease of Implementation: This criterion provides a qualitative assessment of how difficult or easy it will be to implement a given measure. Each measure is scored numerically from 1 to 5, with 1 indicating the measure is extremely difficult to implement with many hurdles and 5 indicating minimal implementation challenges and minimal additional staff/resources required. The ease of implementation scoring for each measure takes into consideration customer/stakeholder acceptance or resistance, programmatic design challenges, enforcement assumptions, and technological hurdles.
- Incremental Customer Cost of Implementation: This criterion characterizes the incremental customer cost of implementing a measure. Each measure is scored numerically from 1 to 5, with 1

indicating significant expense to the customer and 5 indicating minimal customer expense. The customer cost of implementation scoring takes into consideration the potential costs that would be absorbed by the customer for a given measure, such as cost of compliance, equipment/materials, or maintenance, and considers how these costs might change over time.

These four criteria are then combined as follows to develop a single weighted score:

- Incremental Water Savings Potential made up 50% of the weighted score.
- The Incremental Utility Cost of Implementation, Ease of Implementation, and Incremental Customer Cost of Implementation combined made up the other 50% of the weighted score.

For the purposes of calculating the weighted score, the incremental water savings potential was multiplied by three and then added together with the remaining scores. The highest potential score is a 30, which would indicate a demand management measure that has high water savings with low overall costs that is easy to implement.

H.2 Demand Management Options

The demand management options list was defined through a collaborative process, with options developed based on previous task force recommendations, input from the Water Forward Task Force members, AW staff, the public, and the consulting team.

Of the initial 25 options, two were re-categorized as supply side options, two were determined to be continuing best management practices, and three were determined to be necessary implementation components to other options. The remaining options were combined or split out into one or more options, thereby reducing the number of options for screening to thirteen.

Given the list of potential measures that was ultimately developed and for which input was sought, AW staff and the consulting team determined that several options would be best handled through a separate process, as follows:

- The option to require or incentivize expansion of the use of the current reclaimed water system along with an option to require or incentivize building plumbing innovations such as dual plumbing were moved to the supply side list.
- The option to require or incentivize government-recognized energy and water efficiency-labeled residential and commercial fixtures and the option to incentivize or require toilet, urinal, and bathroom faucet aerator efficiencies were determined to be "continued best management practices" to be included in demand offsets separately (i.e., off-the-top reduction from the baseline forecast that does not require evaluation through the IWRP process) and reflects Austin Water's longstanding programs to incentive, require or freely distribute these fixtures.
- Three options were determined to be "implementation components" of a successful conservation program and were not further evaluated or screened. These measures include water rates and fees to promote water use efficiency while maintaining affordability, customer education enhancements, and use of social media programs and web-based content to promote conservation. These types of programs are indeed critical to a successful program but do not have significant water savings of their own, rather they assist the successful implementation of other programs.

The remaining measures were then combined or split out into one or more options so that, if selected to be fully evaluated, the option would represent a single definable measure with scalable parameters. For example, ordinances and incentives for landscape transformation have different costs on a per unit basis at the utility-level, thus the implementation approach was assessed as two different options. This approach allowed further assessment of a range of potential implementation approaches within the options characterization process. As another example, graywater was identified as being an alternative water source that has characteristics that differ from other sources (such as rainwater or stormwater) because of the implementation complexity and thus was analyzed as a separate measure. In total, 13 demand management options for the screening were identified and delineated, as shown in **Table H-1**. The goal of the screening process was to identify the ten demand management options for additional characterization and use within the portfolio development process.

Table H-1. List of demand management measures for screening

Measure Name	Measure Description	Sector; End Use	Target[1]
Alternative Water Incentives	Incentivize on-site (building-scale) alternative water use (for rainwater, stormwater, blackwater, and ac condensate)	All; Nonpotable with potential for potable RWH in Single Family	Existing
Alternative Water Incentives - Graywater	Offer an incentive to encourage the installation and use of graywater systems	All; Nonpotable indoor and irrigation	Existing and New
Alternative Water Ordinances	Require on-site (building-scale) alternative water use (for rainwater, stormwater, blackwater, and AC condensate)	Multifamily, Commercial; Nonpotable	New
Advanced Metering Infrastructure (AMI)	Implement customer-facing programs that provide real-time water use information (including commercial customer benchmarking), including identification of customer-side leaks and other water-saving opportunities (implemented through Advanced Metering Infrastructure - AMI)	All; All	All
CII Ordinances Cooling Towers	Require older cooling towers to meet water efficiency standards and use efficient equipment and require efficiency standards for steam boilers in new development	Commercial; Colling towers, Steam Boilers	Existing
CII Ordinances Swimming Pools	Require swimming pool efficiency (retrofit)	COA, Multifamily, Commercial; Pools	Existing
Water Use Estimates/ Benchmarking Plan Submittal	Require water use estimate submittal for new development concurrent with preliminary plan submittal, to be reviewed by City staff for comparison to benchmarks. As part of this review, City staff will provide potential water use efficiency recommendations and information on available incentive and rebate programs.	All; All	New/Re-development
Water Use Estimates/ Benchmarking Seller Disclosure	Require sellers of commercial property to provide written disclosure of older water using equipment not meeting current standards or fixtures at point of sale to buyers and City staff	Commercial; All	All

[1] For this analysis, the definitions for existing/new sectors are tied to the development permitting and review process. "Existing" is any development that has received a certificate of occupancy. "New" is any new development in the process of obtaining permitting approvals.

Measure Name	Measure Description	Sector; End Use	Target[1]
Irrigation Efficiency Incentives	Expand current irrigation rebate programs to include irrigation system controllers that respond to leaks, high pressure, and soil moisture; Incentivize retrofit of grandfathered irrigation systems to encourage more efficient irrigation systems	All; Irrigation	Existing
Irrigation Efficiency Code Change	Replace existing code that requires installation of a permanent irrigation system with a code that allows for installation of a temporary irrigation system to establish permanent landscaping	Multifamily, Commercial; Irrigation	New
Landscape Transformation Ordinances	Implement ordinances to encourage water use efficiencies and reduce water needs for outdoor irrigation and other goals through regionally appropriate landscapes with an emphasis on landscape functionality (Implementation of this option could include implementing turf grass area, irrigated area, and/or irrigation area limitations)	All; Irrigation	New
Landscape Transformation Incentives	Implement incentives to encourage water use efficiencies and reduce water needs for outdoor irrigation and other goals through regionally appropriate landscapes with an emphasis on landscape functionality (implementation of this option could include increasing WaterWise landscape rebates for residential and multifamily and implementing a new WaterWise landscape rebate for commercial)	All; Irrigation	Existing
Water Loss Control Utility Side	Enhance current utility-side water loss control programs	System Wide; Nonrevenue Water	N/A

H.3 Screening Results

H.3.1 Summary of Screening Results

Based on the screening criterion described in **Section H.1**, the list of measures identified for screening were characterized based on professional judgement of the CDM Smith team in consultation with AW conservation staff. Results of the screening are provided in **Table H-2**. The tables in the following section provide the general assumptions that went into scoring each measure. Where readily available, examples of similar programs are provided. The top ten ranked measures, shown as bolded in the following table, were carried forward to the options characterization process.

Table H-2. Demand management screening results (bolded options carried forward to characterization)

Rank	Measure Name	Incremental Water Saving Potential	Incremental Cost Implementation Utility	Ease of Implementation	Incremental Cost Implementation Customer	Weighted Score
1	**Landscape Transformation - Ordinances**	**5**	**2**	**2**	**2**	**21**
2	**Advanced Metering Infrastructure (AMI)**	**4**	**1**	**1**	**5**	**19**
3	**Water Loss Control Utility Side**	**3**	**1**	**1**	**5**	**16**
4	**Landscape Transformation - Incentives**	**3**	**2**	**3**	**2**	**16**
5	**Irrigation Efficiency - Incentives**	**2**	**3**	**4**	**2**	**15**

Rank	Measure Name	Incremental Water Saving Potential	Incremental Cost Implementation Utility	Ease of Implemen-tation	Incremental Cost Implementation Customer	Weighted Score
6	**CII Ordinances - Cooling Towers and Steam Boilers**	**2**	**4**	**3**	**2**	**15**
7	**Alternative Water - Ordinances**	**3**	**3**	**1**	**1**	**14**
8	**Water Use Estimates/ Benchmarking - Plan Submittal**	**2**	**2**	**2**	**4**	**14**
9	**Alternative Water -Incentives**	**2**	**2**	**3**	**2**	**13**
10	**Alternative Water Incentives - Graywater**	**1**	**2**	**2**	**3**	**10**
11	Water Use Estimates/ Benchmarking - Seller Disclosure	1	2	1	3	9
12	CII Ordinances - Swimming Pools	1	3	2	1	9
13	Irrigation Efficiency - Code Change	0.5	4	2	1	8.5

H.3.2 Additional Detail on Option Screening Scores

Tables H-3 through **H-15** provide additional detail on the assumptions that went into creating screening scores for each demand management measure.

Table H-3. Screening score detail for landscape transformation ordinances

Landscape Transformation Ordinances		
Measure Name	**Description**	
Definition	Implement ordinances to encourage water use efficiencies and reduce water needs for outdoor irrigation and other goals through regionally appropriate landscapes with an emphasis on landscape functionality. Implementation of this option could include implementing turf grass area, irrigated area, and/or irrigation area limitations.	
Savings Score	5 - Future outdoor use represents the largest potential demand sector in Austin over 100 years. Regionally appropriate landscapes requiring little or no supplemental irrigation beyond establishment could reduce future outdoor use by a considerable amount. Savings from this measure would need to be evaluated in light of current 1x per week irrigation restrictions.	
Utility Cost Score	2 - Landscape ordinances will take time and effort to develop in the beginning and will require additional staff resources to implement and enforces. Costs could reduce in the long-term.	
Implementation Ease Score	2 - In the early phases of implementation, effort will be required to inform, educate and to inspect, and verify to ensure proper implementation. Will require substantial coordination with other departments in Austin and the land development code.	
Customer Cost Score	2 - Customer costs for landscaping may be higher initially until the industry fully adapts to the ordinances. Over the long-term perspective, customer costs would be expected to decline as the incremental costs come down.	
Notes	A long-term effort yielding substantial water savings in a critical sector. Incremental customer costs are expected to decline over time.	
Examples	*California*	The State of California has a Model Water Efficient Landscape Ordinance (MWELO) which sets a maximum applied water allowance on landscape areas for all new construction. The formula used to calculate the estimated total water use has limits on the percent of landscape that is irrigated turf. This percentage has been changed over time.

Landscape Transformation Ordinances		
	Colorado	Westminster Colorado has landscape ordinances requiring minimum soil amendments and mulch for all new landscapes, coupled with inspections and verification. A water use analysis approach to the connection fee calculations provides financial incentive for water efficiency across all new buildings and landscapes.

Table H-4. Screening score detail for AMI

Advanced Metering Infrastructure (AMI)		
Measure Name	**Description**	
Definition	Implement customer-facing programs that provide real-time water use information, including identification of customer-side leaks and other water-saving opportunities (implemented through Advanced Metering Infrastructure - AMI); AMI + customer portal and engagement with personal electronic technology (including commercial customer benchmarking).	
Savings Score	4 - The future efficiency potential from customer information and engagement brought about by AMI is significant. Preliminary studies suggest a 5% reduction in residential usage from engagement efforts. This technology is still in its infancy and implementation anticipated to help reduce customer side leaks and excessive use for years to come.	
Utility Cost Score	1 - AMI and customer engagement software represents a significant investment for AW. Over the next 100 years, the AMI system is likely to be replaced multiple times as equipment ages.	
Implementation Ease Score	1 - Metering and meter replacement is standard utility function, but AMI implementation will require substantially more effort and maintenance over time. Implementation of this option may be more difficult as development of a new customer portal will be required.	
Customer Cost Score	5 - This measure is not anticipated to have required significant customer-side incremental costs.	
Notes	This is an in-process option that is focused on better measuring and managing supply as well as increasing customer engagement. It is expected that all water utilities will eventually utilize these technologies.	
Examples	*Austin, TX*	Pilot scale AMI project underway
	Fort Collins, CO	AMI leak alert program started in 2015, notifying customers with continuous use. Leveraging AMI for Leak Detection www.watersmartinnovations.com/documents/sessions/2015/2015-W-1532.pdf
	East Bay MUD	Various AMI pilots and evaluation of engagement software platforms.
	Valencia, CA	Water budgets linked with AMI technology for advanced customer communication.
	Leesburg, VA	Reduced non-revenue water from 15% to 7% since installing AMI

Table H-5. Screening score detail for utility-side water loss control

Water Loss Control – Utility Side		
Measure Name	**Description**	
Definition	Enhance current utility–side water loss control programs	
Savings Score	3 - As Austin's system ages over the next 100 years, advanced water loss control will yield increased water savings. Water loss in systems 50 - 100 years older than AW is much higher. New water loss control technologies are expected too.	
Utility Cost Score	1 - A significant incremental expense for AW, particularly if the costs of leak repair and pipe replacement are included.	
Implementation Ease Score	1 - Water loss control is already a core AW utility function. The enhanced program will require more utility staff and effort and may face challenges associated with capital project implementation.	
Customer Cost Score	5 - This measure is not anticipated to have required significant customer-side incremental costs.	
Notes	As Austin's system ages, reducing water loss will become increasingly important.	
Examples	*Georgia*	State mandated annual validated water loss audits. Funding tied to steady improvement.
	Texas	The City of Fort Worth submitted a SWIFT application for implementation of AMI with an automated leak detection system. Water loss for the City was estimated at 14%. The expected annual volume of water conserved was estimated at 9,450 AFY. http://texaslivingwaters.org/wp-content/uploads/2016/11/SWIFT-Guidance-Document_FINAL.pdf
	California	Major new state water loss control initiative focused on training, education, audit validation, and continuous improvement.
	Texas	Water loss audits are required by State for all retail public water suppliers every five years. Retail water suppliers with greater than 3,300 connections are required to submit an audit annually.

Table H-6. Screening score detail for landscape transformation incentives

Landscape Transformation Incentives	
Measure Name	**Description**
Definition	Implement incentives to encourage water use efficiencies and reduce water needs for outdoor irrigation and other goals through regionally appropriate landscapes with an emphasis on landscape functionality. Implementation of this option could include increasing WaterWise landscape rebates for residential and multifamily and implementing a new WaterWise landscape rebate for commercial.
Savings Score	3 - Current outdoor use represents about 22% of total metered demand. Regionally appropriate landscapes requiring minimal supplemental irrigation beyond establishment would help adapt landscapes to require less water and could further reduce outdoor use by a considerable amount. Savings from this measure would need to be evaluated in light of current1x per week irrigation restrictions.
Utility Cost Score	2 - AW already offers landscape incentives and has a program in place for implementation. The incremental cost of expanding the program is scalable and comparatively low.
Implementation Ease Score	3 - A moderate level of effort is anticipated as the program expands. This option will require coordination with other departments (WPD) and Land Development Code

Landscape Transformation Incentives		
Measure Name	**Description**	
Customer Cost Score	2 - Customer receives an incentive, but replacing landscaping can be expensive. Compared with other measures, there will be some incremental customer costs.	
Notes	This measure anticipated to accelerate water savings and landscape transformation in Austin.	
Examples	*California*	Metropolitan Water District and member agencies implemented a massive turf replacement program in 2014-16. Thousands of acres of turf were converted and more than $370 million in rebates were provided.
	Nevada	The Southern Nevada Water Authority developed and continues to implement a landscape incentive program focused on locally appropriate plantings. Significant impact and reduction in turf landscapes.
	Colorado	Water utilities and a local non-profit team annual to offer "Garden in a Box" plant packages, aimed a regionally appropriate landscaping.

Table H-7. Screening score detail for water use estimates/ benchmarking plan submittal

Water Use Estimates/ Benchmarking Plan Submittal		
Measure Name	**Description**	
Definition	Require water use estimate submittal for new development concurrent with preliminary plan submittal, to be reviewed by City staff for comparison to benchmarks. As part of this review, City staff will provide potential water use efficiency recommendations and information on available incentive and rebate programs.	
Savings Score	2 - Beginning with a development review process focused on sensible efficiency recommendations, the water savings may be relatively small. Over the 100-year timeframe, this effort will likely evolve into a process where new buildings in Austin are scored against efficiency benchmarks. Eventually this could lead to the creation of a reasonable water allocation (water budget) for every new (and eventually existing) property in Austin that could be used to benchmark efficiency. Phased implementation of this option could lead to more substantial water savings over time.	
Utility Cost Score	2 - This will require significant effort at the outset, but overtime as benchmarks are established and the process becomes more routine, effort is anticipated to be reduced.	
Implementation Ease Score	2 - A challenging implementation for AW at the outset. This option could build off of the Austin Energy Green Building program or AW Service Extension Request process. This option could be resource intensive in terms of staffing and process to establish benchmarks.	
Customer Cost Score	4 - Some additional time and resources may be expended by customer/contractor/engineer for this preliminary submittal. No incremental cost to current customers. Future customers benefit from built-in water efficiency.	
Notes	Could be an important step for AW in the direction of customer-specific water efficiency and ensuring new buildings join the system as highly water efficient from the start.	
Examples	*Colorado*	Westminster Colorado charges substantially higher connection fees based on increased tap size and anticipated water usage based on customer type and size. This brings new buildings to the table with water efficiency built-in to achieve a lower connection fee.
	California	A water budget approach to both new and existing customers has been used by a handful of utilities for years, and has recently been adopted widely across the state. The State has embraced this approach from the customer up through the utility itself.

Table H-8. Screening score detail for irrigation efficiency incentives

Irrigation Efficiency Incentives		
Measure Name	**Description**	
Definition	Expand current irrigation rebate programs to include irrigation system controllers that respond to leaks, high pressure, and soil moisture. Incentivize retrofit of grandfathered irrigation systems to encourage more efficient irrigation systems.	
Savings Score	2 - Impacts existing irrigation systems and savings are assumed to accrue in first 20 - 30 years only. Savings likely to be relatively small with 1x per week irrigation restrictions in place.	
Utility Cost Score	3 - Moderate incremental cost. Scalable, based on rebate level.	
Implementation Ease Score	4 - AW already offers an irrigation incentive for residential and a smart controller incentive for multifamily and commercial with programs in place for implementation. AW also offers free evaluations for residential and mandatory irrigation audits for commercial and multifamily. The incremental effort of expanding the program is scalable and comparatively low.	
Customer Cost Score	2 - Customer's receive an incentive, but must bear the costs of system repair and replacement. Compared with other measures, there will be some incremental customer costs.	
Notes	Incentives could be designed to assist in landscape transformation as well. Impacts existing customers.	
Examples	*Arizona*	Tucson and other cities offer rebates for drip irrigation and climate-based control
	Utah	Salt Lake City. WaterCheck irrigation audits and system upgrades. Rebates.
	Texas	San Antonio (SAWS) has offered a variety of irrigation efficiency programs. Dallas Water Utilities also offers free irrigation system check-ups.

Table H-9. Screening score detail for alternative water ordinances

Alternative Water Ordinances		
Measure Name	**Description**	
Definition	Require on-site (building-scale) alternative water use (for rainwater, stormwater, blackwater, and air conditioning (AC) condensate) for new developments in the multifamily and commercial sectors	
Savings Score	3 - Applies to future construction which represents a big portion of future demand. Scalable.	
Utility Cost Score	3 - These regulations will be complex to design, implement, and regulate, particularly in the early stages. Over time, the implementation effort could be reduced.	
Implementation Ease Score	1 - The challenges of design and early stage implementation are unknown and could be significant.	
Customer Cost Score	1 - Mandating these systems will increase the cost of land development. Installation of these systems would require dual plumbing. Long term maintenance of these systems adds to customer expense as well.	
Notes	While generally expensive and challenging to implement, this option could provide savings and other benefits. As with all measures, savings must be proven for this to be considered a reliable source of future demand reduction for Austin.	
Examples	*Australia*	Gold Coast Water, south of Brisbane mandated dual plumbing and on-site capture systems during the millennial drought. Most systems were quickly abandoned once the drought ended. AWE published a "lessons learned" from the Australian drought report.
	San Antonio, Texas	San Antonio requires new commercial construction on or after January 1, 2006, to have a single independent condensate collection line to collect condensate for use as process water, cooling tower makeup, and landscape irrigation.

Table H-10. Screening score detail for cii ordinances for cooling towers and steam boilers

CII Ordinances: Cooling Towers and Steam Boilers		
Measure Name	**Description**	
Definition	Require older cooling towers to meet water efficiency benchmarks and use efficient equipment and require efficiency standards for steam boilers in new development	
Savings Score	2 - Impacts cooling towers installed prior to 2008. New equipment is assumed efficient by code. All savings accrue in the first 30 - 40 years.	
Utility Cost Score	4 - Incremental utility cost is comparatively small.	
Implementation Ease Score	3 - Enforcement and verification patterned after existing car wash program through registration, third-party inspection paid by customer, and self-reporting will help with ease of implementation.	
Customer Cost Score	2 - Complying with the cooling tower requirement portion of this option would have low to moderate costs for customers.	
Notes	This measure was considered as part of the plumbing code adoption cycle that occurred during the development of the Water Forward IWRP. The Austin City Council approved cooling tower efficiency requirements including mandatory registration and annual inspection requirements on June 8, 2017 as part of the adoption of local amendments to the 2015 Uniform Mechanical Code	
Examples	*Colorado*	Denver Water has had trouble maintaining long term water savings from cooling tower retrofits.
	California	Metropolitan Water District (MWD) offers different cooling tower incentives but has not established formal requirements.

Table H-11. Screening score detail for alternative water incentives

Alternative Water Incentives		
Measure Name	**Description**	
Definition	Incentivize on-site (building-scale) alternative water use (for rainwater, stormwater, blackwater, and AC condensate) for existing developments	
Savings Score	2 - Applies to existing development as retrofit. Scalable.	
Utility Cost Score	2 - Program would add to complexity of existing programs. Over time, the implementation effort could be reduced.	
Implementation Ease Score	3 - Design and early stage implementation could be built off of existing incentive programs for rainwater harvesting and ac condensate.	
Customer Cost Score	2 - Even with an incentive, these systems are usually expensive to retrofit. Installation of these systems would require dual plumbing for use indoors.	
Examples	*Australia*	Gold Coast Water, south of Brisbane mandated and incentivized dual plumbing and on-site capture systems during the millennial drought. Most systems were quickly abandoned once the drought ended. Alliance for Water Efficiency (AWE) published a "lessons learned" from the Australian drought report.

Table H-12. Screening score detail for alternative water incentives - graywater

Alternative Water Incentives - Graywater		
Measure Name	**Description**	
Definition	Offer an Incentive to encourage the installation and use of graywater systems, which are defined as shower-to-toilet and landscape irrigation systems that collect shower, faucet, and laundry discharge, provide some element of filtration and treatment and then reuse the water.	
Savings Score	1 - Limited water savings potential as clothes washers, faucets, and showers become more efficient and use less and less water. Less and less graywater will be produced.	
Utility Cost Score	2 - Comparatively expensive to implement. Incentives would need to be substantial to achieve meaningful participation rates. 2017 Alliance for Water Efficiency (AWE) study found some potential long-term benefits for water utilities, but also cautioned about the lack of cost effectiveness and demonstrable savings data.[2]	
Implementation Ease Score	2 - Graywater systems are complex. Implementation from the utility perspective will be on a long-term time frame requiring staff effort.	
Customer Cost Score	3 - From the AWE report, "if the total life-cycle costs of the system exceed the total life-cycle savings from reduced potable water purchases, the system will have a net cost to the homeowner." This is the expected outcome from most systems.	
Notes	The 2017 research indicates that graywater systems have yet to be proven cost-effective from the customer or the utility perspective.	
Examples	*Australia*	Gold Coast Water began installing on-site systems during the millennial drought. Generally these systems were quickly abandoned once the drought ended.

[2] Gauley, Bill (2017) *Water Savings and Financial Benefits Associated with Single-Family Package Graywater Systems*. Alliance for Water Efficiency. Chicago, IL.

Table H-13. Screening score detail for water use estimates/ benchmarking - seller disclosure

Water Use Estimates/ Benchmarking - Seller Disclosure		
Measure Name	**Description**	
Definition	Require sellers of commercial property to provide written disclosure of older water using equipment not meeting current standards or fixtures at point of sale to buyers and City staff	
Savings Score	1 – This is not a mandate for water efficient fixtures, only for disclosure. Water savings could be significant if turned into a "retrofit on resale" requirement as California has just done. Without a mandate or incentive, the potential for water savings should be assumed limited, until proven.	
Utility Cost Score	2 - Setting the "current standards" and developing the process that must be met would be an on-going challenge for AW. Requires staff effort and will likely require new staff because of real estate transaction complexity and reporting.	
Implementation Ease Score	1 - Expect significant pushback from the real estate industry and commercial property owners. Anything that complicates the transfer of real property is seen as an impediment. Monitoring real estate transaction will be very difficult, especially for the commercial sector.	
Customer Cost Score	3 - Customer cost would likely be low to moderate but could have cost and transaction time impacts.	
Notes	While savings are scored low, the effort could evolve into a major contributor to future water efficiency in Austin if retrofit on resale was included.	
Examples	*California*	State law mandates 1.28 gallons per flush (gpf) toilets and other fixtures in all single-family residences. Effectively a retrofit on re-sale ord. Expected to be enforced as part of the inspection and title transfer of real estate.
	California	City of Burbank has “retrofit upon resale” requirements for residential properties that went into effect in 2010. https://www.burbankwaterandpower.com/water/rules-and-regulations-water/retrofit-upon-resale-requirements
	California	City of San Diego has “retrofit upon resale” requirements for residential properties that went into effect in 2000. https://www.sandiego.gov/water/conservation/selling

Table H-14. Screening score detail for cii ordinance for swimming pools

CII Ordinances: Swimming Pools	
Measure Name	**Description**
Definition	Require swimming pool efficiency (retrofit)
Savings Score	1 - The sector impacted is comparatively small. 100-year savings are small.
Utility Cost Score	3 – Varies; measures range from water efficient backwash filters to major leak repairs.
Implementation Ease Score	2 – High level of staff expertise and effort required for successful implementation.
Customer Cost Score	1 – Incremental cost of implementation for customers with pools could be substantial.
Notes	Require swimming pool efficiency (retrofit)

Table H-15. Screening score detail for irrigation efficiency code change

Irrigation Efficiency Code Change	
Measure Name	**Description**
Definition	Replace existing code that requires installation of a permanent irrigation system with a code that allows for installation of a temporary irrigation system to establish permanent landscaping
Savings Score	0.5 - Water savings would be realized only when combined with another option like landscape transformation.
Utility Cost Score	4 – Once implemented this requirement would not have a significant utility cost impact.
Implementation Ease Score	2 – Challenging to implement initially, but easier over time. Would require coordination with Watershed Protection Department and consistency with the Innovative Commercial Landscape Ordinance.
Customer Cost Score	1 – Could be “cost neutral” to customers depending on implementation approach.

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APPENDIX I: WATER SUPPLY OPTION SCREENING PROCESS

A diverse, cost effective and resilient future water supply portfolio is a primary objective of the Austin Water (AW) Integrated Water Resource Plan (IWRP). The process for evaluating future water supply portfolios began with a high-level assessment of potential demand management and water supply options. With review and input from the public, AW and the Water Forward Task Force identified over twenty supply options for possible inclusion in developing water supply portfolios. As there were many possible supply options, the IWRP process included a method to screen out water supply options which, for this cycle of the planning process, were not recommended for more detailed study and possible recommendation. The screening process focused on describing the supply options identified and screening them against high-level criteria including cost, yield, supply type, implementation challenges, and resiliency. This appendix describes the screening process and the metrics which were used to screen each option.

I.1 Screening Process and Criteria

The IWRP screening process consisted of several steps. First, criteria to asses each option was defined. Option-level assessments were then conducted which generated estimates for the criteria values. Then, options scores were binned or scaled to evaluate their performance relative other options. Finally, options were compared and the highest-performing options, as indicated by the previous screening steps, were generally selected for further analysis.

The screening process used for this effort focused on four broad criterion used to assess each option: cost, yield, implementation challenges, and hydrologic resilience. Each criterion is described in more detail in the following subsections. Criteria estimates for each option were based on previously published studies, cost estimates, and the best professional judgement of the IWRP project team (including AW staff and the IWRP consultants). After development, these criteria estimates were evaluated by assigning a categorical bin (for cost and yield) or score on a qualitative scale (for implementation challenges and hydrologic resilience). In this appendix, higher-numbered bins or scores are more favorable to AW's long-term water supply objectives. For screening, the AW IWRP evaluated each water supply option under its own merit and did not explicitly consider any synergies or potential conflict between options in the group of water supply options evaluated. These interactions were considered later in the IWRP process during portfolio evaluation. Due to the complexity of assessing and comparing various water supply options, data visualization graphics were used to convey the high-level screening information.

I.1.1 Annual Unit Cost of Water

The annual unit cost of water in this analysis included the total option capital cost (annualized over the lifetime of the option and including debt financing interest), the annual operations and maintenance costs, annual energy costs, and annual treatment costs. This total annual cost was then divided by the average annual water supply yield to generate an annual unit cost of water (in acre-feet/year). Development of supply option screening level costs were based on previous work completed by the Austin Water Resource Planning Task Force in 2014, associated feasibility studies, Texas Water Development Board (TWDB) Regional Water Plans, and other related studies that provided relevant costing information. When applicable, assumptions consistent with AW's internal financing methods and the TWDB Unified Costing Model were applied. For the purposes of screening, water supply options were categorized by a range of annual unit costs and assigned to an overall cost bin. The screening level annual unit cost bins are shown in **Table I-1.** These annual unit costs were high-level in nature and were primarily intended for comparison within the group of water supply options under consideration. Costs were further evaluated in option characterization (see **Appendix J** for more detail on option characterization) and portfolio evaluation (see **Appendix L** for more detail on portfolio evaluation).

Table I-1. Annual unit cost - screening bins

Annual Unit Cost	Bin
$0/AF to $500/AF	4
$500/AF to $2,000/AF	3
$2,000/AF to $4,000/AF	2
$4,000/AF and above	1

I.1.2 Average Annual Yield

A primary objective of the AW IWRP is to evaluate the quantity and reliability of AW's future water resource portfolio, including demand measures and water supply options. One way this objective was addressed at the screening level was by estimating the potential average annual yield of each water supply option as part of the screening evaluation. Yields were further refined in option characterization, but the screening-level estimates were important to inform decision making about which options should more forward for further analysis.

Like the annual unit cost, water supply option yields were categorized using a range and assigned an overall potential annual yield screening bin. The yield bins are shown in **Table I-2.** These yield estimates were high-level in nature and were used for comparison within the group of water supply options under consideration.

Table I-2. Potential annual yield - screening bins

Potential Annual Yield	Bin
0 AF to 10,000 AF	1
10,000 AF to 35,000 AF	2
35,000 AF and above	3

I.1.3 Implementation Challenges

This criterion provided a qualitative assessment of how difficult or easy it would be to implement a given water supply option. Each water supply option was scored numerically from one to five, with one indicating the water supply option may be extremely difficult or time-consuming to implement, with many uncertainties involved, and five indicating minimal implementation challenges. The implementation challenge score for each water supply option is based on consideration of anticipated customer/stakeholder acceptance or resistance, programmatic design challenges, permitting and legal complexities, enforcement assumptions, scalability of the water supply option, and technological hurdles.

I.1.4 Hydrologic Resiliency

This criterion qualitatively assesses each water supply option's susceptibility to future variations in hydrology and climate. Each water supply option is scored numerically from one to five, with one indicating a water supply option may be highly impacted or variable under future hydrologic and climatic variations, and five indicating minimal impact to a water supply option's performance under future hydrologic or climatic variations.

I.1.5 Other Scoring Considerations

I.1.5.1 Performance Score

For the purposes of portfolio screening, the implementation challenges and hydrologic resiliency criterion scores were combined into one overall "performance score" that was a representation of a portfolio's general performance. The overall performance score was developed by equally weighting (50/50) the implementation challenges and resiliency scores. For example, a water supply option that received an implementation challenge score of 3 and a resiliency score of 4 would receive an overall performance score of 3.5.

I.2 Preliminary Water Supply Options

The AW IWRP preliminary water supply options list was created through a collaborative process that involved AW staff, the consulting team, the current IWRP Task Force, the 2014 Austin Water Resource Planning Task Force report, and consideration of public input. In total, 21 water supply options were identified for screening, as shown in **Table I-3**. This table includes the water supply option number, name, and associated primary supply type. Colors for the supply types correspond to graphics presented later in the document.

Table I-3. List of the 21 preliminary supply options for screening

Option Number	Option Name	Supply Type
1	Edwards/Trinity Aquifer Storage and Recovery (Feasibility and Engineering Analysis 5)	Storage
2	Direct Non-Potable Reuse (Reclaimed Water System)	Reuse
3	Lake Austin Operations	Surface Water
4	Stormwater Harvesting (community-scale)	Decentralized
5	Rainwater Harvesting (community-scale)	Decentralized
6	Sewer mining (wastewater scalping)	Decentralized
7	Distributed wastewater systems	Decentralized
8	Capture Lady Bird Lake Inflows (Feasibility and Engineering Analysis 4)	Surface Water
9	Indirect Potable Reuse – Through Bed and Banks	Reuse
10	Indirect Potable Reuse – Through Lady Bird Lake (Feasibility and Engineering Analysis 2)	Reuse
11	Indirect Potable Reuse – Through Alluvial Aquifer	Reuse
12	Direct Potable Reuse	Reuse

Option Number	Option Name	Supply Type
13	Brackish Groundwater Desalination	Desalination
14	Seawater Desalination	Desalination
15	Lake Evaporation Suppression	Storage
16a	Conventional Groundwater (Developed)	Groundwater
16b	Conventional Groundwater (Purchased)	Groundwater
17	Additional supply from LCRA	Surface Water
18a	Carrizo-Wilcox Aquifer Storage and Recovery (Infiltration)	Storage
18b	Carrizo-Wilcox Aquifer Storage and Recovery (Conventional)	Storage
19	Regional partnership with Corpus Christi	Surface Water
20	Interbasin transfers	Surface Water
21	Off-Channel Reservoir	Storage

I.3 Screening Results

Each water supply option listed in the previous table was evaluated against the screening criteria described in **Section I.1**. **Table I-4** presents the metrics for each option that were used to determine their score within each criterion. As noted previously, cost and yield information were largely based on previous studies and reports; however, when necessary, the reference costs were adjusted or scaled to better reflect the water supply option being evaluated in this plan. Option 19, regional partnerships, was determined to be a potential implementation strategy and was therefore not screened as a unique water supply option.

Table I-5 presents the screening score for each water supply option. The screening score was created based on the results from **Table I-4** and the bins and scales described in the first section. Data presented in both tables are high-level screening results and may have changed between this step and option characterization, when more detailed analysis on each selected screened option is performed.

Table I-4. Option screening-level metrics (metrics may be different from characterization-level estimates)

Option No.	Description	Yield (AF)	Annual Unit Cost ($/AFY)	Implementation Challenges	Hydrologic Resiliency
1	Edwards/Trinity Aquifer Storage and Recovery	4,300	$ 2,631	Current regulations do not allow injection wells that transect or terminate in the Edwards Aquifer in Travis County.	Little sensitivity to variation in hydrology or climate. Recovery rate may be influenced by fluctuations in supply available for storage.
2	Direct Non-Potable Reuse	43,100	$ 1,132	Coordination with customers (location)	Actual water demands may increase faster/slower than projected.
3	Lake Austin Operations	2,500	$ 218	Public acceptance	Hydrology impacts long-term reliability. Concerns with low lake levels.
4	Stormwater Harvesting (community-scale)	18,558	$ 4,122	Variable water quality can impact yield, current regulation may limit-large scale stormwater harvesting (waters of the state), retrofitting is expensive.	Yield is climate-dependent. Provides less supply benefit during drought.
5	Rainwater Harvesting (community-scale)	7,886	$ 8,383	Storage issues, lot-scale rainwater or community-scale stormwater often more cost effective, collection of rainwater from property may be perceived negatively.	Yield is relatively small and climate dependent. Provides less supply benefit during drought.
6	Sewer mining (wastewater scalping)	19,117	$ 3,977	Retrofitting has many challenges, site suitability impacted by considerations of sewer system, cost-effectiveness highly site-specific, benefits difficult to quantify.	Moves toward constant closed loop supply.
7	Distributed wastewater systems	20,639	$ 2,744	Public accepts treatment plants in growth areas of Austin. Benefits hard to quantify.	Moves toward constant closed loop supply.
8	Capture Lady Bird Lake Inflows	3,000	$ 456	Public acceptance due to new infrastructure. Potential operational constraint.	Actual hydrology would impact the long-term reliability of option. Limited depth could affect pump. Potential ecological concerns.
9	Indirect Potable Reuse – Through Bed and Banks	20,000	$ 529	Water rights permitting, coordination with LCRA, coordination with TCEQ.	Supplies all end uses and moves toward closed loop supply. Potential impacts of downstream environmental conditions.
10	Indirect Potable Reuse – Through Lady Bird Lake	20,000	$ 621	Public acceptance and permitting.	Supplies all end uses and moves toward closed loop supply.
11	Indirect Potable Reuse – Through Alluvial Aquifer	11,000	$ 1,287	Public acceptance concerns, amount of excavation needed, extensive permitting to ensure compliance with all environmental considerations.	Supplies all end uses and moves toward closed loop supply. Yield uncertainty due to effectiveness of infiltration and well.
12	Direct Potable Reuse	20,000	$ 1,940	Public acceptance, regulatory uncertainty, permitting challenges, coordination with TCEQ, concentrate disposal options are limited, potential water quality issues.	Supplies all end uses and moves toward closed loop supply.
13	Brackish Groundwater Desalination	10,000	$ 2,078	Uncertain timeframe fir water rights and permitting, permitting within groundwater districts, changes in groundwater rules, public acceptance, water quality issues.	Sensitivity to variations in climate and hydrology would vary depending on source aquifer and utilization rates.
14	Seawater Desalination	84,000	$ 2,716	Coordination, construction /O&M of pipeline/pump station, public acceptance, brine.	Minimal dependence on hydrologic and climate variability.
15	Lake Evaporation Suppression	827	$ 252	Public acceptance.	Mild to moderate winds could affect suppressant effectiveness.
16a	Conventional Groundwater (Developed)	20,000	$ 1,087	Uncertain timeframe fir water rights and permitting, permitting within groundwater districts, changes in groundwater rules, public acceptance, water quality issues.	Sensitivity to variations in climate and hydrology would vary depending on source aquifer and utilization rates.
16b	Conventional Groundwater (Purchased)	20,000	$ 975	Austin Water would not own supply, contract insecurity, ongoing changes in groundwater regulation, public acceptance, water quality compatibility.	Sensitivity to variations in climate and hydrology would vary depending on source aquifer and utilization rates.
17	Additional supply from LCRA	54,600	$ 352	Uncertainty regarding new contracts, cost.	Highly dependent on variations in climate and hydrology.
18a	Carrizo-Wilcox Aquifer Storage and Recovery (Infiltration)	20,000	$ 495	Water trading agreement with LCRA, permitting, ongoing changes in groundwater regulation and court decisions, public acceptance.	Little sensitivity to variation in hydrology or climate. Recovery rate may be influenced by fluctuations in supply available for storage.
18b	Carrizo-Wilcox Aquifer Storage and Recovery (Conventional)	10,000	$ 1,014	Permitting, ongoing changes in groundwater regulation and court decisions, public acceptance	Little sensitivity to variation in hydrology or climate. Recovery rate may be influenced by fluctuations in supply available for storage.
19	Regional partnership	Considered as an implementation strategy.			
20	Interbasin transfers	100,000	$ 1,153	Interbasin transfer permitting, public acceptance.	Yield dependent on rainfall, surface water subject to evaporation.
21	Off-Channel Reservoir	25,000	$ 812	Could limit yield of stormwater harvesting or raise water rights issues (state permits).	Vulnerable to evaporation. Yield dependent on inflows or local rainfall.

Table I-5 Supply option screening results

Opt. #	Option Name	Cost Bin (1-4)	Yield Bin (1-3)	Implementation Challenge Score (1-5)	Resiliency Score (1-5)	Performance Score (1-5)
1	Edwards/Trinity Aquifer Storage and Recovery (Feasibility and Engineering Analysis 5)	3	2	3	4	3.5
2	Direct Non-Potable Reuse (Reclaimed Water System)	3	3	3	5	4
3	Lake Austin Operations	4	1	3	2	2.5
4	Stormwater Harvesting (community-scale)	2	2	4	2	3
5	Rainwater Harvesting (community-scale)	1	1	4	1	2.5
6	Sewer mining (wastewater scalping)	2	2	3	5	4
7	Distributed wastewater systems	2	2	3	5	4
8	Capture Lady Bird Lake Inflows (Feasibility and Engineering Analysis 4)	4	1	2	2	2
9	Indirect Potable Reuse – Through Bed and Banks	4	2	2	4	3
10	Indirect Potable Reuse – Through Lady Bird Lake (Feasibility and Engineering Analysis 2)	3	2	2	4	3
11	Indirect Potable Reuse – Through Alluvial Aquifer	3	2	2	4	3
12	Direct Potable Reuse	3	2	1	5	3
13	Brackish Groundwater Desalination	3	2	2	3	2.5
14	Seawater Desalination	2	3	1	5	3
15	Lake Evaporation Suppression	4	1	2	3	2.5
16a	Conventional Groundwater (Developed)	3	3	2	3	2.5
16b	Conventional Groundwater (Purchased)	3	3	2	3	2.5
17	Additional supply from LCRA	4	3	4	2	3
18a	Carrizo-Wilcox Aquifer Storage and Recovery (Infiltration)	4	2	2	4	3
18b	Carrizo-Wilcox Aquifer Storage and Recovery (Conventional)	3	2	3	4	3.5
19	Regional partnership with Corpus Christi	Not screened, option considered an implementation strategy				
20	Interbasin transfers	3				
21	Off-Channel Reservoir	3	2	3	3	3

After scoring, the water supply option screening analysis used data visualization graphics to better understand, compare, and analyze the list of water supply options. **Figure I-1** illustrates the previous table to show how options scored according to the primary screening criteria: cost (yield is added in the next figure) and performance score (which includes implementation challenges and hydrologic resiliency). In each figure, the x-axis displays the annual unit cost bin, with water supply options further to the left on this axis considered more cost-effective. The y-axis displays the overall performance score; water supply options further down on the y-axis were considered higher-performing with respect to AW IWRP objectives. To increase display clarity, performance scores and/or placement of water supply options within the cost bins were adjusted slightly to avoid overlapping. The position of water supply options corresponds to a relative "greater than" or "less than", but the spacing is not to scale. Because of this, options should be viewed by their overall cost bin and closest performance score integer.

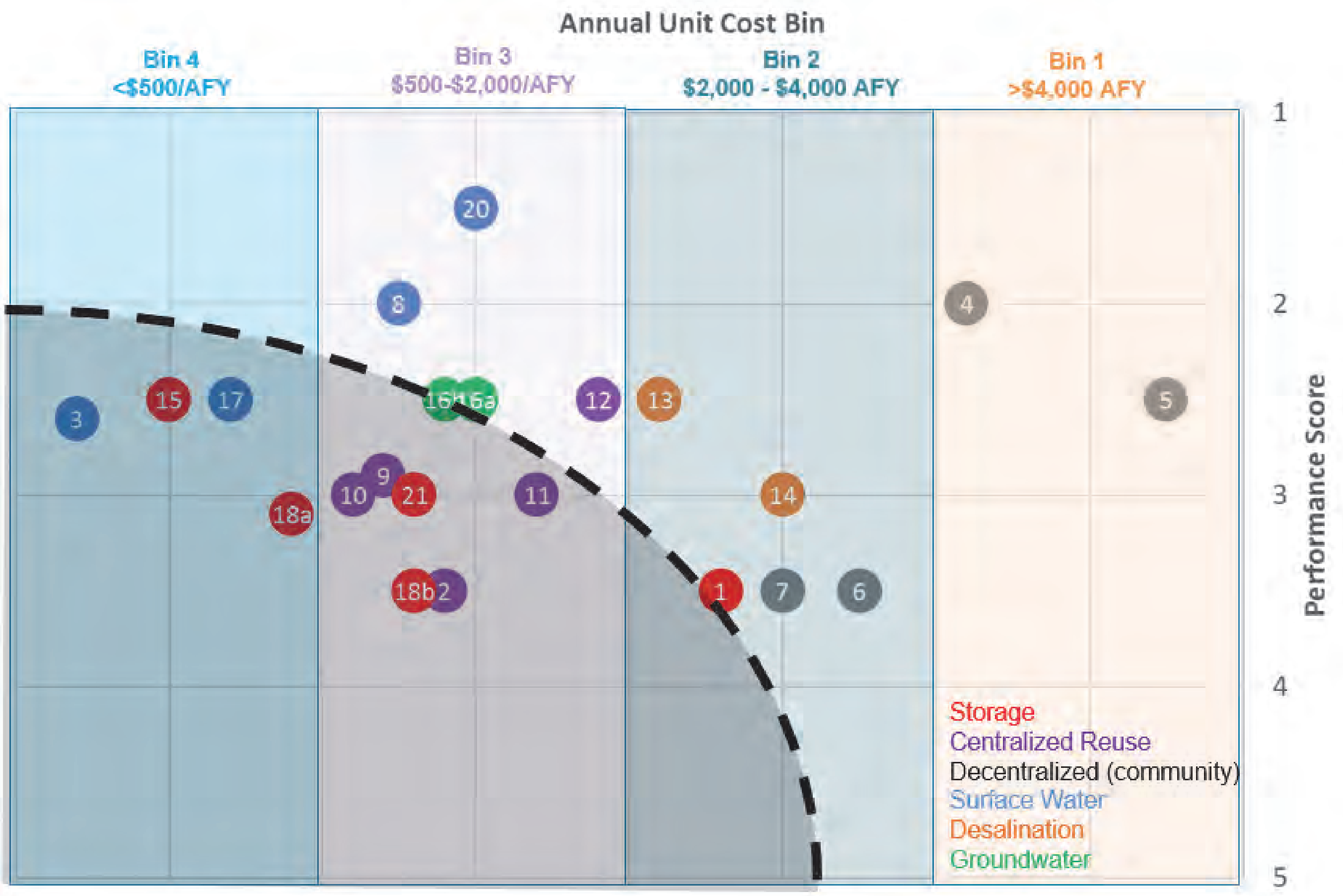

Figure I-1. Supply screening results

The previous figure provides a visual summary of the water supply options screening results. Generally, water supply options that are placed lower and to the left are considered more favorable. A screening arc was superimposed on each figure to highlight the group of water supply options that demonstrate a reasonable balance between both unit cost and performance score. Another important consideration was potential yield from the water supply options. To allow visualization of that information in concert with the screening results, **Figure I-2** was developed to vary each option's representative dot size by the potential supply yield bin.

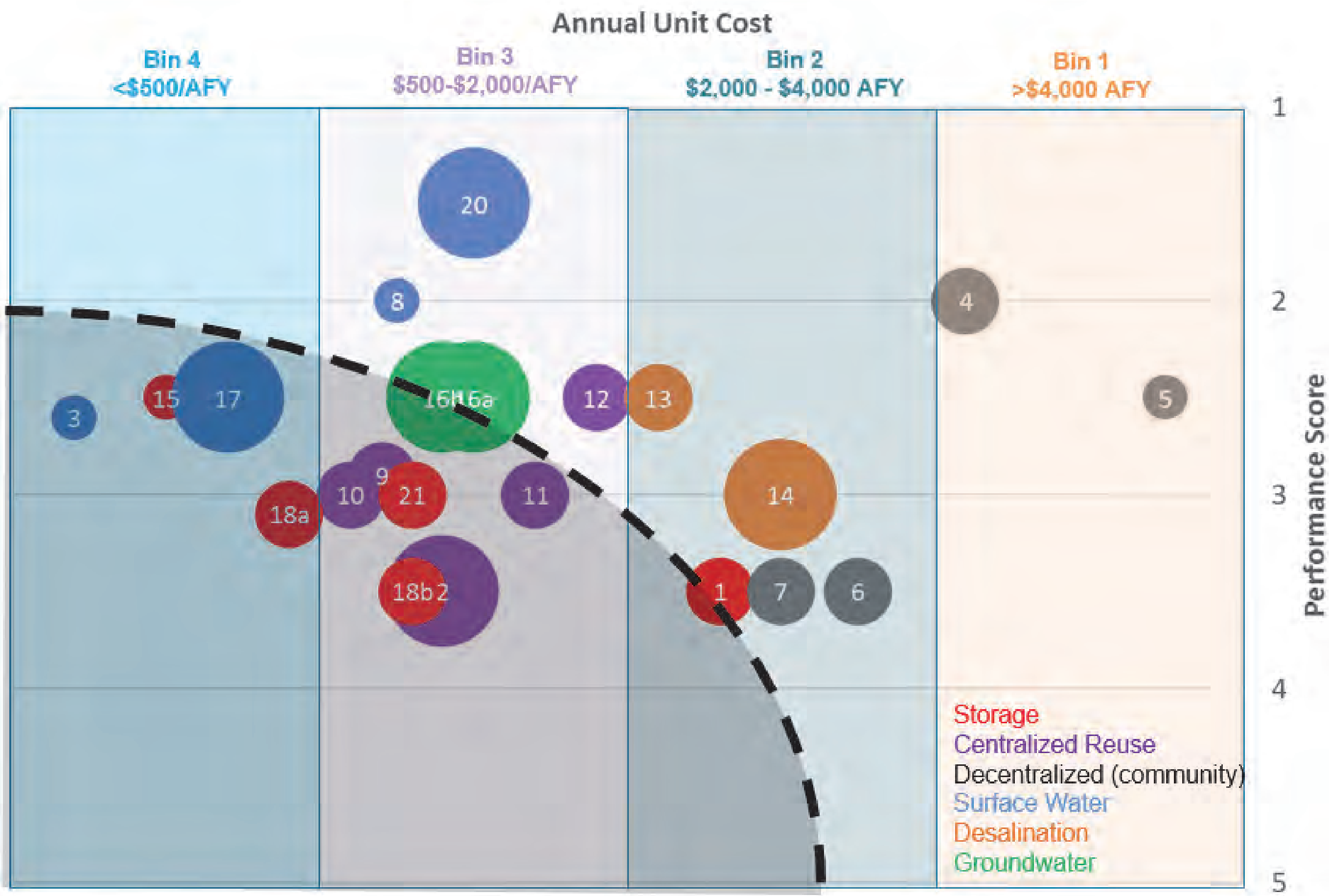

Figure I-2. Supply screening results with relative yield (final option selection based on screening analysis and task force feedback)

I.4 Candidates for Characterization

The water supply options screening analysis was used to identify a suite of candidate water supply options for characterization. The 21 water supply options were narrowed down to thirteen candidates based on the screening assessment presented in the previous sections and feedback from the Water Forward Task Force. As part of this process, several decisions were made to consolidate and/or group options in order to carry more options through characterization while still staying within the scope of the project. A summary of these key decisions is found below.

I.4.1 Combined Options

As previously described, some water supply options were combined to represent a single definable option to move on to characterization. These water supply options were combined because they ultimately rely on the same or a similar type of source water and primarily differ only in implementation strategy. The combined options include:

Aquifer Storage and Recovery (ASR) – this combination groups Options 1, 18a, and 18b (Edwards/Trinity ASR, Carrizo-Wilcox Infiltration ASR, and Carrizo-Wilcox Conventional ASR). The representative water supply option from the grouping that was used for characterization is Option 18b—Carrizo-Wilcox Conventional Aquifer Storage and Recovery.

Indirect Potable Reuse (IPR) – this combination of water supply options groups Options 8, 9, 10, and 11 from the screening analysis (capture Lady Bird Lake inflows, IPR through bed and banks, IPR through Lady Bird Lake, and IPR through alluvial aquifer). The representative water supply option moving forward to characterization was one option including both Option 8 and Option 10 (capture Lady Bird Lake inflows and IPR through Lady Bird Lake). This decision was made because the infrastructure needed for Option 8 is essentially the same as the infrastructure for Option 10.

Off-Channel Reservoir – this representative option will combine elements of Option 15 (lake evaporation suppression) with Option 21 (off-channel reservoir). The option moving forward to characterization was one item which included both screening options; it was characterized as an off-channel reservoir with lake evaporation suppressant applied.

I.4.2 Large-Scale Import Options

Another consideration that was addressed during the screening process was the identification of large-scale import water supply options. One of the primary objectives of the screening process was to ensure that there are adequate water supply options to meet water supply needs throughout the IWRP planning horizon and develop reliable portfolios. To this end, three large-scale water supply options were identified which include seawater desalination, conventional groundwater, and interbasin transfers. Based on the preliminary needs assessment discussed in **Appendix F**, the need for these large-scale supply options is anticipated sometime after 2070. Due to the relatively distant planning horizon, implementing these larger-scale import options is quite uncertain.

Of the larger-scale import options, only seawater desalination and conventional groundwater were selected as representative options for the large-scale import group for characterization. The conventional groundwater group combines Options 16a and 16b (conventional groundwater—developed, and conventional groundwater—purchased). The representative option used for portfolio analysis was developed conventional groundwater. In the future, interbasin transfer or purchased conventional groundwater could still be a water supply strategy, but for the purposes of this plan, seawater desalination and groundwater represented the large supply options that could be used to meet needs at distant planning horizons.

I.4.3 Best Practice Option

Option 3 (Lake Austin operations) was identified as a best practice water supply option due to its high level of certainty for implementation. For the IWRP, this means that it will be included in all AW IWRP portfolios.

I.4.4 Implementation Strategy Options

As noted previously, Option 19 (regional partnerships) was considered more as an implementation strategy than a unique option. It was not specifically characterized or evaluated in the subsequent steps of the IWRP; however, it will be considered during implementation of the AW IWRP's preferred portfolio.

I.4.5 Deferred Options

A small group of water supply options were assigned a deferred status, including interbasin transfers. These water supply options should be considered in future AW IWRP efforts; however, at this time they will not move on to characterization and subsequent portfolio analysis.

I.4.6 Final Candidates for Characterization

In total, thirteen water supply options were identified as candidates for characterization, as shown in **Table I-6,** and moved forward in the IWRP process. Potential interactions between options and use of the same source water were addressed as part of the portfolio analysis phase of the IWRP process. The table also identifies the screening status of all other "non-candidate" water supply options classified as either best practice, large-scale (narrative), implementation, or deferred.

Table I-6. Summary of candidates for characterization

Screening Result	Option Characterization Candidate ID	Screening Option Number	Option Name	Supply Type
Candidate Options for Characterization				
Candidate	1	1, 18a, 18b	Aquifer Storage and Recovery	Storage
Candidate	2	13	Brackish Groundwater Desal	Desalination
Candidate	3	2	Direct Non-Potable Reuse	Reuse
Candidate	4	12	Direct Potable Reuse	Reuse
Candidate	5	8, 9, 10, 11	Indirect Potable Reuse and Capture Lady Bird Lake Inflows	Reuse
Candidate	6	17	Additional Supply From LCRA	Surface Water
Candidate	7	15, 21	Off-Channel Reservoir with Lake Evaporation Suppression	Storage
Candidate	8	14	Seawater Desalination	Desalination
Candidate	9	16a, 16b	Conventional Groundwater	Groundwater
Candidate	10	7	Distributed wastewater systems	Decentralized
Candidate	11	6	Sewer mining (wastewater scalping)	Decentralized
Candidate	12	4	Stormwater Harvesting (community-scale)	Decentralized
Candidate	13	5	Rainwater Harvesting (community-scale)	Decentralized
Non-Candidate Options for Characterization				
Best Practice	na	3	Lake Austin Operations	Surface Water
Implementation	na	19	Regional Partnerships	Surface Water
Large-Scale Import Group	na	20	Interbasin Transfers	Surface Water

APPENDIX J: OPTIONS CHARACTERIZATION SHEETS

Options Characterization Sheets Index

Acronym Glossary

Sectors

SFR	Single-family residential customer class
MFR	Multi-family residential customer class
COM	Commercial customer class
WS	Wholesale customer class
LV	Large-volume customer class
COA	City of Austin customer class

Residential End-Use Fields

SB	Showers/Baths
TL	Toilets
CW	Clothes washers
DW	Dishwashers
FB	Faucets/Basins
LK	Leaks
IRR	Irrigation/Landscaping

Commercial End-Use Fields

MEQ	Medical Equipment
POL	Pools
LND	Laundry
KCH	Kitchen/Dishwashing
HVC	Cooling and Heating
DOM	Domestic/Restroom
MISC	Miscellaneous/Other
IRR	Irrigation/Landscaping

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Demand Management Option Name:

Advanced Metering Infrastructure

DRAFT RESULTS 8-1-2017

Short Description:

Customer-facing real time water information and metering through AMI

Details:

Implement customer facing programs that provide real-time water use information, including commercial customer benchmarking. Savings are achieved through identification of customer-side leaks, behavior modification, and other water-saving opportunities. Implemented through Advanced Metering Infrastructure (AMI). Assumes meter deployment by 2022 (dependent upon Council approval). Current pilot studies underway studying savings from residential customer engagement via mobile and web-based application. Texas Water Development Board State Water Implementation Fund for Texas (SWIFT) application for funding meters, meter boxes, and accompanying data transmission infrastructure has been submitted and contractors are being sought for AMI design and implementation. Note that information provided herein is for planning purposes only and will likely vary from actual AMI implementation, depending on the package selected and decisions made by the Utility. While the measure analysis focuses on reduction in water loss through identification of customer side leaks, implementation of AMI may lead to additional reductions in apparent losses. There are four pillars of apparent water loss control: (1) improving customer meter accuracy, (2) reducing unauthorized consumption, (3) reducing data transfer/archive errors, and (4) reducing data billing errors. This option represents savings from reductions in apparent losses and has potential synergies with strategies like Utility Side Water Loss Control which targets real losses. Real losses are almost entirely comprised of leaks in the distribution system whereas apparent losses are almost entirely comprised of meter inaccuracies.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM
End Uses: All, leaks assumed to mirror City-wide usage patterns in indoor/outdoor split
Both new and existing developments

Timing of Implementation:

Fully metered by 2022, dependent upon Council approval.

Lifespan (years):

20 years

WATER SAVINGS ANALYSIS

Assumptions:

Implementation of an AMI program is assumed to entail high-resolution usage reporting for all participants as well as customer-side leak identification and notification. To this end, AMI is expected to produce savings primarily from reducing the occurrence of large customer-side leak events (100 - 550 Gallons per day, per 2015 REUWS2 study). Previous studies have shown a reduction of large customer-side leak volumes of approximately 50% from this type of implementation (Naphade, 2011). Therefore, we assume a total 15% reduction in total estimated leak volume for this analysis. Note that by 2020, it is assumed that AMI implementation will have reached 20% of all customers. Therefore, savings in 2020 represent 20% of the total estimated savings potential produced by this option.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	210	170	200	10	0	590
2040	1,280	1,120	1,370	110	0	3,880
2070	1,820	1,710	2,080	150	0	5,760
2115	2,670	3,170	3,310	230	0	9,380

Average Weather Cumulative Total Water Savings (in AF over 100 year planning period):

TOTAL	163,630	166,910	190,630	14,000	0	535,170

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	720	620	760	60	0	2,160

AVOIDED COST ANALYSIS[1]

Assumptions:

The avoided cost analysis includes reduced marginal water treatment and wastewater treatment costs (for the indoor portion of the savings). With AMI, there are potential cost savings experienced by the Utility, such as from improvements in customer billing (increased revenues), reduction in meter reading, reduced phone call answering times, and reduced paper mailings. These reductions are somewhat unknown and dependent upon the actual AMI system and implementation level selected by the Utility. Some of the cost reductions, such as reduced staff hours, would likely be absorbed into other Utility activities. Therefore, cost savings beyond the avoided water and wastewater treatment costs are not estimated in the IWRP cost calculation.

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$102,400	$90,600	$11,800
2040	$664,900	$580,800	$84,100
2070	$995,800	$862,600	$133,200
2115	$1,629,200	$1,401,900	$227,300

Cumulative Total (in $ over 100 year planning period):

TOTAL	$92,514,600	$80,063,300	$12,451,300

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	72%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The avoided costs/comparison method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

The initial costs are assumed at $80.2 million for an engineering study, meters, infrastructure, and construction (per the current SWIFT application). Annual data hosting fees, application development, and communication costs are estimated at $326,000 per year, however these costs are high level planning estimates as the AMI selected design and implementation is to be determined. One additional full-time equivalent (FTE) employee is assumed for business intelligence management activities. After initial deployment, annual operations and maintenance (O&M) costs include meter replacements at a placeholder amount of $1 million per year over current replacement costs. The useful life of this investment is assumed at 20 years, as a capital reinvestment is likely at that point, with debt terms assumed for 20 years.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$68,160,000	$11,914,700	$120,400	$0	$12,839,600	$93,034,700
Customer Cost						
Community Cost**	$68,160,000	$11,914,700	$120,400	$0	$12,839,600	$93,034,700

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$4,651,735	$ 1,400,800	$0	$0	$0	$0
Customer Cost						
Community Cost**	$4,651,735	$1,400,800	$0	$0	$0	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 6,052,500	$2,800
Customer Cost		
Community Cost**	$ 6,052,500	$2,800

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Comment: Majority of savings are indoor and not susceptible to climate change. Outdoor leak volumes are more susceptible to variations in temperature and precipitation.

Comments:

Literature Review/Case Studies:

2015 REUWS2 study found that leakage events makes up approximately 12.4% of total indoor water usage. Of this amount, approximately 30% are attributed to "large leaks" ranging from 100 - 550 gallons per day. Therefore, large leaks make up approximately 4% of total SFR indoor demand.
City of Dubuque (IA) estimated a 44% reduction in baseline for leaks alone from pilot study participants with access to AMI Portal and usage statistics, though no information was provided as to the volumetric composition of this reduction (i.e., large or small leak events) nor to the number of households contributing to this reduction. Therefore, reductions were assumed to apply to "large leak" events as these are typically most identifiable.

References:

City of Las Virgenes. 2012. "Cost-Benefit Analysis for the AMR/AMI Installation Project." http://www.lvmwd.com/home/showdocument?id=1712
City of Corona (CA). 2012. Advanced Metering Infrastructure Program. Water SMART: Water and Energy Efficiency Grants for Fiscal Year 2012. https://www.usbr.gov/watersmart/weeg/docs/2012apps/1038.pdf
Hawkins, Chelsea and Allen Berthold. 2015. "Considerations for Adopting AMI and AMR." http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=9674
DeOreo, W. 2014. "Some Key Findings of the 2014 REUWS Update Study". Sustainable Water Management Conference. Denver, CO.
City of Dubuque, IA & IBM. 2011. "Smart Water Pilot Study Report". http://www.cityofdubuque.org/DocumentCenter/Home/View/3116
Water Research Foundation. 2011. "Advanced Metering Infrastructure: Best Practices For Water Utilities." http://www.waterrf.org/Pages/Projects.aspx?PID=4000

WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Demand Management Option Name:

Water Loss Control Utility Side

DRAFT RESULTS 8-1-2017

Short Description:

Enhance current utility-side water loss control programs

Details:

There are approximately 3,837 miles of water pipeline citywide. From FY2013 – 2015, Austin lost an average of 4.88 billion gallons of water a year from leaks in the city water distribution system. This equates to an ILI (Infrastructure Leakage Index) of 3.26. In 2011, Austin Water launched the "Renewing Austin Program (RAP)" focusing on replacing and upgrading aging water distribution infrastructure to ensure the reliability and quality of Austin's Water supply. Austin Water has replaced and relocated a total of about 62 miles of water mains under the RAP at the end of 2016. Austin Water's current plan is to continue the Renewing Austin Program to replace aged water mains at about 10 miles per year with spending at about $15 million annually. The target ILI for Austin is sustaining an ILI at or below 2.7. This measure represents an aggressive leak detection, correction, and prevention program to reduce the ILI to 2.7 by 2020 and further reduce and sustain a 2.0 ILI from 2040 to 2115. The measure analysis focuses on four pillars of real water loss control: (1) active leak detection, (2) response to leaks, (3) pressure management, and (4) pipeline and asset management selection, installation, maintenance, renewal, and replacement. This option represents savings from reductions in real losses and has potential synergies with strategies like Advanced Metering Infrastructure (AMI) which may also target apparent losses. Real losses are almost entirely comprised of leaks in the distribution system whereas apparent losses are almost entirely comprised of meter inaccuracies.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: System-wide
End Uses: Water losses (NRW)
Both new and existing developments

Timing of Implementation:

While utility-side water loss reduction strategies have been in place for many years, implementation of this strategy is assumed to begin in 2015 and continue through 2115 for analysis purposes.

Lifespan (years):

30 years

WATER SAVINGS ANALYSIS

Assumptions:

ILI of 2.7 by 2020 reducing to 2.0 by 2040 and maintaining the 2.0 to 2115. No assumptions are made for reduction of losses between the diversions and treatment plant. Yield is calculated as a function of baseline demands.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	0	0	0	0	3,110	3,110
2040	0	0	0	0	9,330	9,330
2070	0	0	0	0	10,920	10,920
2115	0	0	0	0	13,060	13,060

Average Weather Water Savings - Cumulative Total (in AF over 100 year planning horizon):

TOTAL	0	0	0	0	975,680	975,680

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	0	0	0	0	10,160	10,160

AVOIDED COST ANALYSIS[1]

Assumptions:

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$464,900	$464,900	$0
2040	$1,395,200	$1,395,200	$0
2070	$1,633,300	$1,633,300	$0
2115	$1,954,400	$1,954,400	$0

Cumulative Total (in $ over 100 year planning horizon):

TOTAL	$145,963,619	$145,963,619	$0

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	0%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The avoided costs/comparison method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

Assumes $93 million for assets management capital improvements per five year cycle over 30 year lifespan.
Assumes $1.75 million per year for active leak detection O&M over 30 year lifespan.
Costs for a pressure management study are included at $250,000.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$446,400,000	$106,270,000	$ 5,580,000		$514,466,000	$1,072,716,000
Customer Cost						
Community Cost **	$ 446,400,000	$ 106,270,000	$ 5,580,000	$ -	$ 514,466,000	$ 1,072,716,000

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 35,748,900	$ 1,750,000	$ -	$ -	$ -	$ -
Customer Cost						
Community Cost **	$ 35,748,900	$ 1,750,000	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 37,498,900	$ 3,690
Customer Cost		
Community Cost **	$ 37,498,900	$ 3,690

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Comment: Water loss control measures generally are not susceptible to climate change. However, climate extremes may exacerbate expansion and contraction of soils, leading to more frequent main breaks and requiring greater investment to achieve savings goals.

Comments:

Austin Water's Renewing Austin Program (RAP) is part of a sustained, long-term approach to ensuring the reliability of Austin's water distribution system. This program has multiple benefits of the Austin community. In addition to contributing to water loss control, the RAP upgrades aged system water lines as part of Austin Water's asset management efforts and efforts to ensure on-going system reliability.

Literature Review/Case Studies:

References:

Pressure Management: Industry Practices and Monitoring Procedures, Water Research Foundation 2014
http://cuwcc.org/Portals/0/Document%20Library/Resources/Publications/Potential%20BMP%20Reports/2010%20PBMP%20Report-%20Distribution%20System%20Pressure%20Management.pdf

Demand Management Option Name:

CII Ordinances for Cooling Towers and Steam Boilers

DRAFT RESULTS 8-1-2017

Short Description:

Require older cooling towers and steam boilers to meet efficiency standards

Details:

Require older cooling towers to meet water efficiency benchmarks and use efficient equipment and require efficiency standards for steam boilers in new development. No assumptions made for boilers as it is thought to be a small incremental amount of savings. This would change city code to require: 1) all cooling towers to meet same efficiency equipment standards currently only required for new and replacement towers since 2008 (makeup and blowdown submeters, conductivity controller, drift eliminator and overflow alarm) and achieve 5 cycles of concentration (added to code December 2010); and 2) all steam boilers to have conductivity controllers, makeup meters, steam condensate return systems and blowdown heat exchangers for steam boilers. These code changes were approved by Council action in June 2017.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: MFR, COM, and COA
End Uses: HVAC
Existing development

Timing of Implementation:

100% compliance by 2040

Lifespan (years):

Through 2115

WATER SAVINGS ANALYSIS

Assumptions:

Assumed 400 cooling towers that currently have 3 cycles of concentration will have 5 cycles of concentration when in compliance. The average tonnage is assumed at 375 which translates to 6750 gallons per day for blowdown under current conditions. Under future conditions, blowdown is estimated to reduce to 3375 gallons per day. Water savings are assumed for 9 months of operation. The following table shows the demand reductions associated with the cooling tower retrofits throughout the entire planning horizon.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	0	40	950	70	0	1,060
2040	0	40	950	70	0	1,060
2070	0	40	950	70	0	1,060
2115	0	40	950	70	0	1,060

Average Weather Cumulative Total Water Savings (in AF over 100 year planning period):

TOTAL	0	3,540	91,460	7,080	0	102,080

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	0	40	950	70	0	1,060

AVOIDED COST ANALYSIS[1]

Assumptions:

Includes reduced marginal water treatment and wastewater treatment costs (for indoor portion of savings). The following table shows avoided costs associated with the 400 cooling tower retrofits throughout the entire planning horizon.

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$248,100	$159,100	$89,000
2040	$248,100	$159,100	$89,000
2070	$248,100	$159,100	$89,000
2115	$248,100	$159,100	$89,000

Cumulative Total (in $ over 100 year planning period):

TOTAL	$23,818,330	$15,270,349	$8,547,981

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	100%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The avoided costs/comparison method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

The cost of retrofit for the 400 customers assumes $600 for submetering (NC DENR, 1998), $4,400 for controller and sensors (parts and installation) (CUWCC, 2016). O&M is assumed for code enforcement. One full-time equivalent (FTE) employee is assigned for initial inspections and administration of this program. There are no capital investments required by the Utility.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost						$ -
Customer Cost	$ 4,000,000					$ 4,000,000
Community Cost*	$ 4,000,000	$ -	$ -	$ -	$ -	$ 4,000,000

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost		$ 75,000				
Customer Cost	$ 40,000					
Community Cost**	$ 40,000	$ 75,000	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 75,000	$ 71
Customer Cost		
Community Cost**	$ 75,000	$ 71

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Comment: Increased temperature might diminish efficiency of the cooling process and could cause increases in seasonal use of cooling system

Comments:

Literature Review/Case Studies:

Data/information from Austin Water: 400 RZP permitted cooling towers in WIERS data base. Based on AW potable water quality, 3-5 cycles considered easily achievable for cooling towers without requirements. Increasing from 3 to 5 cycles would result in approx. 17% water savings. Average capacity for cooling towers estimated to be approx. 350-400 tons. Average lifetime for galvanized steel cooling tower is 20 years. Without these additional requirements for older towers, savings from 2008 and 2010 code changes would be realized by 2030. 2007 WCTF indicates a peak day savings of 0.95 MGD by the 10th year of implementation if 2008 and 2010 code changes would have applied to both new and existing towers.
Cooling tower sophistication can vary greatly and the cost is specific to the cooling tower. From the CUWCC 2016 - A basic conductivity controller with a single pump can cost $700. Conductivity controllers with two pump relays with more sophisticated software algorithms cost roughly $1,400. A sensor and pump relay to more finely administer a biocide and oxidizer raises the cost of the controller to approximately $2,400. A pH sensor and additional pump relay for administering acid would increase the price to $3,400.
Percent of make up water saved can be estimated from an equation (CUWCC, 2016). The NC DENR estimates make-up water saved by going from an initial concentration to a new concentration (1998).
Cooling towers offer substantive water savings potential, but have proved vexing for voluntary conservation efforts. In Denver, after spending money to improve efficiency via rebate programs, many towers reverted back to inefficient operations within a few years. Water efficiency in cooling towers requires careful management and attention. Lower water costs may sometimes discourage O&M spending for water efficiency.

References:

Innovations in Efficiency Showcase Cooling Tower Management Oct 2015 www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=9416
The Dollar Side of Water Conservation in the CII Sector, presentation by Bill Hoffman, Water Management
North Carolina Water Efficiency Manual for CII Facilities (1998), NC DENR. (http://water.monroenc.org/wp-content/uploads/Water-efficency-for-industrial-commercial-and-institutional-customers.pdf)
BMP Cost and Savings Study Update (June 2016), California Urban Water Conservation Council.
Bill Hoffman, P.E. "The Energy - Water Nexus of Cooling Towers"

Austin WATER | WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Demand Management Option Name:

Development-focused Water Use Benchmarking and Budgeting

DRAFT RESULTS 8-1-2017

Short Description:

Requirement of water use estimate submittal paired with enhanced outreach and education with transition to water budgeting

Details:

By 2020, as part of an education and outreach program, this option would require submittal of water use estimates for new development. City staff will provide potential water use efficiency and alternative water recommendations and information on available incentive and rebate programs. This information will tie into the development of databases to be used to develop benchmarks for efficient water usage for various development types. Implementation of the measure will look for ways to tie into the Service Extension Request (SER) and Austin Energy Green Building (AEGB) programs. By 2040, this option is expanded to include requirement of water use estimate submittals for new development concurrent with preliminary plan submittal to be reviewed by City staff and a requirement that new development meet a benchmark water budget usage that is lower than comparable existing buildings (compliance mechanism to be determined).

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM, and COA
End Uses: All
New development

Timing of Implementation:

2020 - water use estimate submittal required; 2040 - buildings assumed to be required to meet a benchmark usage 10% lower than comparable existing buildings

Lifespan (years):

Through 2115

WATER SAVINGS ANALYSIS

Assumptions:

No savings are assumed for the water estimate submittal action; however this is a critical step to getting to the water budgeting measure which has more substantial savings potential. At the 2040 planning horizon, savings are assumed at 10% for the residential (SFR/MFR), COM, and City of Austin (COA) sectors for new development. An assumption of 10% savings is maintained for the 2070 and 2115 planning horizons. The underlying assumption is that Advanced Metering Infrastructure (AMI) messaging is fully implemented and utilized for the water budgeting action.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	0	0	0	0	0	0
2040	2,400	2,260	2,050	70	0	6,780
2070	4,370	4,430	4,310	340	0	13,450
2115	8,880	10,030	9,290	1,480	0	29,680

Average Weather Cumulative Total Water Savings (in AF over 100 year planning period):

TOTAL	405,200	431,990	407,220	47,710	0	1,292,120

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	5,330	5,680	5,360	630	0	17,000

AVOIDED COST ANALYSIS[1]

Assumptions:

Includes reduced marginal water treatment and wastewater treatment costs (for indoor portion of savings).

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$0	$0	$0
2040	$1,411,300	$1,014,700	$396,600
2070	$2,804,900	$2,012,000	$792,900
2115	$6,209,100	$4,440,200	$1,768,900

Cumulative Total (in $ over 100 year planning period):

TOTAL	$269,870,500	$193,303,600	$76,566,900

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	71%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The avoided costs/comparison method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

Two full-time equivalent (FTEs) employees are assumed for program administration in 2040. An annual budget of $200,000 is assumed for the education and outreach component of this option.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost						$ -
Customer Cost						$ -
Community Cost*	$ -	$ -	$ -	$ -	$ -	$ -

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost		$ 350,000				
Customer Cost	$ -					
Community Cost**	$ -	$ 350,000	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 350,000	$ 21
Customer Cost		
Community Cost**	$ 350,000	$ 21

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Comment: Not susceptible to future hydrologic variability

Comments:

Literature Review/Case Studies:

References:

WaterDM 2008 summary report can be downloaded from http://www.waterdm.com/sites/default/files/JAWWA%20(2010)%20Water%20Budgets%20and%20Rate%20Structures%20-%20Innovative%20Management%20Tools.pdf

Irvine Ranch Water District began program in 1991 http://irwd.com/images/pdf/doing-business/environmental-documents/UWMP/IRWD_UWMP_2015_rev_01-03-17_FINAL.pdf

Presentation from Mouton Miguel Water District from WSI 2016 https://www.watersmartinnovations.com/documents/sessions/2015/2015-T-1546.pdf

Reidy, K. 2005. From Drought Response to Water Conservation Ethic: Implementation of the Water Budget Concept in Aurora, Colorado. AWWA 2005 Annual Conference Proceedings. San Francisco, CA.

Bohlig, C. and R. Harris. 2014. EBMUD Informational Water Budget Program – Honey I Shrunk the Water Budget. Water Smart Innovations 2014. Las Vegas, Nevada. ttps://www.watersmartinnovations.com/documents/sessions/2014/2014-T-1402.pdf

Atwater D. 2015. Drought Planning Through Integrated Rate Design. Water Smart Innovations 2015. Las Vegas, Nevada. https://www.watersmartinnovations.com/documents/sessions/2015/2015-T-1546.pdf

Michelon, C. 2014. Performance Based Irrigation Management Incentives. Water Smart Innovations 2014. Las Vegas, Nevada. https://www.watersmartinnovations.com/documents/sessions/2014/2014-T-1443.pdf

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Demand Management Option Name:

Landscape Transformation Ordinance

DRAFT RESULTS 8-1-2017

Short Description:

Require regionally appropriate landscapes

Details:

Implement ordinances to encourage water use efficiencies and reduce water needs for outdoor irrigation and other goals through regionally appropriate landscapes with an emphasis on landscape functionality (Implementation of this option could include implementing turf grass area, irrigated area, and/or irrigation area limitations).
Note that current Landscape Ordinance has existing requirements for landscaped areas, plant selection, and irrigation systems for Commercial and Multifamily properties. As there is no current plan review process for single family residential, the existing Landscape Ordinance does not currently apply to this sector.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM
End Uses: Outdoor Irrigation
New development

Timing of Implementation:

2025

Lifespan (years):

Through 2115

WATER SAVINGS ANALYSIS

Assumptions:

Savings Forecast:
Ordinance would only apply to new construction parcels. Average Single Family (SF) transformed landscape area assumed as product of average SF parcel size (6300 sq. ft.), average SF pervious area (70% per COA Watershed Protection Department), maximum recommended turf grass area (50% per Austin Homebuilders' Association Sensible Landscape Guidance Document) and average proportion of yard scape that is turf grass (1500 sq. ft. of turf per 1900 sq. ft. of total yard area per AW Conservation staff). This results in an average converted area of ~1800 sq. ft. per SF parcel.

Significant outdoor water savings have been achieved to date through the combined effect of the existing landscape ordinance for COM/MF development, in effect since 1982 and most recently revised in 2010, recent market trends that have shifted toward native and adaptive plant palettes, and City water codes including the Water Conservation Code. A new Landscape Transformation Ordinance is assumed to entail further requirements to reduce irrigation water use by 10% as compared to similar existing development. This reduction could be achieved through a variety of mechanisms, including reduction of irrigated area, installation of drought tolerant plants, and reductions of turf area. The total number of parcels were estimated and projected into the future by assuming a constant ratio of 9 multi-family (MF) units per parcel and 56 commercial (COM) employees per parcel, from historical data.

Note: The above assumptions were developed for the high-level strategic integrated water resource plan (IWRP) development process. Should this option be incorporated into IWRP plan recommendations, actual new ordinance details would need to be developed through subsequent implementation processes with future additional stakeholder and public input opportunities.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	0	0	0	0	0	0
2040	2,490	280	460	0	0	3,230
2070	6,440	770	810	0	0	8,020
2115	13,510	1,320	1,750	0	0	16,580

Average Weather Water Savings - Cumulative Total (in AF over 100 year planning period):

TOTAL	614,280	66,350	82,120	0	0	762,750

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	6,750	730	900	0	0	8,380

AVOIDED COST ANALYSIS[1]

Assumptions:

Includes reduced marginal water treatment costs.

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$0	$0	$0
2040	$483,400	$483,400	$0
2070	$1,200,000	$1,200,000	$0
2115	$2,479,300	$2,479,300	$0

Cumulative Total (in $ over 100 year planning period):

TOTAL	$114,109,100	$114,109,100	$0

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	0%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The avoided costs/comparison method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

Two full-time equivalent (FTEs) employees and two vehicles assumed for additional single family plan residential review process.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost						
Customer Cost						
Community Cost*	$ -	$ -	$ -	$ -	$ -	$ -

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost		$ 190,000				
Customer Cost						
Community Cost**	$ -	$ 190,000	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 190,000	$ 23
Customer Cost		
Community Cost**	$ 190,000	$ 23

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Comment: Outdoor water use may increase regardless of plant type or amount of turf in especially dry conditions.

Comments:

Literature Review/Case Studies:

USEPA. " WaterSense New Home Specification". 2014. https://19january2017snapshot.epa.gov/www3/watersense/docs/home_finalspec508.pdf
USEPA. "WaterSense Water Budget Tool". 2014. https://www.epa.gov/watersense/water-budget-tool

References:

Austin Homebuilders Association - Sensible Landscaping for Central Texas (https://www.hbaaustin.com/wp-content/uploads/2016/05/HBA_Sensible_Landscaping_Bro.pdf)
City of Austin WaterWise Landscape Rebate http://www.austintexas.gov/sites/default/files/files/Water/Conservation/Rebates_and_Programs/WaterWise_Landscape_Residential_Rebate_Application.pdf
City of Austin Land Development Code § 25-2 (Landscaping Ordinance)
City of Austin Code of Ordinances § 6-4 (Water Conservation Code)

Demand Management Option Name:

Landscape Transformation Incentives

DRAFT RESULTS 8-1-2017

Short Description:

Landscape incentives to encourage water use efficiency and reduce outdoor water use

Details:

Implement incentives to encourage water use efficiencies and reduce water needs for outdoor irrigation and other goals through regionally appropriate landscapes with an emphasis on landscape functionality (implementation of this option could include increasing WaterWise landscape rebates for SFR and MFR and implementing a new WaterWise landscape rebate for COM beyond City of Austin Land Development Code requirements). The current WaterWise landscape rebate offers $35 for every 100 sq ft ($0.35/sq ft) converted with a minimum of 500 sq ft but has a very low participation rate. The maximum rebate is $1,750 per property.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM
End Uses: Outdoor Irrigation
Existing development

Timing of Implementation:

2020

Lifespan (years):

10 years

WATER SAVINGS ANALYSIS

Assumptions:

Savings Forecast:
Incentive would only apply to existing customers who have satisfied rebate requirements similar to those in effect now. Assuming average conversion of 900 sq. ft. per single family residential (SFR) participant and assuming 5 Gallons reduction of demand per sq. ft. converted, from previous AW Landscape Transformation Rebate data.

Currently existing MFR/COM participants are assumed to convert 30% of their improved landscape on average (improved landscape assumed to be 50% of total pervious cover on parcel) from turf to water-saving vegetation. Future COM/MF parcels are assumed to develop in accordance with the existing Landscape Ordinance, which requires plant selection from the City of Austin Preferred Plant List for landscaped areas. This requirement does not apply to SFR parcels.

The same savings per square foot of converted area are assumed as for the SFR sector.

Program Participation:
Participation rates for all three sectors assumed to reach 10% by 2040, 20% by 2070 and 30% by 2115.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	0	0	0	0	0	0
2040	290	10	11	0	0	311
2070	840	21	22	0	0	883
2115	1,880	31	33	0	0	1,944

Average Weather Cumulative Total Water Savings (in AF over 100 year planning period):

TOTAL	82,010	1,750	1,840	0	0	85,600

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	850	20	20	0	0	890

AVOIDED COST ANALYSIS[1]

Assumptions:

Includes reduced marginal water treatment costs.

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$0	$0	$0
2040	$46,900	$46,900	$0
2070	$132,300	$132,300	$0
2115	$290,100	$290,100	$0

Cumulative Total (in $ over 100 year planning period):

TOTAL	$12,806,100	$12,806,100	$0

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	0%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The Avoided Costs calculation method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

One full time equivalent (FTE) employee and half a vehicle (due to potential vehicle sharing across programs) assumed for administration of this program.

Note that rebate amount is not included in this cost analysis. A preliminary placeholder rebate amount will be developed during the portfolio development and evaluation process. Specific program detail including rebate amounts would be developed during later implementation stages.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost						
Customer Cost						
Community Cost*	$ -	$ -	$ -	$ -	$ -	$ -

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/ Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost		$ 85,000				
Customer Cost						
Community Cost**	$ -	$ 85,000	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)	
Utility Cost	$ 85,000	$ 96	Not including rebate costs (see note above)
Customer Cost			
Community Cost**	$ 85,000	$ 96	Not including rebate costs (see note above)

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Comment: Outdoor water use may increase regardless of plant type or amount of turf in especially dry conditions.

Comments:

Literature Review/Case Studies:

References:

City of Austin WaterWise Landscape Rebate http://www.austintexas.gov/sites/default/files/files/Water/Conservation/Rebates_and_Programs/WaterWise_Landscape_Residential_Rebate_Application.pdf
City of Austin Land Development Code § 25-2 (Landscaping Ordinance)
City of Austin Code of Ordinances § 6-4 (Water Conservation Code)

Demand Management Option Name:

Irrigation Efficiency Incentives

DRAFT RESULTS 8-1-2017

Short Description:

Expand current program to include smart irrigation system controllers

Details:

Expand current irrigation rebate programs to include irrigation system controllers system controllers that make flow data accessible and are capable of responding to leaks and high flow situations. There are ~89,300 existing single family residential irrigation systems and ~3,500 commercial/multi-family irrigation systems on parcels greater than 1 acre. COM/MF systems less than one acre (and therefore not under annual inspection requirements) account for approximately 30% of COM/MF irrigation system permits on average. Therefore, there are an estimated 5030 total COM/MF irrigations systems as of 2015.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM
End Uses: Outdoor Irrigation
New and existing development

Timing of Implementation:

2020

Lifespan (years):

10 years

WATER SAVINGS ANALYSIS

Assumptions:

The program incentivizes adoption of smart irrigation controllers to improve irrigation system efficiency by identifying leaks and zones with high flows and reducing excessive watering related to improper irrigation scheduling , with 8% savings associated with improved irrigation system performance based on previous literature review and adjustment for one-day-a-week watering restrictions. Base case irrigation system usage (per year) was assumed as the median of MF/COM billing data for 2015 and average of Base Year Irrigation Demand per SF Household from Disaggregated Demand Model.

Number of eligible irrigation systems were projected for each planning horizon using ratio of parcels with registered irrigation systems to total parcels for each sector (assumed constant during planning period) and growing with total number of existing parcels in each planning horizon. Some percentage of these systems are likely to abandoned (i.e., not in-use) which reflects a caveat of this estimation process. Therefore, reported savings represent the maximum savings potential.

Participation rates for all three sectors are projected to reach 20% by 2040 and 30% by 2070. Participation is assumed to remain constant beyond 2070 due to assumed saturation of smart irrigation system controllers in the marketplace by the 2070 planning horizon.

Average Weather Water Savings Summary (in AF per year):

Savings estimates are subject to change dependent on implementation approach and portfolio context.

YEAR	SFR	MFR	COM	COA	NRW	TOTAL
2020	20	10	10	0	0	40
2040	140	40	70	0	0	250
2070	310	90	170	0	0	570
2115	310	90	170	0	0	570

Average Weather Cumulative Total Water Savings (in AF over 100 year planning period):

TOTAL	22,190	6,230	12,220	0	0	40,640

Average Weather Annual Average Water Savings (in AF per year):

TOTAL	230	60	130	0	0	420

AVOIDED COST ANALYSIS[1]

Assumptions:

Includes reduced marginal water treatment costs.

Avoided Cost Summary (current dollars):

	TOTAL Costs Avoided	Water Treatment Cost Avoided	Wastewater Treatment Cost Avoided
2020	$6,300	$6,300	$0
2040	$36,700	$36,700	$0
2070	$84,200	$84,200	$0
2115	$84,200	$84,200	$0

Cumulative Total (in $ over 100 year planning period):

TOTAL	$6,079,500	$6,079,500	$0

Avoided Cost Input Assumptions (current dollars):

Water Treatment Cost ($/KGAL)*	$0.46
Wastewater Treatment Cost ($/KGAL)**	$0.26
Indoor Percent of Measure Savings	0%

*Per the AW Water Loss Report to TWDB, Line 44, CY 2016

**Assumed all chemical costs and 90% of electrical costs at treatment plants and all chemical and electrical costs at lift stations

[1]This information is provided for Utility planning purposes only. The avoided costs/comparison method for portfolio analysis is more comprehensive.

COST ANALYSIS

Assumptions:

One full time equivalent (FTE) employee and half a vehicle (due to potential vehicle sharing across programs) assumed for program administration and inspections.

Note that rebate amount is not included in this cost analysis. A preliminary placeholder rebate amount will be developed during the portfolio development and evaluation process. Specific program detail including rebate amounts will be developed during later implementation stages.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost						
Customer Cost						
Community Cost*	$ -	$ -	$ -	$ -	$ -	$ -

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost		$ 85,000				
Customer Cost						
Community Cost**	$ -	$ 85,000	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)	
Utility Cost	$ 85,000	$ 202	Not including rebate costs (see note above)
Customer Cost			
Community Cost**	$ 85,000	$ 202	Not including rebate costs (see note above)

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Comment: Increases in temperature or prolonged drought periods may result in changes to customer system management resulting in higher water use.

Comments:

Literature Review/Case Studies:

A literature review conducted by the Lawrence Berkeley National Laboratory surveyed experimental and real-word savings produced by various classes of irrigation controllers including, producing an average savings of 24%.
Another literature conducted by the Alliance for Water Efficiency cited several studies that showed increases in water use when weather-based irrigation controllers were installed and improved water use adequacy at the sake of water use efficiency, in an experimental setting. They highlight the need for further data related to more efficient system operation and management.
The RainBird Corporation in collaboration with the University of Arizona, found an estimated savings ranging from 15 - 22% from retrofits of irrigation spray heads with pressure regulating heads designed to reduce high-pressure flows and improve distribution uniformity. However, the State of Texas requires irrigation systems to operate at the manufacturer's specified operating pressure. This provision reduces the opportunity for water savings from flow pressure reduction to only systems that are improperly installed and operating in violation of state requirements.

References:

Lawrence Berkeley National laboratory. (2014) "Estimates of Savings Achievable from Irrigation Controller". https://eta.lbl.gov/sites/all/files/publications/lbnl-6604e.pdf
Mayer, et al. 2015. "A review, analysis, and synthesis of published and pending research on outdoor water use and water savings.". Alliance for Water Efficiency. www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=9155
Brown and Gilbert, 2015. "Application Efficiency and Distribution Uniformity of Pressure-Regulated and Non-Pressure-Regulated Rotor Irrigation Heads Analysis". Submitted to RainBird Corporation. http://prs.rainbird.com/sites/default/files/_media/resource/prs-research-results_0.pdf

Demand Management Option Name:

Alternative Water Ordinances

DRAFT RESULTS 8-1-2017

Short Description:

Require on-site (building-scale) alternative water use of rainwater, stormwater, blackwater, and/or AC condensate

Details:

This option would require on-site (building-scale) alternative water use of rainwater, stormwater, blackwater, and/or AC condensate. Should this option be incorporated into IWRP plan recommendations, actual new ordinance details would need to be developed through subsequent implementation processes with future additional stakeholder and public input opportunities.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: MFR, COM, COA
End Uses: Non-potable indoor and outdoor
New development

Timing of Implementation:

TBD

Lifespan (years):

TBD

WATER SAVINGS ANALYSIS

Assumptions:

See attached alternative source water sheets for estimates of potential demand volumes that could be met by this option.

COST ANALYSIS

Assumptions:

See attached alternative source water sheets for estimates of potential costs that may be associated with this option.

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Demand Management Option Name:

Alternative Water Incentives - Rainwater, Stormwater, AC Condensate

DRAFT RESULTS 8-1-2017

Short Description:

Incentivize on-site (building-scale) alternative water use of rainwater, stormwater, and ac condensate

Details:

This option would offere an incentive to encourage the installation and use of rainwater and stormwater harvesting and AC condensate reuse systems. Should this option be incorporated into IWRP plan recommendations, incentive program details would be developed through subsequent implementation processes including interdepartmental coordination.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM, COA
End Uses: Non-potable indoor and outdoor
Existing and new development

Timing of Implementation:

TBD

Lifespan (years):

TBD

WATER SAVINGS ANALYSIS

Assumptions:

See attached alternative source water sheets for estimates of potential demand volumes that could be met by this option.

COST ANALYSIS

Assumptions:

See attached alternative source water sheets for estimates of potential costs that may be associated with this option.

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Demand Management Option Name:

Alternative Water Incentives - Graywater and Blackwater

DRAFT RESULTS 8-1-2017

Short Description:

Offer an incentive to encourage the installation and use of graywater and onsite blackwater reuse systems

Details:

This option would offere an incentive to encourage the installation and use of graywater harvesting and onsite blackwater reuse systems. Should this option be incorporated into IWRP plan recommendations, incentive program details would be developed through subsequent implementation processes including interdepartmental coordination.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: SFR, MFR, COM, COA
End Uses: Non-potable indoor and outdoor
Existing and new development

Timing of Implementation:

TBD

Lifespan (years):

TBD

WATER SAVINGS ANALYSIS

Assumptions:

See attached alternative source water sheets for estimates of potential demand volumes that could be met by this option.

COST ANALYSIS

Assumptions:

See attached alternative source water sheets for estimates of potential costs that may be associated with this option.

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Alternative Source Water Name:

AC Condensate Reuse

DRAFT RESULTS 8-1-2017

Short Description:

Collection and reuse of condensate water from Air Handling Units (AHUs) for cooling systems from new development with cooling capacity over 200 tons

Details:

to collect and make beneficial use of AC Condensate from cooling systems. This condensate can be used for any non-potable applicable including (but not limited to): cooling tower makeup water, irrigation, indoor toilet flushing, etc.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Sectors: MFR, COM, COA
End Uses:
New and existing development

Characterization Year:

2115

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Assumed total square footage per sector will scale with MF Units and or COM/COA Employment projections, with per unit/per employee square footage rate estimated from ECAD Ordinance Audit data available form Austin Energy. AC Condensate production estimated using the rule of thumb of 0.5-0.6 gallons/hour produced per 1000 sq. ft. of conditioned area (per SAWS AC Condensate Collection Manual). Finally, total square footage was scaled to 2015 percentage of MF/COM/COA buildings greater than 50,000 sq. ft. (equivalent to an average cooling load of 200 tons) from aforementioned ECAD Audit data and held constant into future. Assumed 80% average cooling capacity factor and operation during 9 months of year, per SAWS AC Condensate Collection Manual guidance.

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems.

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	-	1,770	3,380
Annual Average System Volume (Gal/Year)	-	109,774	125,463

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o AC condensate recovery system estimated as 3% of total cooling mechnical engineering costs for a new building
o Total cost of cooling for a new buiding estimated using rule of thumb dollar per square foot amounts and estimated square footage for new development through 2115
Engineering, Legal Costs and Contingencies
o 35% cost of facilities
Mitigation and Permitting
o 5% cost of facilities
Annual O&M – Labor & Material
o Not included in analysis
Annual O&M – Energy
o Not included in analysis
Annual O&M - Advanced/Decentralized Treatment
o Not included in analysis
Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost						
Customer Cost	$ 309,194,430	$ 108,218,051	$ 15,459,722	$ -	$ -	$ 417,412,481
Community Cost*	$ 309,194,430	$ 108,218,051	$ 15,459,722	$ -	$ -	$ 432,872,202

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost						
Customer Cost	$ 13,913,749	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 13,913,749	$ -	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 13,913,749	$ 2,702
Community Cost**	$ 13,913,749	$ 2,702

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield
**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Comment: Increased temperature might diminish efficiency of the cooling process and could cause increases in seasonal use of cooling system

Comments:

Literature Review/Case Studies:

A/C Condensate collection systems can vary in cost depending on the intended end-use of condensate water. Most cooling towers can accommodate gravity-fed collection of condensate from AHUs to supplement makeup water in the cooling tower system. However, systems in which the cooling tower sits above AHUs will require storage and pumping to deliver condensate for makeup water.
Alternatively, condensate can be reused for irrigation or treated and return inside a COM/MFR (per plumbing and state codes) for use in non-potable end-uses (toilet flushing, clothes washing, etc.). These systems would increase system cost due to requirement for additional storage, treatment, and reticulation. If these additional provisions are not required, additional system cost can be considered negligible for a gravity-fed makeup water supplement.

References:

North Carolina Water Efficiency Manual for CII Facilities (1998), NC DENR. (http://water.monroenc.org/wp-content/uploads/Water-efficency-for-industrial-commercial-and-institutional-customers.pdf)
Bill Hoffman, P.E. "The Energy - Water Nexus of Cooling Towers"
Glawe, D. 2013. "San Antonio Condensate Collection and Use Manual for Commercial Buildings". San Antonio Water System. http://www.saws.org/conservation/commercial/Condensate/docs/SACCUManual_20131021.pdf
City of Austin, ECAD Ordinance
Guz, K. 2005. "Condensate Water Recovery". ASHRAE Journal. Vol. 47, No. 6, June 2005

Alternative Source Water Name:

Rainwater Harvesting

DRAFT RESULTS 8/1/17

Short Description:

Lot or building scale rainwater (roofwater) harvesting

Details:

Rainwater Harvesting involves the capture and storage of roof water to supply a range of onsite demands at the lot/building scale. Implementing rainwater harvesting in new developments provides an opportunity to plumb the residence or building with internal connections for toilet flushing or clothes washing. Where used indoor treatment is required.

Three scenarios are considered for simplicity. These are:
1. A proportion of newly constructed SFR, MFR and COM buildings have a rainwater tank supplying outdoor end uses.
2. A proportion of newly constructed SFR, MFR and COM buildings have a rainwater tank supplying outdoor end uses and indoor (non-potable) end uses via dual reticulation.
3. A proportion of newly constructed SFR buildings have a rainwater tank supplying all end uses (i.e. potable supply).

All scenarios assume back-up supply from the centralized water distribution system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor: SFR - IRR; MFR - IRR; COM - IRR.
2. Outdoor + Indoor Non Potable: SFR - IRR, TL, CW; MFR - IRR, TL; COM - IRR, TL, HVC.
3. Potable: SFR - ALL USES

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 40

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand
o Variable per DTI (estimated from demand model)
o Monthly outdoor demand profile generated using historical gross lake evaporation data (quadrangle 811) and precipitation data in a standard irrigation model to account for monthly and year to year variation in outdoor demand based on climate.
Yield
o Daily water balance calculation for historical time series
o Daily rainfall analyzed for the historical period (1938 – 2016) using Station: AUSTIN CAMP MABRY TX US
o Note: Climate change adjusted dataset can be used instead of historical dataset in the portfolio evaluation process
o Typical or Average Roof Areas, per DTI, are based on current Land Uses building footprint data and demographic projections:
- [SFR] Average roof varies per DTI, between approx. 1500-3700 ft2 per house.
- [MFR] Nominal building = 5,000 sq ft (noting that the density, in terms of units/building, varies by DTI)
- [COM] Nominal building = 10,000 sq ft (noting that the density, in terms of employees/building, varies by DTI)
- Current roof areas and building numbers estimated based on Current Land uses building footprint data
- Future roof areas estimated taking into account demographic changes (increase in units/employees) and growth/change in land use (including densification) from the future land use map generated for this project.

o Connected Roof Area = 67% (of total roof area). Previous project estimates have estimated between 50% - 80%.
o Roof Runoff coefficient = 0.9
o Tank volumes optimised from yield/storage curve in order to maximise yield and minimise cost & tank footprint/space:
- [SFR] 2000 Gallons per house
- [MFR] 5000 Gallons per building
- [COM] 10,000 Gallons per building

Year
2115

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor: SFR - IRR; MFR - IRR; COM - IRR

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	11,955	2,786	3,966
Annual Average System Volume (Gal/Year)	8,790	29,230	59,109

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR - IRR, TL, CW; MFR - IRR, TL; COM - IRR, TL, HVC

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	23,378	4,627	6,489
Annual Average System Volume (Gal/Year)	16,305	50,694	100,104

SCENARIO 3 - Potable: SFR - ALL USES

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	27,662	N/A	N/A
Annual Average System Volume (Gal/Year)	20,888	N/A	N/A

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs will likely be borne by the customer/developer. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for the typical building per DTI using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number of houses, buildings, roof areas)

o Cost elements include:

- Treatment (e.g. Filter + UV Disinfection) if used indoor non-potable or potable supply
- Storage
- Pump (assume 50% are gravity fed if supplying IRR only)
- Reticulation (within building) if used for indoor non-potable supply

Engineering, Legal Costs and Contingencies

o 20% of capital cost

Mitigation and Permitting

o 0% of capital cost if used only for irrigation; 5% of capital cost otherwise

Annual O&M – Labor & Material

o Estimated as proportion of capital cost (Civil 0.5%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping Energy = 750 kWh/ML (2839 kWh/MG) (outdoor) and 1500 kWh/ML (5678 kWh/MG) (indoor & outdoor) (per previous projects & water-energy nexus studies)

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital cost and O&M in other categories)

o UV Disinfection: 82 kWh/ML (310 kWh/MG)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor: SFR - IRR; MFR - IRR; COM - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 1,211,204,086	$ 242,240,817	$ -	$ -	$ -	$ 1,453,444,903
Community Cost	$ 1,211,204,086	$ 242,240,817	$ -	$ -	$ -	$ 1,453,444,903

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 36,336,123	$ 11,873,202	$ 778,727	$ -	$ -	$ -
Community Cost**	$ 36,336,123	$ 11,873,202	$ 778,727	$ -	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 48,988,051	$ 2,619
Community Cost**	$ 48,988,051	$ 2,619

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	$ 2,023	$ 4,300	$ 8,283
Annual O&M	$ 22	$ 42	$ 79

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR - IRR, TL, CW; MFR - IRR, TL; COM - IRR, TL, HVC

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 2,615,044,340	$ 523,008,868	$ 130,752,217	$ -	$ -	$ 3,268,805,425
Community Cost	$ 2,615,044,340	$ 523,008,868	$ 130,752,217	$ -	$ -	$ 3,268,805,425

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 81,720,136	$ 49,015,389	$ 5,743,820	$ 313,995	$ -	$ -
Community Cost**	$ 81,720,136	$ 49,015,389	$ 5,743,820	$ 313,995	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 136,793,340	$ 3,966
Community Cost**	$ 136,793,340	$ 3,966

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	$ 4,266	$ 8,726	$ 17,161
Annual O&M	$ 89	$ 194	$ 371

SCENARIO 3 - Potable: SFR - ALL USES

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 1,375,900,982	$ 275,180,196	$ 68,795,049	$ -	$ -	$ 1,719,876,227
Community Cost	$ 1,375,900,982	$ 275,180,196	$ 68,795,049	$ -	$ -	$ 1,719,876,227

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 42,996,906	$ 34,028,610	$ 4,606,236	$ 251,808	$ -	$ -
Community Cost**	$ 42,996,906	$ 34,028,610	$ 4,606,236	$ 251,808	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 81,883,559	$ 2,960
Community Cost**	$ 81,883,559	$ 2,960

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	$ 3,188	N/A	N/A
Annual O&M	$ 90	N/A	N/A

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Annual yields may vary from year to year.

Comments:

Literature Review/Case Studies:

References:

1. https://www.basix.nsw.gov.au/basixcms/images/BASIX_Rainwater_Harvesting_System_Guidelines.pdf
2. http://www.edwardsaquifer.net/pdf/RainwaterCommitteeFinalReport.pdf
3. http://www.twdb.texas.gov/publications/brochures/conservation/doc/RainwaterHarvestingManual_3rdedition.pdf
4. https://austintexas.gov/faq/rainwater-harvesting
5. http://www.austintexas.gov/sites/default/files/files/Water/Conservation/Rebates_and_Programs/Rainwater_Harvesting_Rebate_FAQ.pdf

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Alternative Source Water Name:

Stormwater Harvesting

DRAFT RESULTS 8/1/17

Short Description:

Lot scale stormwater harvesting and reuse

Details:

Lot scale stormwater harvesting involves the capture and storage of stormwater runoff generated from impervious surfaces (including roof water) within the lot boundary of multi-family residential or commercial development to supply a range of onsite demands at the lot/building scale. Implementing stormwater harvesting in new developments provides an opportunity to plumb the building with internal connections for toilet flushing, clothes washing or to cooling towers. Retrofitting existing buildings with internal connections to a dual supply source can be cost prohibitive and/or practically difficult, and so it is assumed for the purposes of this study that stormwater harvesting at the lot scale for existing development would be used solely for irrigation/landscaping. Where used for irrigation/landscaping only, it is assumed that there will be filtration. Where used to supply indoor non-potable end-uses, UV Disinfection is assumed. Storage is assumed to be an underground tank/cistern. All scenarios assume back-up supply from the centralized water distribution system.

Two scenarios are considered for simplicity. These are:
1. A proportion of newly constructed MFR and COM buildings have an underground stormwater harvesting tank supplying outdoor end uses.
2. A proportion of newly constructed MFR and COM buildings have an underground stormwater harvesting tank supplying outdoor end uses and indoor (non-potable) end uses via dual reticulation.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor: MFR - IRR; COM - IRR.
2. Outdoor + Indoor Non Potable: MFR - IRR, TL, CW; COM - IRR, TL, CW, HVC.

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 40

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand

o Variable per DTI (estimated from demand model)

o Monthly outdoor demand profile generated using historical gross lake evaporation data (quadrangle 811) and precipitation data in a standard irrigation model to account for monthly and year to year variation in outdoor demand based on climate.

Yield

o Daily water balance calculation for historical time series

o Daily rainfall analyzed for the historical period (1938 – 2016) using Station: AUSTIN CAMP MABRY TX US

o Note: Climate change adjusted dataset can be used instead of historical dataset in the portfolio evaluation process

o Nominal Building Roof Areas (i.e. Building Footprints) were selected for MFR and COM for the purpose of the rainwater harvesting analysis: 5,000 sq ft for MFR and 10,000 sq ft for COM. The total number of nominal buildings per DTI was informed the assumed increase in MFR or COM land use area between now and 2115. This results in the density of MFR buildings (units/building) and COM buildings (employees/building) being variable per DTI, in order to reflect higher and lower density areas. The total current roof area and building numbers were estimated based on the Current Land uses building footprint data. The total future roof area was estimated taking into account demographic changes (increase in units/employees) and growth/change in land use (including densification) from the future land use map generated for this project.

o For these nominal buildings, the amount of impervious area on the lot (additional to the roof area) per nominal building was informed by analysis of the current land use and building footprint data. This identified that the ratio of roof area to other impervious area for MFR was in the order of 1:1 and for COM in the order of 1:2.

o Connected Catchment Area = 67% (of total impervious catchment area). This is an allowance for not all runoff generated onsite necessary being directed to the one location.

o Runoff coefficient = 0.9

o Tank volumes optimised from yield/storage curves in order to maximise yield, whilst minimise cost & tank footprint/space (& cost):

- [MFR] 10,000 Gallons per nominal building/lot (noting stormwater runoff from catchment approx 111,000 gallons)
- [COM] 30,000 Gallons per nominal building/lot (noting stormwater runoff from catchment approx 335,000 gallons)

Year

2115

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor: MFR - IRR; COM - IRR

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	N/A	4,973	9,464
Annual Average System Volume (Gal/Year)	N/A	52,180	146,228

SCENARIO 2 - Outdoor + Indoor Non Potable: MFR - IRR, TL, CW; COM - IRR, TL, CW, HVC

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	N/A	8,961	15,511
Annual Average System Volume (Gal/Year)	N/A	99,161	247,652

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs will likely be borne by the customer/developer. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for the typical building per DTI using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number of houses, buildings, roof areas)

o Cost elements include:
- Treatment (Filtration only if used for irrigation landscaping only; Filtration + UV Disinfection if used for indoor non-potable)
- Storage (underground tank/cistern)
- Pump
- Reticulation (within building) if used for indoor non-potable supply

Engineering, Legal Costs and Contingencies

o 20% cost of facilities

Mitigation and Permitting

o 0% cost of facilities if used only for irrigation; 5% cost of facilities otherwise

Annual O&M – Labor & Material

o Estimated as proportion of capital costs (Civil 0.5%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping Energy = 750 kWh/ML (2839 kWh/MG) (outdoor) and 1500 kWh/ML (5678 kWh/MG) (indoor & outdoor) (per previous projects & water-energy nexus studies)

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital costs and O&M in other categories)

o For outdoor use: 0 kWh/ML (0 kWh/MG)

o For indoor use: 82 kWh/ML (310 kWh/MG)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor: MFR - IRR; COM - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 2,025,635,817	$ 405,127,163	$ -	$ -	$ -	$ 2,430,762,980
Community Cost	$ 2,025,635,817	$ 405,127,163	$ -	$ -	$ -	$ 2,430,762,980

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 60,769,074	$ 17,580,054	$ 1,202,068	$ -	$ -	$ -
Community Cost**	$ 60,769,074	$ 17,580,054	$ 1,202,068	$ -	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 79,551,197	$ 5,510
Community Cost**	$ 79,551,197	$ 5,510

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	N/A	$ 22,394	$ 63,071
Annual O&M	N/A	$ 214	$ 576

SCENARIO 2 - Outdoor + Indoor Non Potable: MFR - IRR, TL, CW; COM - IRR, TL, CW, HVC

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 2,434,020,724	$ 486,804,145	$ 121,701,036	$ -	$ -	$ 3,042,525,905
Community Cost	$ 2,434,020,724	$ 486,804,145	$ 121,701,036	$ -	$ -	$ 3,042,525,905

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 76,063,148	$ 43,513,828	$ 4,074,948	$ 222,764	$ -	$ -
Community Cost**	$ 76,063,148	$ 43,513,828	$ 4,074,948	$ 222,764	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 123,874,688	$ 5,062
Community Cost**	$ 123,874,688	$ 5,062

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	N/A	$ 28,910	$ 77,554
Annual O&M	N/A	$ 596	$ 1,483

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Annual yields may vary from year to year.

Comments:

Literature Review/Case Studies:

References:

1. http://www.twdb.texas.gov/publications/brochures/conservation/doc/RainwaterHarvestingManual_3rdedition.pdf
2. https://austintexas.gov/faq/rainwater-harvesting

Alternative Source Water Name:

Graywater Harvesting

DRAFT RESULTS 8/1/17

Short Description:

Lot or building scale graywater diversion or treatment systems

Details:

Graywater harvesting is defined, for the purpose of this project, as the reuse of water from the laundry, shower and bath at the lot/building scale to meet non-potable demands. There are two main types, graywater diversion devices and graywater treatment systems. Graywater diversion is untreated, and therefore cannot be stored and can only be used to supply sub-surface irrigation. They typically include a surge-tank and may include a filter. The system may be gravity fed or require a pump, depending on the site. Graywater treatment systems include treatment, storage and a pump. The treated graywater can be reused to supply outdoor end use demands as well as non-potable indoor end use demands (toilet flushing and clothes washing). Graywater is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone.

Two scenarios are considered for simplicity. These are:
1. A proportion of newly constructed SFR, MFR and COM buildings have a graywater diversion system supplying outdoor end uses.
2. A proportion of newly constructed SFR, MFR and COM buildings have a graywater treatment system supplying outdoor and indoor end uses.

All scenarios assume back-up supply from the centralized water distribution system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor: SFR - IRR, MFR - IRR, COM - IRR
2. Outdoor + Indoor Non Potable: SFR - IRR, TL, CW; MFR - IRR, TL, CW; COM - IRR, TL

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 30

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand
o Variable per DTI (estimated from demand model)
o For graywater diversion, it is assumed that only 75% of the IRR demand can be accessed. (For SFR, for the 50% of systems that are assumed to be gravity fed, it is assumed than only 50% of the IRR demand, whereas if pressurised it is assumed that 100% of the demand can be accessed. This averages at 75%. For MFR & COM, there will be landscaped areas there may be areas that are not suitable for supply by a sub-surface system, so although pressurised 75% has also been assumed.)
Source generation
o Average daily graywater generation volumes are calculated from the demand model end use volumes, based on the following assumptions:
o Graywater [SFR & MFR] = 100% * Shower/Baths + 100% * Clotheswashing + 50% * Faucets/Basins (assumes the other 50% is assumed to be used in the kitchen)
o Graywater [COM] = 100% * Laundry + 50% * Domestic (assumes the other 50% is for toilets)
o This is the same for graywater diversion and graywater treatment
Storage
o Graywater diversion: Surge tanks for capturing instantaneous/peak flows (can't store untreated graywater)
o Graywater treatment: Storage size is variable by customer class and DTI, and is automatically sized at 3 times the average daily graywater generation volume.
Yield
o Graywater yield (the volume of demand that is supplied by graywater) is calculated from a water balance calculation of graywater supply and graywater demand.
Other
o For a given building, the gray water available to reuse for the supply of end use demands within that building is limited to the volume of graywater generated from that building.
o Note that for higher saturation scenarios, 50% and higher, there would need to be consideration given to the minimum dry weather flows that must be retained in the centralized wastewater system to maintain the necessary scouring velocities.
Year
2115

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor: SFR - IRR, MFR - IRR, COM - IRR

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	9,778	8,275	5,706
Annual Average System Volume (Gal/Year)	8,663	109,774	125,463

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR - IRR, TL, CW; MFR - IRR, TL, CW; COM - IRR, TL

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	28,844	30,926	11,892
Annual Average System Volume (Gal/Year)	20,379	340,036	186,192

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs will likely be borne by the customer/developer. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for the typical building per DTI using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number and characteristics of houses, buildings)

o Cost elements for graywater diversion include:
- Collection (dual plumbing)
- Diversion system (typically includes filtration and surge tank)
- Pump (assume 50% of installations are gravity fed and 50% require a pump)

o Cost elements for graywater treatment systems include:
- Collection (dual plumbing)
- Treatment system
- Balancing Storage
- Pump
- Reticulation (within building)

o Note: Treatment systems will vary. For example, the New South Wales government (Australia) accredited graywater systems include: (i) MBR (combination of biological treatment and advanced membrane filtration) and UV disinfection; (ii) aeration, membrane filtration and UV disinfection; (ii) aeration and chlorination; (iii) vertical flow reed bed filter and UV disinfection. See http://www.health.nsw.gov.au/environment/domesticwastewater/Pages/gts.aspx

Engineering, Legal Costs and Contingencies

o 35% of capital cost

Mitigation and Permitting

o 0% for SFR Gray Water Diversion, 5% of capital cost for all other contexts

Annual O&M – Labor & Material

o Estimated as proportion of capital cost (Civil 0.5%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping Energy = 750 kWh/ML (2839 kWh/MG) (outdoor) and 1500 kWh/ML (5678 kWh/MG) (indoor & outdoor) (per previous projects & water-energy nexus studies)

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital cost and O&M in other categories)

o For graywater diversion: no treatment

o For graywater treatment systems: 1000 kWh/ML (3785 kWh/MG)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor: SFR - IRR, MFR - IRR, COM - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 939,932,459	$ 328,976,361	$ 5,810,642	$ -	$ -	$ 1,274,719,462
Community Cost	$ 939,932,459	$ 328,976,361	$ 5,810,642	$ -	$ -	$ 1,274,719,462

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 42,490,649	$ 18,821,920	$ 661,836	$ -	$ -	$ -
Community Cost**	$ 42,490,649	$ 18,821,920	$ 661,836	$ -	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 61,974,405	$ 3,898
Community Cost**	$ 61,974,405	$ 3,898

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	$ 2,239	$ 6,687	$ 7,288
Annual O&M	$ 47	$ 131	$ 138

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR - IRR, TL, CW; MFR - IRR, TL, CW; COM - IRR, TL

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 8,682,069,072	$ 3,038,724,175	$ 434,103,454	$ -	$ -	$ 12,154,896,700
Community Cost	$ 8,682,069,072	$ 3,038,724,175	$ 434,103,454	$ -	$ -	$ 12,154,896,700

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 405,163,223	$ 339,267,657	$ 11,933,248	$ 7,955,498	$ -	$ -
Community Cost**	$ 405,163,223	$ 339,267,657	$ 11,933,248	$ 7,955,498	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 764,319,627	$ 10,666
Community Cost**	$ 764,319,627	$ 10,666

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	$ 9,309	$ 108,397	$ 56,520
Annual O&M	$ 329	$ 5,102	$ 2,701

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	This option is not significantly impacted by hydrologic or climatic variability.

Comments:

Literature Review/Case Studies:

References:

1. http://www.health.nsw.gov.au/environment/domesticwastewater/Pages/gts.aspx
2. https://www.austintexas.gov/sites/default/files/files/Water/Conservation/GrayWater-FAQ.pdf
3. https://www.austintexas.gov/sites/default/files/files/Watershed/growgreen/2015LPT/Gray-Water-Navigating-Through-City-Code-Stefani.pdf

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Alternative Source Water Name:

Building Scale Wastewater Reuse

DRAFT RESULTS 8/1/17

Short Description:

Lot or building scale blackwater treatment plants

Details:

This involves the onsite capture and treatment of the wastewater stream generated from a building for onsite reuse via a dual (purple) pipe system to supply outdoor demands (irrigation/landscaping) and non-potable indoor demands (toilets and potentially also laundry and cooling towers). Blackwater treatment plants are most commonly installed in commercial buildings and high density, multi-story multi-family residential buildings. Treatment of blackwater to Type 1 quality is required. Treatment may be one of a combination of Membrane Bioreactor (MBR), Moving Bed Biofilm Reactor (MBBR), passive (e.g. engineered wetlands) or other systems, with microfiltration or ultrafiltration, and UV disinfection and/or chlorination. Wastes (sludge) from the treatment process are discharged back to the wastewater network. Blackwater reuse is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone. This option assumes back-up supply from the centralized water distribution system.

One scenario is considered for simplicity. This is:
1. A proportion of newly constructed MFR and COM buildings have a blackwater treatment system supplying outdoor and non-potable indoor end uses.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. MFR - IRR, TL, CW; COM - IRR, TL, CW, HVC

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 30

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand
o Variable per DTI (estimated from demand model)
o For MFR customer sector, the Irrigation/Landscaping end use demand may incorporate some water use by pools which may slightly overestimate the demand. Many pools may be sourced with water that would be metered as irrigation and therefore be represented in a different demand sector in the model, so although a limitation of the demand model it is not considered significant.
Source generation
o Blackwater [MFR] = Total Demand - Irrigation/Landscaping - Leaks
o Blackwater [COM] = Total Demand - Irrigation/Landscaping - Pool - 50% * Misc (assumes 50% of Misc is consumed or losses)
Storage
o Storage size is variable per customer class and DTI, and is automatically sized at 3 times the average daily blackwater generation volume.
Yield
o Blackwater yield (the volume of demand that is supplied by blackwater) is calculated from a water balance calculation of blackwater supply and demand.
o For a given building, the wastewater available to reuse for the supply of end use demands is limited to the volume of wastewater generated from the building.
Other
Note that for higher saturation scenarios, 50% and higher, there would need to be consideration given to the minimum dry weather flows that must be retained in the centralized wastewater system to maintain the necessary scouring velocities.
Year
2115

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - MFR - IRR, TL, CW; COM - IRR, TL, CW, HVC

	SFR	MFR	Non-Residential
Annual Cumulative Volume (AF/Year)	N/A	38,905	39,731
Annual Average System Volume (Gal/Year)	N/A	402,896	629,853

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs will likely be borne by the customer/developer. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for the typical building per DTI using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number and characteristics of houses, buildings)

o Cost elements include:
- Treatment system
- Balancing Storage
- Pump
- Reticulation (within building)

o Note: Treatment systems will vary. These may include Membrane Bioreactor (MBR), Moving Bed Biofilm Reactor (MBBR), passive (e.g. engineered wetlands such as SFPUC's living machine - see ref #1) or other systems, with microfiltration or ultrafiltration, and UV disinfection and/or chlorination.

Engineering, Legal Costs and Contingencies

o 35% of capital cost

Mitigation and Permitting

o 5% of capital cost

Annual O&M – Labor & Material

o Estimated as proportion of capital cost (Civil 0.5%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping Energy = 1500 kWh/ML (5678 kWh/MG) (per previous projects)

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital cost and O&M in other categories)

o GHD Energy Curve for MBR Treatment Plants (kWh per ML/d capacity). For larger through to smaller MFR & COM treatment plant capacities this ranges between 1400-2100 kWh/ML (5300-7950 kWh/MG)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - MFR - IRR, TL, CW; COM - IRR, TL, CW, HVC

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 10,298,450,129	$ 3,604,457,545	$ 514,922,506	$ -	$ -	$ 14,417,830,181
Community Cost	$ 10,298,450,129	$ 3,604,457,545	$ 514,922,506	$ -	$ -	$ 14,417,830,181

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ -	$ -	$ -	$ -	$ -	$ -
Customer Cost	$ 480,594,339	$ 488,653,797	$ 13,094,353	$ 15,685,328	$ -	$ -
Community Cost**	$ 480,594,339	$ 488,653,797	$ 13,094,353	$ 15,685,328	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ -	$ -
Customer Cost	$ 998,027,817	$ 12,692
Community Cost**	$ 998,027,817	$ 12,692

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

	SFR	MFR	Non-Residential
Capital Cost	N/A	$ 175,286	$ 232,702
Annual O&M	N/A	$ 8,797	$ 11,707

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	This option is not significantly impacted by hydrologic or climatic variability.

Comments:

Literature Review/Case Studies:

References:

1. https://sfwater.org/index.aspx?page=1156

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INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Aquifer Storage and Recovery (ASR)

DRAFT RESULTS 7/28/17

Short Description:

Carrizo-Wilcox ASR (Conventional) used as the representative option for analysis

Other ASR options considered in screening and combined for this option:
o Trinity ASR
o Edwards ASR
o Carrizo-Wilcox ASR (Infiltration)

Details:

Aquifer storage and recovery is a strategy in which water (ex: potable drinking water) can be stored in an aquifer during wetter periods and recovered for use during drier periods. Storing water underground can improve drought preparedness and reduces the amount of water that evaporates compared to water storage in open above-ground reservoirs. This type of strategy is currently being used by cities in Texas including San Antonio, Kerrville and El Paso. Exploring aquifer storage and recovery as a potential option was a recommendation of the 2014 Task Force and has been analyzed by Austin Water as part of Feasibility and Engineering Analysis #5 (Northern Edwards and Trinity Aquifers).

Carrizo-Wilcox ASR (Conventional) option includes facilities to pipe treated drinking water from the City of Austin's distribution system to an ASR wellfield for injection and storage in the Carrizo-Wilcox aquifer. Facilities also include a pump station and storage tank to convey recovered water from the ASR wellfield to the City of Austin distribution system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Drought

Supply Type: Storage

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o 5 cycles: 4 years in at 15,000 AF/y, 2 years out at 30,000 AF/y

Average Weather Yield Summary (Acre Feet):

*Drought yields to be determined

Annual Yield (AF/Year)
10,000

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o Reversible pipeline 28 miles long, sized for 30,000 AF/yr
o Wells at 1,800 gpm each
o Pump station in at 15,000 AF/y, out at 30,000 AF/yr

Engineering, Legal Costs and Contingencies
o 35% cost of facilities

Mitigation and Permitting
o 5% cost of facilities

Land Acquisition
o Calculated at 4% cost of facilities

Annual O&M – Labor & Material
o Consultant estimate

Annual O&M – Energy
o Pipeline in at 15,000 AF/y, out at 30,000 AF/yr
o Wells' energy use based on estimated pumping level at 30,000 AF/yr
o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment
o None

Annual O&M - Conventional W/WW Treatment
o Calculated based on proportion of water and wastewater treatment for each option

Annual Purchase/Import Cost
o None

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$69,120,780	$24,192,273	$6,912,078	$2,764,831	$97,999,384	$200,989,347

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$6,699,645	$650,000	$1,100,000	$0	$2,081,862	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 10,531,507	$1,053

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Little sensitivity to variation in hydrology or climate. Recovery rate may be influenced by fluctuations in supply available for storage.

Comments:

Underground storage option; water not subject to evaporation

Literature Review/Case Studies:

http://www.saws.org/Your_Water/WaterResources/projects/asr.cfm

References:

Water Forward IWRP Consultant team developed cost and yield information for this option

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Supply Option Name:

Brackish Groundwater Desalination

DRAFT RESULTS 7/28/17

Short Description:

Desalination of brackish groundwater; source aquifer for option concept is the Trinity Aquifer

Details:

Desalination is the process of removing dissolved solids from seawater or brackish groundwater, often by forcing the source water through membranes under high pressure. The specific process used to desalinate water varies depending upon the total dissolved solids, the temperature, and other physical characteristics of the source water but always requires disposal of concentrate that has a higher total dissolved content than the source water. Disposal may take the form of an injection well, evaporation beds, or an ocean outfall diffuser. Exploring desalination of brackish groundwater as a potential option was a recommendation of the 2014 Task Force.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Constant

Supply Type: Desalination

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o Estimated based on typical Trinity well capacity

Average Weather Yield Summary (Acre Feet):

*Drought yields to be determined

Annual Yield (AF/Year)
10,000

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o All-in costs from SAWS on a similar project
o Pipeline distance of approximately 22 miles, 75% rural, 25% urban
Engineering, Legal Costs and Contingencies
o 35% cost of facilities
Mitigation and Permitting
o 5% cost of facilities
Land Aquisition
o 4% cost of facilities
Annual O&M – Labor & Material
o Based on SAWS project O&M costs
Annual O&M – Energy
o Estimated based on pipeline length and pumping level
o Electricity cost 0.09 $USD/kWh
Annual O&M - Advanced/Decentralized Treatment
o Water treatment (2.5% cost of facilities)
Annual O&M - Conventional W/WW Treatment
o Calculated based on proportion of water and wastewater treatment for each option
Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$200,885,586	$70,309,955	$10,044,279	$8,035,423	$275,257,849	$564,533,093

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$18,817,770	$1,370,000	$1,100,000	$5,022,140	$586,206	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 26,896,115	$2,690

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Sensitivity to variations in climate and hydrology would vary depending on source aquifer and utilization rates.

Comments:

Literature Review/Case Studies:

SAWS Groundwater Desalination Project (http://www.saws.org/Your_Water/WaterResources/Projects/desal.cfm) - Wilcox Aquifer

References:

Water Forward IWRP Consultant team developed cost and yield information for this option

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Direct Non-potable Reuse (Reclaimed Water System)

DRAFT RESULTS 7/28/17

Short Description:

Reclaimed water purple pipe system expansion (based on current Master Plan and Region K Plan); Expanded option beyond Master Plan/Region K Plan currently under development

Details:

Through its Water Reclamation Initiative (WRI) program, AW provides highly treated wastewater effluent for non-potable uses such as irrigation, cooling, manufacturing, and toilet flushing. Austin's direct reuse (purple pipe) system currently supplies approximately 4,600 AF per year. To meet projected demands, an additional 28,000 AFY are needed for direct municipal purposes by year 2070. An additional 10,500 AFY were projected for steam electric needs in Travis County.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

Non-potable End Uses, Both Development Types

Characterization Year: 2115

Intended use of supply: Constant

Supply Type: Reuse

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o 4,600 AFY existing direct reuse supply
o Additional 28,000 AFY for direct municipal and manufacturing non-potable purposes
o Additional 10,500 AFY of COA direct non-potable use for steam electric needs in Travis County
o Expanded option beyond Master Plan/Region K Plan currently under development

Average Weather Yield Summary (Acre Feet):

*Drought yields to be determined

Annual Yield (AF/Year)
43,100

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
- o Intake pump station
- o Transmission pipeline
- o Storage tanks
- o Wastewater treatment plant filter and process improvements

Engineering, Legal Costs and Contingencies
- o 35% cost of facilities

Mitigation and Permitting
- o 5% cost of facilities

Land Acquisition
- o Calculated at 4% cost of facilities

Annual O&M – Labor & Material
- o Intake, pipeline, pump station (1% cost of facilities)

Annual O&M – Energy
- o Approx. 8,910,000 kW-hr per year
- o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment
- o Water treatment (2.5% cost of facilities)

Annual O&M - Conventional W/WW Treatment
- o Calculated based on proportion of water and wastewater treatment for each option

Annual Purchase/Import Cost
- o Not applicable

Note: additional cost estimates including customer costs and costs for expanded option beyond Master Plan/Region K Plan, are currently under development.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$403,697,211	$141,294,024	$20,184,861	$16,624,000	$553,607,839	$1,135,407,934

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$37,846,931	$4,036,972	$801,900	$10,092,430	$180,468	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 52,958,701	$1,229

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Actual water demands may increase faster/slower than projected.

Comments:

Literature Review/Case Studies:

https://www.austintexas.gov/department/water-reclamation

References:

Austin Water - Direct Reuse Strategy in Region K Plan used as references for cost and yield information; Region K Water Plan, Vol2, pages 5-55 through 5-57, Chapter 5 Appendix pdf page 53
http://www.regionk.org/wp-content/uploads/2016_Region_K_Plan_Chpt_5.pdf
http://www.regionk.org/wp-content/uploads/2016_Region_K_Plan_Chpt_5_Appendices.pdf

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Supply Option Name:

Direct Potable Reuse (DPR)

DRAFT RESULTS 7/28/17

Short Description:

Direct Potable Reuse

Details:

This option would convey highly treated reclaimed water from one treatment train at South Austin Regional (SAR) WWTP to the Ullrich WTP to meet city demands. This approach would include advanced water treatment, potentially including microfiltration and reverse osmosis. The treated water would then be blended with raw water prior to being pumped back to the headworks of Ullrich WTP for conventional treatment.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Reuse

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o Estimated based on approximate yield available from one treatment train at South Austin Regional WWTP.

Average Weather Yield Summary (Acre Feet):

*Drought yields to be determined

Annual Yield (AF/Year)
20,000

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o Pump station at WWTP
o Transmission pipeline from WWTP to WTP (approx. 15 miles)
o Membrane plant and UV facility to treat reclaimed water and blend with raw water before introducing to WTP
Engineering, Legal Costs and Contingencies
o 35% cost of facilities
Mitigation and Permitting
o 15% cost of facilities
Land Acquisition
o 4% cost of facilities
Annual O&M – Labor & Material
o Intake, pipeline, pump station (1% cost of facilities)
Annual O&M – Energy
o Approx. 5,000,000 kW-hr per year
o Electricity cost 0.09 $USD/kWh
Annual O&M - Advanced/Decentralized Treatment
o Water treatment (2.5% cost of facilities)
Annual O&M - Conventional W/WW Treatment
o Calculated based on proportion of water and wastewater treatment for each option
Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$291,984,864	$102,194,702	$43,797,730	$11,679,395	$427,867,700	$877,524,390

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$29,250,813	$2,919,849	$450,000	$7,299,622	$4,163,724	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 44,084,007	$ 2,204

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Supplies all end uses and moves toward closed loop supply.

Comments:

Literature Review/Case Studies:

Texas Water Development Board - Direct Potable Reuse Resource Document (April 2015)
http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1248321508_Vol1.pdf?d=1501294805363

References:

Conceptually, treatment facilities and other necessary infrastructure associated with this option would be constructed at South Austin Regional WWTP using same approach as Big Spring and Wichita Falls

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Supply Option Name:

Indirect Potable Reuse (IPR) with Capture Lady Bird Lake Inflows

DRAFT RESULTS 7/28/17

Short Description:

A combined option of IPR Through Lady Bird Lake and Capture Lady Bird Lake Inflows used as the representative option for analysis.

Other options considered in screening and combined for this option:
o IPR - Alluvial Aquifer
o IPR - Bed and Banks

Details:

This option would convey highly treated reclaimed water from one treatment train at South Austin Regional (SAR) WWTP to Lady Bird Lake and subsequently divert water by a potential new intake pump and piping system downstream of Tom Miller Dam to the Ullrich WTP to meet city demands. This approach would supplement water releases from Lakes Buchanan and Travis to extend water supplies during severe drought. This option is a drought strategy that would be recommended for implementation in the event of 400,000 AF of combined storage or less in Lakes Buchanan and Travis. In addition, this option would capture available spring flows into Lady Bird Lake and convey the water to Ullrich WTP through a potential new intake pump and piping system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Drought

Supply Type: Reuse

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o Estimated based on approximate yield available from one treatment train at South Austin Regional WWTP: 20,000 AFY (drought option)
o Yield from capturing spring inflows estimated based on analysis conducted as part of Austin Water's Feasibility and Engineering Analysis (FEA) #4: long term average: 3,000 AFY

Average Weather Yield Summary (Acre Feet):

Annual Yield (AF/Year)
3,000

Target Drought Yield Summary (Acre Feet):

Annual Yield (AF/Year)
20,000

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o Pump stations (25MGD capacity) to convey treated effluent from SAR WWTP to Lady Bird Lake, just upstream of Longhorn Dam
o Transmission line from SAR WWTP to Lady Bird Lake, just upstream of Longhorn Dam (48-inch pipeline, 10 miles)
o Intake & Pump station (20 MGD capacity) & Transmission line from pump station to Ullrich intake

Engineering, Legal Costs and Contingencies
o 35% cost of facilities

Mitigation and Permitting
o 5% cost of facilities

Land Acquisition
o 4% cost of facilities

Annual O&M – Labor & Material
o Intake, pipeline, pump station (1% cost of facilities)

Annual O&M – Energy
o Approx. 900,000 kW-hr per year
o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment
o Water treatment (2.5% cost of facilities)

Annual O&M - Conventional W/WW Treatment
o Calculated based on proportion of water and wastewater treatment for each option

Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$61,100,793	$21,385,278	$3,055,040	$2,444,032	$83,721,651	$171,706,794

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$5,723,560	$611,008	$81,000	$1,527,520	$4,163,724	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 12,106,812	$ 605

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Supplies all end uses and moves toward closed loop supply.

Comments:

Indirect Potable Reuse (IPR) Through Lady Bird Lake (LBL) is a drought option that would be recommended for implementation in the event of 400,000 AF of combined storage or less in Lakes Buchanan and Travis. Approximate drought yield target volume of 20,000 AFY used for unit cost calculation. Average weather yield of approximately 3,000 AFY is based on long term average yield estimate for the Capture Local Inflow to Lady Bird Lake option.

The capital cost estimates for the IPR Through LBL option include the infrastructure costs for the Capture Local Inflows to LBL option. For the operations and maintenance (O&M) costs, the IPR through LBL option was assumed to be in drought operation mode (approximate 20,000 AFY). Under average weather conditions the O&M costs would be significantly lower due to the lower amount of long-term average yield for the Capture Local Inflow to LBL option (approximately 3,000 AFY).

Literature Review/Case Studies:

References:

Austin Water - Capture Local Inflows to Lady Bird Lake and Indirect Potable Reuse Strategy in Region K Plan used as references for developing cost and yield information; Region K Water Plan, Vol2, pages 5-65 through 5-68, Chapter 5 Appendix pdf pages 59 and 60
http://www.regionk.org/wp-content/uploads/2016_Region_K_Plan_Chpt_5.pdf
http://www.regionk.org/wp-content/uploads/2016_Region_K_Plan_Chpt_5_Appendices.pdf
Feasibility and Engineering Analysis (FEA2 and FEA4) draft reports

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CDM Smith

Supply Option Name:

Additional Supply from Lower Colorado River Authority (LCRA)

DRAFT RESULTS 7/28/17

Short Description:

Additional Supply from LCRA

Details:

This would involve securing additional supply from the Lower Colorado River Authority (LCRA). Currently LCRA has approximately 54,600 acre-feet of water available for contracting (50,000 acre-feet of which is the LCRA Board's reserve amount and is subject to contracting approval by the LCRA Board). There could be additional supply volumes available for contracting over time as LCRA plans to continue to develop additional supplies in the future.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Constant

Supply Type: Surface Water

Timing of Implementation: NA

Lifespan (years): TBD

YIELD ANALYSIS

Assumptions:

o Based on availability per discussion with LCRA.

Average Weather Yield Summary (Acre Feet):

*Drought yields to be determined

Annual Yield (AF/Year)
54,600

COST ANALYSIS

Assumptions:

Capital Cost – Facilities

o Not Applicable

Engineering, Legal Costs and Contingencies

o Not Applicable

Mitigation and Permitting

o Not Applicable

Land Aquisition

o Not Applicable

Annual O&M – Labor & Material

o Not Applicable

Annual O&M – Energy

o Not Applicable

Annual O&M - Advanced/Decentralized Treatment

o Not Applicable

Annual O&M - Conventional W/WW Treatment

o Calculated based on proportion of water and wastewater treatment for each option

Annual Purchase/Import Cost

o Water cost assumed to be $145/AF (current LCRA firm water use rate).

o In the portfolio process, will need to acccount for potential variations in amounts to be secured and timing of reservation fees to secure this water.

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$0	$0	$0	$0	$0	$0

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$0	$0	$0	$0	$11,366,967	$7,830,000

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 19,196,967	$ 352

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Dependent on variations in climate and hydrology but this risk is buffered some by system storage. Hydrology data from the latest drought (2007-2016) is being prepared for use in updating the firm yield analysis and the LCRA Water Management Plan update scheduled to begin in 2018.

Comments:

Literature Review/Case Studies:

References:

https://www.lcra.org/water/water-supply/water-supply-contracts/Pages/default.aspx

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CDM Smith

Austin WATER | WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Off-Channel Reservoir (OCR) with Lake Evaporation Suppression

DRAFT RESULTS 7/28/17

Short Description:

This option is a combination of the Off-Channel Reservoir option with the Lake Evaporation Suppression option

Details:

This strategy would involve the construction of a new off-channel reservoir in the Austin region. The approximate size of this reservoir would be about 25,000 AF. An evaporation suppressant would be applied during summer months to reduce water lost through evaporation.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Constant

Supply Type: Storage

Timing of Implementation: NA

Lifespan (years): 50

YIELD ANALYSIS

Assumptions:

o Off channel reservoir is an estimated yield based on anticipated potential size
o Lake Evaporation Suppression: surface area of 1300 acres; 52.14”/year (median evaporation)

Average Weather Yield Summary (Acre Feet):

*Drought yields to be determined

Annual Yield (AF/Year)
25,827

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o 25,000 AF off-channel reservoir in the Austin region
o New river intake, pump station, and pipeline (to pump from river to reservoir)
o New pump station and pipeline from the reservoir to the point of use
o Boat for application of lake evaporation suppressant
Engineering, Legal Costs and Contingencies
o 35% cost of facilities
Mitigation and Permitting
o 5% cost of facilities
Land Acquisition
o 4% cost of facilities
Annual O&M – Labor & Material
o Intake, pipeline, pump station (1.5% cost of facilities)
Annual O&M – Energy
o Approx. 3,750,000 kW-hr per year
o Electricity cost 0.09 $USD/kWh
Annual O&M - Advanced/Decentralized Treatment
o Not applicable
Annual O&M - Conventional W/WW Treatment
o Calculated based on proportion of water and wastewater treatment for each option
Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$226,171,476	$79,160,016	$11,307,777	$9,046,222	$309,883,308	$635,568,799

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$12,713,096	$3,426,229	$337,210	$0	$5,376,825	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 21,853,361	$ 846

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Surface water is vulnerable to evaporation. If Colorado River system used as a source of supply, yield would be dependent on rainfall and inflows. If stormwater used as a source of supply, yield would be dependent on rainfall within local watersheds.

Comments:

Literature Review/Case Studies:

References:

Austin WATER | WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Imported Option Category - Seawater Desalination

DRAFT RESULTS 7/28/17

Short Description:

Seawater Desalination used as the representative option for analysis

Other options considered in screening and combined for this option:
o Conventional Groundwater
o Interbasin Transfer

Details:

This option would involve sourcing water from the Gulf of Mexico and treating it via a desalination plant where dissolved solids are removed by forcing the source water through membranes at high pressure. The specific process used to desalinate water varies depending on the total dissolved solids, the temperature, and other physical characteristics of the source water, but always requires the disposal of concentrate that has a higher total dissolved content than the source water. Disposal may take the form of an injection well, evaporation beds, or an ocean outfall diffuser. This option could be implemented through a regional partnership approach.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Constant

Supply Type: Desalination

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o This is a large scale imported water option. Yield has been scaled to reflect the large-scale nature of the infrastructure required.

*Drought yields to be determined

Average Weather Yield Summary (Acre Feet):

Annual Yield (AF/Year)
84,000

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o 75MGD desalination facility
o Intake Pump Station
o Transmission Pipeline (approximately 250 miles)
o Concentrate Disposal Pipeline
o Transmission Pump Stations
o Treatment Plant
o Distribution Improvements- Terminal Storage

Engineering, Legal Costs and Contingencies
o 35% cost of facilities

Mitigation and Permitting
o 5% cost of facilities

Land Acquisition
o Land acquisition is scaled from San Antonio Bay Desal Project, based on mileage

Annual O&M – Labor & Material
o Intake, pipeline, pump station (1% cost of facilities)

Annual O&M – Energy
o Approx. 250,000,000 kW-hr per year
o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment
o Water treatment based on SAWS project

Annual O&M - Conventional W/WW Treatment
o Calculated based on proportion of water and wastewater treatment for each option

Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest (5% over 30 yrs)	Total Capital/Upfront/ Interest/Land Cost
Community Cost**	$1,393,976,750	$487,891,862	$69,698,837	$55,759,070	$1,910,057,604	$3,917,384,123

Annual Cost Summary (current dollars):

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Community Cost**	$130,579,471	$7,925,246	$22,500,000	$76,213,000	$17,487,641	$0

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Community Cost**	$ 254,705,358	$ 3,032

*Annual Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	Minimal dependence on hydrologic and climate variability.

Comments:

Literature Review/Case Studies:

http://www.twdb.texas.gov/innovativewater/desal/seaprojects.asp

References:

2016 Region L Water Plan (used for reference scaling)
2016 Region L Water Plan, Vol2, pdf pg 275-293 (San Antonio Bay Desal Project)

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Supply Option Name:

Community Rainwater Harvesting

DRAFT RESULTS 8/1/17

Short Description:

Community Scale Rainwater Harvesting and Reuse

Details:

Community scale rainwater harvesting is defined for the purpose of this project as the collection of roofwater from new development areas from a dedicated (dual) roofwater drainage network for storage at a central downstream location, for treatment and reuse via dual pipe systems at new developments at the community scale. This is assumed to require UV Disinfection. Storage is assumed to be an underground tank/cistern. This option assumes back-up supply from the centralized water distribution system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 50

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand

o Variable per DTI (estimated from demand model)

o Monthly outdoor demand profile generated using historical gross lake evaporation data (quadrangle 811) and precipitation data in a standard irrigation model to account for monthly and year to year variation in outdoor demand based on climate.

Yield

o Daily rainfall analyzed for the historical period (1938 – 2016) using Station: AUSTIN CAMP MABRY TX US

o Note: Climate change adjusted dataset can be used instead of historical dataset in the portfolio evaluation process

o Connected Catchment Area = 67% (of total roof catchment area). This is an allowance for not all roof areas being able to be connected.

o Runoff coefficient = 0.9

Year

Analysis completed at ultimate timeslice of 2115.

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Annual Cumulative Volume (AF/Year)	1,540
Annual Average System Volume (Gal/Year)	33,464,807

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs may be borne by the customer/developer or the Utility. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for each project opportunity using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number of houses, buildings, area serviced, transfer distance, etc.)

o Cost elements include:

- Roofwater Collection System (dual roofwater drainage system)
- Storage
- Treatment
- Balancing storage
- Transfer pump station and pipeline
- Distribution pipelines (e.g. throughout streets)
- Reticulation (e.g. on-lot & within building)

Engineering, Legal Costs and Contingencies

o 35% cost of facilities

Mitigation and Permitting

o 5% cost of facilities

Annual O&M – Labor & Material

o Estimated as proportion of capital costs (Civil 1%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping energy calculated based on estimated design flow, hours operation, and pump duty power, for a project opportunity

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital costs and O&M in other categories)

o UV Disinfection: 82 kWh/ML (310 kWh/MG)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ 184,090,753	$ 64,431,764	$ 9,204,538		$ 245,238,388	$ 502,965,442
Customer Cost	$ 39,002,927	$ 13,651,024	$ -	$ -	$ -	$ 52,653,951
Community Cost	$ 223,093,680	$ 78,082,788	$ 9,204,538	$ -	$ 245,238,388	$ 555,619,393

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 10,059,309	$ 3,661,376	$ 14,907	$ 18,698	$ -	$ -
Customer Cost	$ 1,053,079	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 11,112,388	$ 3,661,376	$ 14,907	$ 18,698	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 13,754,290	$ 8,928
Customer Cost	$ 1,053,079	$ 684
Community Cost**	$ 14,807,369	$ 9,612

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

Capital Cost	$ 12,272,717
Annual O&M	$ 246,332

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Annual yields may vary from year to year.

Comments:

Literature Review/Case Studies:

References:

http://www.wannonwater.com.au/2015/june/roof-water-harvesting-project-expanded-in-warrnambool.aspx

Austin WATER | WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Community Stormwater Harvesting

DRAFT RESULTS 8/1/17

Short Description:

Community Scale Stormwater Harvesting and Reuse

Details:

Stormwater harvesting is defined for the purpose of this project as the collection of stormwater runoff from urban areas (e.g. impervious surfaces including roads, pavements and roofs), for treatment and reuse for irrigation/landscaping or reuse for dual pipe systems at the community scale.

Implementing stormwater harvesting in new developments provides an opportunity to plumb buildings with internal connections for toilet flushing, clothes washing or to cooling towers. Retrofitting existing buildings with internal connections to a dual supply source can be cost prohibitive and/or practically difficult, and so it is assumed for the purposes of this study that stormwater harvesting for existing developed areas would be used solely for irrigation/landscaping of public open space. Where used for irrigation/landscaping only, it is assumed that there will be filtration. Where used to supply indoor non-potable end-uses, it is assumed UV Disinfection is also required. Storage is assumed to be an underground tank/cistern or more typically an open storage. All scenarios assume back-up supply from the centralized water distribution system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor: SFR, MFR, COM - IRR
2. Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 50

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand

o Variable per DTI (estimated from demand model)

o Monthly outdoor demand profile generated using historical gross lake evaporation data (quadrangle 811) and precipitation data in a standard irrigation model to account for monthly and year to year variation in outdoor demand based on climate.

Yield

o Daily rainfall analyzed for the historical period (1938 – 2016) using Station: AUSTIN CAMP MABRY TX US

o Note: Climate change adjusted dataset can be used instead of historical dataset in the portfolio evaluation process

o Connected Catchment Area = 67% (of total impervious catchment area). This is an allowance for not all runoff generated onsite necessarily being directed to one location.

o Runoff coefficient = 0.9

o Perviousness per Land Use type (assumptions drawn from Remaining Pervious 2013 dataset obtained from the Austin Open Data Portal) applied to future (2070) land use map to calculate future stormwater runoff volumes.

o Catchment Areas of proposed storages calculated from Travis County Contours 2012 (dataset obtained from the Austin Open Data Portal). Alternatively, for new development areas, the development itself is taken as the stormwater catchment.

o Stormwater may be harvested from storm drains or flood detention structures

Year

Analysis completed at ultimate timeslice of 2115.

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor: SFR, MFR, COM - IRR

Annual Cumulative Volume (AF/Year)	10,700
Annual Average System Volume (Gal/Year)	25,449,796

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Annual Cumulative Volume (AF/Year)	22,387
Annual Average System Volume (Gal/Year)	46,169,282

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs may be borne by the customer/developer or the Utility. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for each project opportunity using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number of houses, buildings, area serviced, transfer distance, etc.)

o Cost elements include:

- Diversion structures (e.g. pit and pipeline)
- Storage
- Treatment
- Balancing storage
- Transfer pump station and pipeline
- Distribution pipelines (e.g. throughout streets)
- Reticulation (e.g. on-lot & within building)

Engineering, Legal Costs and Contingencies

o 35% cost of facilities

Mitigation and Permitting

o 5% cost of facilities

Annual O&M – Labor & Material

o Estimated as proportion of capital costs (Civil 1%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping energy calculated based on estimated design flow, hours operation, and pump duty power, for a project opportunity

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital costs and O&M in other categories)

o For outdoor use: 82 kWh/ML (310 kWh/MG)

o For indoor use: 822 kWh/ML (3100 kWh/MG)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor: SFR, MFR, COM - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ 221,163,653	$ 77,407,279	$ 11,058,183	$ -	$ 294,625,433	$ 604,254,548
Customer Cost	$ -	$ -	$ -	$ -	$ -	$ -
Community Cost	$ 221,163,653	$ 77,407,279	$ 11,058,183	$ -	$ 294,625,433	$ 604,254,548

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 12,085,091	$ 3,939,736	$ 133,652	$ 129,871	$ -	$ -
Customer Cost	$ -	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 12,085,091	$ 3,939,736	$ 133,652	$ 129,871	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 16,288,350	$ 1,522
Customer Cost	$ -	$ -
Community Cost**	$ 16,288,350	$ 1,522

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

Capital Cost	$ 1,614,333
Annual O&M	$ 30,681

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ 674,445,435	$ 236,055,902	$ 33,722,272	$ -	$ 898,469,416	$ 1,842,693,025
Customer Cost	$ 306,617,371	$ 107,316,080	$ -	$ -	$ -	$ 413,933,451
Community Cost	$ 981,062,806	$ 343,371,982	$ 33,722,272	$ -	$ 898,469,416	$ 2,256,626,476

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 36,853,861	$ 25,058,469	$ 207,908	$ 1,988,181	$ -	$ -
Customer Cost	$ 8,278,669	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 45,132,530	$ 25,058,469	$ 207,908	$ 1,988,181	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 64,108,419	$ 2,864
Customer Cost	$ 8,278,669	$ 370
Community Cost**	$ 72,387,088	$ 3,233

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

Capital Cost	$ 4,268,642
Annual O&M	$ 172,497

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

Medium	Annual yields may vary from year to year.

Comments:

Literature Review/Case Studies:

References:

1. Waller Creek Case Study
2. Brentwood Case Study
3. http://www.twdb.texas.gov/publications/brochures/conservation/doc/RainwaterHarvestingManual_3rdedition.pdf
4. https://austintexas.gov/faq/rainwater-harvesting
5. Using Graywater and Stormwater to Enhance Supplies: An Assessment of Risks, Costs and Benefits (National Academy of Sciences)

Supply Option Name:

Distributed Waste Water Reuse

DRAFT RESULTS 8/1/17

Short Description:

Community scale distributed waste water reuse

Details:

Distributed Wastewater Reuse is defined for the purpose of this project as the collection of wastewater from the sewerage system in new development areas, treatment to Type 1 quality, and reuse at the local/community scale. These facilities would be completely separate from the centralized wastewater collection system. Facilities may be located at the site of existing local WWTP, or at new potential sites.

Reuse via a dual (purple) pipe system will supply irrigation, landscaping, toilet, laundry (clothes washing), and cooling demands. Treatment plants are sized to meet demand and peak wet weather flow.

Reuse from this option is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 50

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand

o Variable per DTI (estimated from demand model)

o Monthly outdoor demand profile generated using historical gross lake evaporation data (quadrangle 811) and precipitation data in a standard irrigation model to account for monthly and year to year variation in outdoor demand based on climate.

Yield

o Yield calculated from a water balance calculation (with both wastewater generation and end use demands calculated from disaggregating total future DTI demand by customer class to the land use area within the project area).

Year

Analysis completed at ultimate timeslice of 2115.

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Annual Cumulative Volume (AF/Year)	31,391
Annual Average System Volume (Gal/Year)	1,461,260,173

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs may be borne by the customer/developer or the Utility. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for each project opportunity using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number of houses, buildings, area serviced, transfer distance, etc.)

o Cost elements include:

- Treatment (sized for wet weather flows)
- Balancing storage
- Transfer pump station and pipeline
- Distribution pipelines (e.g. throughout streets)
- Reticulation (e.g. on-lot & within building)

Engineering, Legal Costs and Contingencies

o 35% cost of facilities

Mitigation and Permitting

o 5% cost of facilities

Annual O&M – Labor & Material

o Estimated as proportion of capital costs (Civil 1%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping energy calculated based on estimated design flow, hours operation, and pump duty power, for a project opportunity

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital costs and O&M in other categories)

o GHD Energy Curve for MBR Treatment Plants (kWh per ML/d capacity)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ 353,739,609	$ 123,808,863	$ 17,686,980	$ -	$ 471,237,855	$ 966,473,308
Customer Cost	$ 335,795,957	$ 117,528,585	$ -	$ -	$ -	$ 453,324,542
Community Cost**	$ 689,535,567	$ 241,337,448	$ 17,686,980	$ -	$ 471,237,855	$ 1,419,797,850

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 19,329,466	$ 16,867,063	$ 309,147	$ 3,292,390	$ -	$ -
Customer Cost	$ 9,066,491	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 28,395,957	$ 16,867,063	$ 309,147	$ 3,292,390	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 39,798,067	$ 1,268
Customer Cost	$ 9,066,491	$ 289
Community Cost**	$ 48,864,558	$ 1,557

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

Capital Cost	$ 50,534,230
Annual O&M	$ 2,924,086

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	This option is not significantly impacted by hydrologic or climatic variability.

Comments:

Literature Review/Case Studies:

References:

When does building an MBR make sense? How variations of local construction and operating cost parameters impact overall project economics (Thor Young*, Sebastian Smoot*, Jeff Peeters**, Pierre Côté)
Emory Water Hub Case Study
Highland Mall Case Study

Austin WATER | WATER FORWARD INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Waste Water Scalping (Sewer Mining)

DRAFT RESULTS 8/1/17

Short Description:

Community Scale Waste Water Scalping and Reuse

Details:

Local Wastewater Scalping (or 'Sewer Mining') is defined for the purpose of this project as involving the extraction of wastewater from the existing centralized wastewater collection system, treatment to Type 1 quality, and reuse at the local/community scale. The treatment plant is situated close to both the demand and to the sewer extraction point, to reduce reticulation and pumping costs. This can be located either within existing open space or within a new development.

Reuse via a dual (purple) pipe system will supply irrigation, landscaping, toilet and potentially also laundry (clothes washing) and cooling demands. Treatment plant wastes (sludge) from the treatment process are discharged to the centralized wastewater collection system for subsequent treatment at the downstream WWTPs.

Reuse from this option is not considered for outdoor end uses in Critical Water Quality Zones, floodplains, or the Edwards Aquifer Recharge Zone. All scenarios assume back-up supply from the centralized water distribution system.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

1. Outdoor: COA - IRR
2. Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Characterization Year: 2115

Intended use of supply: Variable

Supply Type: Decentralized

Timing of Implementation: NA

Lifespan (years): 50

DEMAND MET BY OPTION ANALYSIS

Assumptions:

Demand

o Variable per DTI (estimated from demand model)

o Monthly outdoor demand profile generated using historical gross lake evaporation data (quadrangle 811) and precipitation data in a standard irrigation model to account for monthly and year to year variation in outdoor demand based on climate.

Yield

o Upstream contributing areas of proposed sewer mining opportunities calculated from spatial analysis that identifies the existing sewer network from any given point.

o Possible extraction locations identified as manholes on sewers with minimum diameter of 16 inches and maximum depth of 50 feet.

o Maximum wastewater availability was set at 50% of average dry weather flow, allowing a minimum base flow to be retained in the sewer, so as not to block or negatively impact infrastructure.

o Yield calculated from a water balance calculation (with demand calculated from disaggregating total future DTI demand by customer class to the land use area within the project area).

Year

Analysis completed at ultimate timeslice of 2115.

Average Weather Demand Met By Option in 2115 Summary (Acre Feet):

Note: Drought yields to be determined. Results reported from the 75th percentile of project opportunities/systems identified in the analysis. Yields are subject to change dependent on implementation approach and portfolio context. Annual cumulative volume represents the total volume produced from all systems identified within the 75th percentile. Annual average system volume represents the average yield from each project opportunity/system.

SCENARIO 1 - Outdoor: COA - IRR

Annual Cumulative Volume (AF/Year)	801
Annual Average System Volume (Gal/Year)	16,318,864

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Annual Cumulative Volume (AF/Year)	16,440
Annual Average System Volume (Gal/Year)	66,960,556

COST ANALYSIS

Assumptions:

NB: Capital and Annual O&M costs may be borne by the customer/developer or the Utility. The below costs are total community costs.

Capital Cost – Facilities

o Cost elements calculated for each project opportunity using unit costs and cost curves from GHD's cost databases, and using water balance outputs (demand and supply volumes) and GIS outputs (e.g. number of houses, buildings, area serviced, transfer distance between sewer and demand center, etc.)

o Cost elements include:

- o Extraction (maintenance shaft, connection to sewer, pump, rising main)
- o Treatment (note not required to handle wet weather flows)
- o Balancing storage
- o Transfer pump station and pipeline
- o Distribution pipelines (e.g. throughout streets)
- o Reticulation (e.g. on-lot & within building)

Engineering, Legal Costs and Contingencies

o o 35% cost of facilities

Mitigation and Permitting

o 5% cost of facilities

Annual O&M – Labor & Material

o Estimated as proportion of capital costs (Civil 1%, Pumps 5%, Treatment 5%)

Annual O&M – Energy

o Pumping energy calculated based on estimated design flow, hours operation, and pump duty power, for a project opportunity

o Electricity cost 0.09 $USD/kWh

Annual O&M - Advanced/Decentralized Treatment

o Represents the treatment energy cost (treatment capital cost and O&M in other categories)

o GHD Energy Curve for MBR Treatment Plants (kWh per ML/d capacity)

Annual O&M - Conventional W/WW Treatment

o Not applicable

Annual Purchase/Import Cost

o Not applicable

SCENARIO 1 - Outdoor: COA - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ 51,729,827	$ 18,105,439	$ 2,586,491	$ -	$ 68,912,420	$ 141,334,177
Customer Cost	$ -	$ -	$ -	$ -	$ -	$ -
Community Cost	$ 51,729,827	$ 18,105,439	$ 2,586,491	$ -	$ 68,912,420	$ 141,334,177

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 2,826,684	$ 2,214,940	$ 6,226	$ 116,024	$ -	$ -
Customer Cost	$ -	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 2,826,684	$ 2,214,940	$ 6,226	$ 116,024	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 5,163,874	$ 6,444
Customer Cost	$ -	$ -
Community Cost**	$ 5,163,874	$ 6,444

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

Capital Cost	$ 3,233,114
Annual O&M	$ 146,074

SCENARIO 2 - Outdoor + Indoor Non Potable: SFR, MFR, COM - IRR, TL , CW, HVC and COA - IRR

Capital Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront/ Interest/Land Cost
Utility Cost	$ 437,849,002	$ 153,247,151	$ 21,892,450	$ -	$ 583,285,046	$ 1,196,273,649
Customer Cost	$ 138,702,039	$ 48,545,714	$ -	$ -	$ -	$ 187,247,753
Community Cost	$ 576,551,042	$ 201,792,865	$ 21,892,450	$ -	$ 583,285,046	$ 1,383,521,403

Annual Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Annual Capital/Upfront/Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$ 23,925,473	$ 19,832,782	$ 101,113	$ 2,210,978	$ -	$ -
Customer Cost	$ 3,744,955	$ -	$ -	$ -	$ -	$ -
Community Cost**	$ 27,670,428	$ 19,832,782	$ 101,113	$ 2,210,978	$ -	$ -

Unit Cost Summary (current dollars):

Note: Represents cumulative costs for all project opportunities/systems identified within the 75th percentile

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	$ 46,070,347	$ 2,802
Customer Cost	$ 3,744,955	$ 228
Community Cost**	$ 49,815,302	$ 3,030

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

**Community Cost = Utility Cost + Customer Cost

Per System Cost Summary (current dollars):

Note: Represents average per project opportunity/system cost

Capital Cost	$ 5,473,113
Annual O&M	$ 276,811

ADDITIONAL INFORMATION

Climate Resiliency Indicator:

High	This option is not significantly impacted by hydrologic or climatic variability.

Comments:

Literature Review/Case Studies:

References:

1. Emory Water Hub Case Study
2. Highland Mall Case Study

Austin WATER | WATER FORWARD
INTEGRATED WATER RESOURCE PLAN

Supply Option Name:

Imported Option Category - Conventional Groundwater

DRAFT RESULTS 11/19/2017

Short Description:

Conventional Groundwater

Details:

Conventional groundwater sourced from the Carrizo-Wilcox east of Austin. Austin Water acquires water rights, and develops all source water, treatment, and disposal infrastructure.

Applicable Customer Sectors, End Uses, and Development Types (new, existing, or both):

All End Uses and Development Types

Characterization Year: 2115

Intended use of supply: Constant

Supply Type: Groundwater

Timing of Implementation: NA

Lifespan (years): 30

YIELD ANALYSIS

Assumptions:

o Estimated based on typical Carrizo-Wilcox well development program

Average Weather Yield Summary (Acre Feet):

Annual Yield (AF/Year)
20,000

COST ANALYSIS

Assumptions:

Capital Cost – Facilities
o Wells are 1,500 gpm
o Pipeline length of 66 miles, 75% rural, 25% urban
o Pipeline sized for constant average delivery
Engineering, Legal Costs and Contingencies
o 35% cost of facilities
Mitigation and Permitting
o 5% cost of facilities
Land Aquisition
o Land aquifision for water rights purchase based on 2 AF/acre and $10k/acre
Annual O&M – Labor & Material
o 1% cost of facilities
Annual O&M – Energy
o Estimated based on pipeline length and pumping level
o Electricity cost 0.09 $USD/kWh
Water Treatment
o Estimated based on treatment level (disinfection) from Unified Costing Model
o Electricity cost 0.09 $USD/kWh
Annual Purchase/Import Cost
o Not applicable

Capital Cost Summary (current dollars):

	Capital Cost - Facilities	Engineering, Legal Costs & Contingencies	Mitigation & Permitting	Land Acquisition	Interest	Total Capital/Upfront / Interest/Land Cost
Utility Cost	$107,346,120	$37,571,142	$15,000,000	$100,000,000	$247,322,464	$507,239,726
Customer Cost	$ -	$ -	$ -	$ -	$ -	$ -
Community Cost	$ -	$ -	$ -	$ -	$ -	$ -

Annual Cost Summary (current dollars):

	Annual Capital/Upfront /Interest/Land Cost ($/yr)	Annual O&M - Labor & Material ($/yr)	Annual O&M - Energy ($/yr)	Annual Advanced/ Decentralized Treatment O&M ($/yr)	Annual Conventional W/WW Treatment O&M ($/yr)	Annual Purchase/Import ($/yr)
Utility Cost	$16,907,991	$1,000,000	$3,300,000	$0	$1,172,412	$0
Customer Cost	$ -	$ -	$ -	$ -	$ -	$ -
Community Cost	$ -	$ -	$ -	$ -	$ -	$ -

Unit Cost Summary (current dollars):

	Total Annual Cost ($/yr)	Annual Unit Cost* ($/AF/yr)
Utility Cost	22,380,403	$1,119
Customer Cost	$ -	$ -
Community Cost	$ -	$ -

*Unit Cost = Total Annual Cost ÷ Annual Average Yield

ADDITIONAL INFORMATION

Climate Resiliency Score:

Medium	Sensitivity to variations in climate and hydrology would vary depending on source aquifer and utilization rates

Comments:

Literature Review/Case Studies:

San Antonio Water System

References:

San Antonio Water System

APPENDIX K: WATER FORWARD DECENTRALIZED OPTIONS MODELING

K.1 Introduction

Subconsultant GHD performed a geospatial analysis to characterize decentralized supply and demand management options for input to the IWRP portfolios. Options considered included lot/building scale wastewater reuse, lot scale graywater reuse, lot scale stormwater harvesting, lot scale rainwater harvesting, community scale distributed wastewater reuse, community scale sewer mining, community scale stormwater harvesting, and community scale rainwater harvesting. The analysis considered potential opportunities across the entire city to use these alternative source waters to meet non-potable outdoor and indoor demands for a range of sectors.

Due to the decentralized nature of the options, a geo-spatial approach was used to explore at a strategic level where in Austin Water's projected future service it would be more or less suitable to implement each of the decentralized options. This resulted in the development of spatially variable yields and costs for each of the decentralized options (using Delphi Trend and Imagine Austin (DTI) polygons as the reporting scale) across the study area. While this work provides a more disaggregated spatial resolution understanding of the opportunity for decentralized options, it is important to understand that this work is based on a high-level assessment and further detailed analysis for specific suitability in any given location is recommended.

K.2 Methodology

K.2.1 Analysis Approach

The geospatial analysis explored the potential opportunities for decentralized options to meet non-potable demands for Austin in the future. It is important to note that by their very nature decentralized opportunities are spatially variable, with local conditions impacting the viability of options and the scale of potential options. For this reason, spatial analysis was the primary approach used to identify opportunities.

The approach can be summarized in **Figure K-1**, where future demand is matched with potential future supply from decentralized alternative water sources, with their particular characteristics and constraints to identify an Opportunity. Each Opportunity is then analyzed to develop a series of performance measures, such as yield and cost. Many potential opportunities were identified across the City and a subset of opportunities for each option was selected to achieve the desired volumetric total to meet demands and then summarized at the DTI level for inclusion in the portfolios.

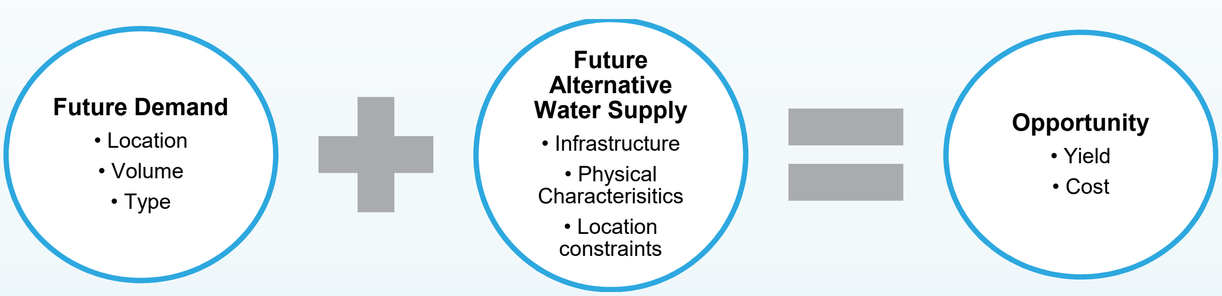

Figure K-1. Geospatial analysis method summary

Table K-1 below outlines the options that were considered in the analysis, including the sub-options or scenarios evaluated. More details regarding assumptions used to develop cost and yield estimates for each option and sub-option evaluated is available in **Appendix J**.

Table K-1. Options considered in Water Forward geospatial decentralized analysis

#	Option	Sub-option /Scenario	SFR	MFR	COM	COA	End Uses
D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR
		Outdoor			Y		IRR
		Dual pipe		Y			IRR TL CW
		Dual pipe			Y		IRR TL CW HVC
D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR
		Outdoor		Y			IRR
		Outdoor			Y		IRR
		Dual pipe	Y				IRR TL CW
		Dual pipe		Y			IRR TL
		Dual pipe			Y		IRR TL HVC
		Potable	Y				ALL
D10	Gray Water Harvesting	Outdoor	Y				IRR
		Outdoor		Y			IRR
		Outdoor			Y		IRR
		Dual pipe	Y				IRR TL CW
		Dual pipe		Y			IRR TL CW
		Dual pipe			Y		IRR TL
D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW
		Dual pipe			Y		IRR TL CW HVC
S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC
S10	Sewer Mining	Outdoor				Y	IRR
		Dual pipe	Y	Y	Y	Y	IRR TL CW HVC
S11	Community Stormwater	Outdoor				Y	IRR
		Outdoor	Y	Y	Y	Y	IRR
		Dual pipe	Y	Y	Y	Y	IRR TL CW HVC
S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC

K.2.2 Key Information

This section describes some of the key information and assumptions used in this analysis. With the key concepts described in the previous section, these are the foundation of the analysis.

K.2.2.1 Delphi Trend and Imagine Austin (DTI) polygons

The Delphi Trend and Imagine Austin (DTI) polygons are the geographic unit of analysis and reporting for this work as well as the Disaggregated Demand Model (described below). The data include long-range, small-polygon-based population and employment forecasts produced by the City Demographer in conjunction with Austin Water. Contains estimates of water service population, single family and multifamily units, and employment for 2010, as well as projections for 2020, 2040, 2070, and 2115.

K.2.2.2 Future Demand Estimates

Future demand estimates were derived from the Disaggregated Demand Model (DDM) developed by Austin Water. The DDM makes use of historical billing, historical land use, and historical and projected demographic data to project potential water use broken down by sector and end use for each IWRP planning horizon (2020, 2040, 2070, 2115) (see **Appendix C** for more information about the DDM). Future water demands at the DTI polygon level were allocated spatially at a more refined level using some high-level assumptions about growth/change in development patterns over time.

K.2.2.3 Residential and Commercial Building Characteristics

Assumptions regarding building characteristics were required to generate option yield estimates. This includes roof areas and/or density (units or employees per building). Current roof areas and building numbers were estimated based on current building footprint GIS data. Future roof areas were estimated by taking into account demographic changes (increase in units/employees) and growth/change in development patterns over time. Key assumptions are listed below:

- Single family residential - Average roof varies per DTI, between approx. 1500-3700 ft2 per house
- Multi-family residential - Nominal building = 5,000 ft (noting that the density, in terms of units/building, varies by DTI)
- Commercial - Nominal building = 10,000 ft (noting that the density, in terms of employees/building, varies by DTI)

K.2.2.4 Historical Weather Data

The following historical climate data was used in the analysis to generate yield estimates for the rainwater and stormwater options.

- Precipitation - Daily rainfall (1938 – 2016) (Station: AUSTIN CAMP MABRY TX US)
- Evaporation - Monthly gross lake evaporation data (Quadrangle 811).

K.2.2.5 Environmental Constraints

The unique environment of Austin means that there are areas where it is prohibited to apply recycled water and graywater for outdoor uses and this was reflected in the analysis. These areas include the Edwards Aquifer Recharge Zone and the Contributing Zone (catchment) of Barton Creek, and are north-west, west and south west of the central business district of Austin.

K.3 Results and Use in Portfolio Building

The decentralized options analysis outputs are yield and cost results for each option and sub-option at the DTI scale. This means, there can be a high degree of complexity in how portfolios (combinations of options) can be selected/defined. To enable additional functionality in selecting portfolios, GHD developed a decentralized portfolio tool that allowed the user to quickly set a level of implementation for each decentralized alternative water source water scenario. Each strategy at its specified level of implementation was added together, summing up to a total volume of alternative water available to meet non-potable demands across the City. Alternative water supplies were constrained to the volume of non-potable demand available to be met.

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APPENDIX L: PORTFOLIO SCORING DETAILS

As described in the main report, options were combined into groupings known as portfolios, which were scored according to the objectives and sub-objectives identified through the Water Forward process (see **Section 3.5** of the main plan report). The composition of options for each portfolio is included in **Section L.7** of this appendix. The full Water Forward plan objectives and subobjectives weighting can be found in **Table L-24** at the end of the report. The ability of each portfolio to meet each sub-objective was determined by a set of metrics, which were used to measure portfolio performance. These performance metrics fall into three broad measurement categories as follows:

1. **Quantitative Metrics** – These are measured on a continuous scale, and are based on modeling results (e.g., water availability model simulations or demand forecasting model output) or engineering cost estimates using standard practice.

2. **Purely Qualitative Metrics** – These are scored from one to five (with five being the best score), based on professional judgement and insights. The scores are first assessed at an individual demand-management or supply option level, then rolled up to create a full portfolio estimate using the average of option scores weighted by option yields. To increase differentiation between portfolios to better evaluate performance, the spread of portfolio scores was designed to span from one to five, with the other scores scaled to fall in between.

3. **Qualitative Informed by Quantitative Metrics** – These metrics were determined in one of two ways: 1) qualitative professional judgement informed by quantitative model output or engineering cost estimates, or 2) the metric was created from a mathematical index based on quantitative option-level water yield estimates multiplied by a qualitative score. These metrics were then converted to a one to five scale in the same manner as the purely qualitative metrics.

Once the metrics were developed, they were inputted to a tool known as Criterium Decision Plus (CDP). CDP is a software tool that converts metrics like those described, which each have different measurement units, into standardized scores so that the performance measures can be summarized into an overall value based on the sub-objective and objective weights. Those overall values can then be compared to evaluate overall relative performance; in the case of Water Forward, the overall portfolio scores were used to compare the relative performance of portfolios in meeting the plan objectives. This appendix provides details on how the scoring metrics were derived, summarizes the assumptions used for the calculations, shows the various performance metrics that were input to CDP, and shows the CDP output for each sub-objective.

L.2 Water Supply Benefits

Water supply benefits were evaluated using two metrics: reliability and vulnerability. The reliability metric was intended to show how often modeling indicated the City would not have enough water to meet all its identified needs, while the vulnerability metric was intended to show the magnitude of shortages, if they were projected to occur. The vulnerability and reliability metrics were inputted into CDP, which generated the standardized water supply benefits scores illustrated in **Figure L-1**. More detail on how each element of the total Water Supply Benefits score was calculated is presented in the rest of this section.

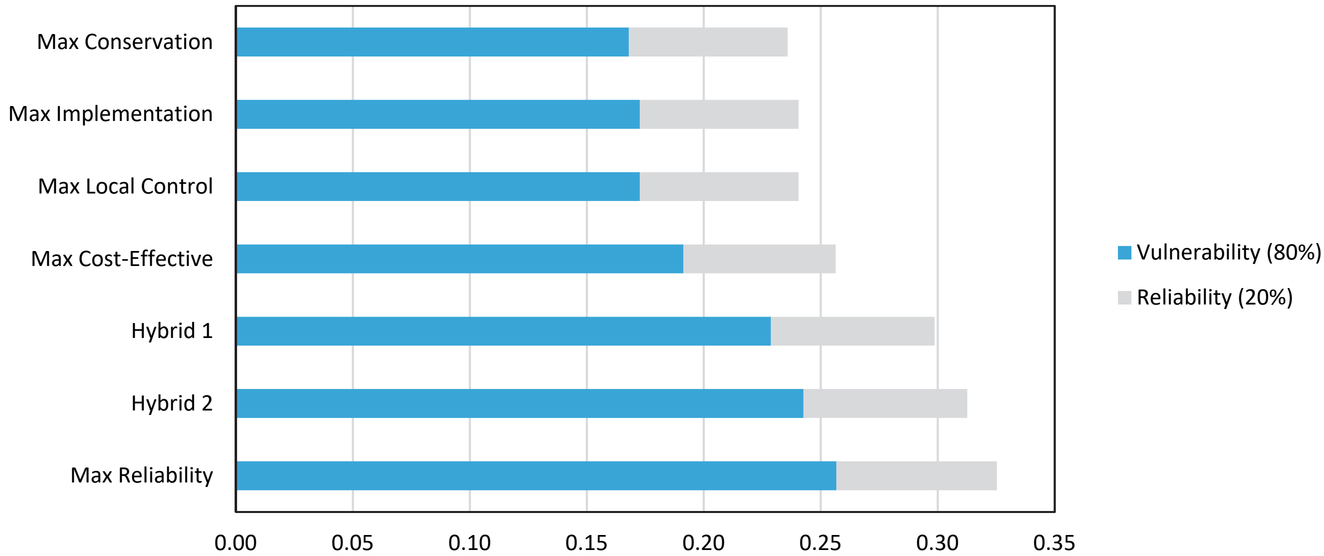

Figure L-1. Water supply benefits standardized score output from CDP

Performance metrics under the water supply benefits objective were tied to three types of City of Austin needs for water that were specific to the Water Forward planning context (the City's identified needs are described in more detail in **Appendix F**). Identified needs were calculated using output from Austin Water's Water Forward Water Availability Model (WAM). The Water Forward Water Availability Model is a computer modeling system for simulating surface water availability (see **Appendix E** for more detail). Modeling showed that regional shortages over and above City of Austin's identified needs may also be present in certain projected time horizons and hydrology scenarios. The City's identified needs do not include those potential regional shortages. For example, Hybrid 1 met all the City's identified needs and showed no additional regional shortages when modeled in the Scenario A historical period of record hydrology. Using the Scenario B period of record climate change-adjusted hydrology, however, the portfolio met all the City's identified needs while the region experienced some shortages. Austin Water plans to continue to work with our partners in the Colorado River Basin to help address these regional needs in a collaborative way to improve basin-wide reliability in the future.

For each portfolio, the model was run under hydrologic scenarios B and D (the period of record and extended period, both with climate change) for the three planning horizons: 2040, 2070, and 2115. The vulnerability metric was calculated based on the geometric mean of how much of the City's identified water needs are met during the worst 12 months of drought during Scenario B and the worst 12 months of drought in candidate droughts in Scenario D. The reliability metric was calculated as the geometric mean of the percent of months without shortage relative to identified needs during the period of simulation[1]. The results of these calculations are shown in **Table L-1**.

[1] Reliability for the extended simulation excludes months falling within periods of drought that exceed the risk of occurrence of the candidate droughts.

Table L-1 Water supply benefits scoring

Portfolio	Percent of an Identified Need Met During Worst 12-Months of Candidate Drought		Percent of all Months without an Identified Need Shortage		Geometric Mean: Vulnerability	Geometric Mean: Reliability
	Scenario B	Scenario D	Scenario B	Scenario D		
Max Conservation						
2040	96%	87%	99%	99%	76%	97%
2070	96%	62%	99%	99%		
2115	67%	57%	92%	94%		
Max Cost-Effective						
2040	100%	92%	100%	100%	81%	93%
2070	95%	70%	98%	99%		
2115	72%	64%	83%	83%		
Max Reliability						
2040	96%	90%	99%	100%	95%	98%
2070	96%	94%	98%	98%		
2115	98%	98%	96%	97%		
Max Implementation						
2040	95%	82%	99%	99%	77%	97%
2070	93%	63%	98%	99%		
2115	70%	62%	91%	93%		
Max Local Control						
2040	95%	85%	99%	99%	77%	97%
2070	95%	64%	98%	99%		
2115	69%	61%	92%	94%		
Hybrid 1						
2040	100%	91%	100%	100%	89%	100%
2070	100%	73%	100%	99%		
2115	100%	74%	100%	99%		
Hybrid 2						
2040	100%	97%	100%	100%	92%	100%
2070	100%	73%	100%	99%		
2115	100%	86%	100%	99%		

Scoring Method: Quantitative

Note: These vulnerability and reliability results are focused solely on the City's identified water needs (called Type 1, 2, and 3 water needs and described in more detail in **Appendix F**) being met. They do not reflect a basin-wide water supply vulnerability or reliability metric, only as defined by identified needs.

L.3 Economic Benefit Scores

The economic benefit objective was measured based on how well each portfolio met the two economic benefits sub-objectives: maximize cost-effectiveness and maximize advantageous external funding. The maximize cost-effectiveness sub-objective score was determined based on the life cycle unit cost of each portfolio, while the maximize advantageous external funding sub-objective was determined based on the potential for projects owned and operated by AW to receive outside funding and the potential for developer contribution to the cost of implementing a portfolio strategy. Detail on how each of the sub-objective scores were calculated is presented in the following sub-sections. After developing the final cost-effectiveness and advantageous external funding sub-objective score, those values were inputted to CDP, which standardized and weighted the metrics according to the sub-objective weightings developed through the Water Forward process, and produced the final economic benefits score shown in **Figure L-2**.

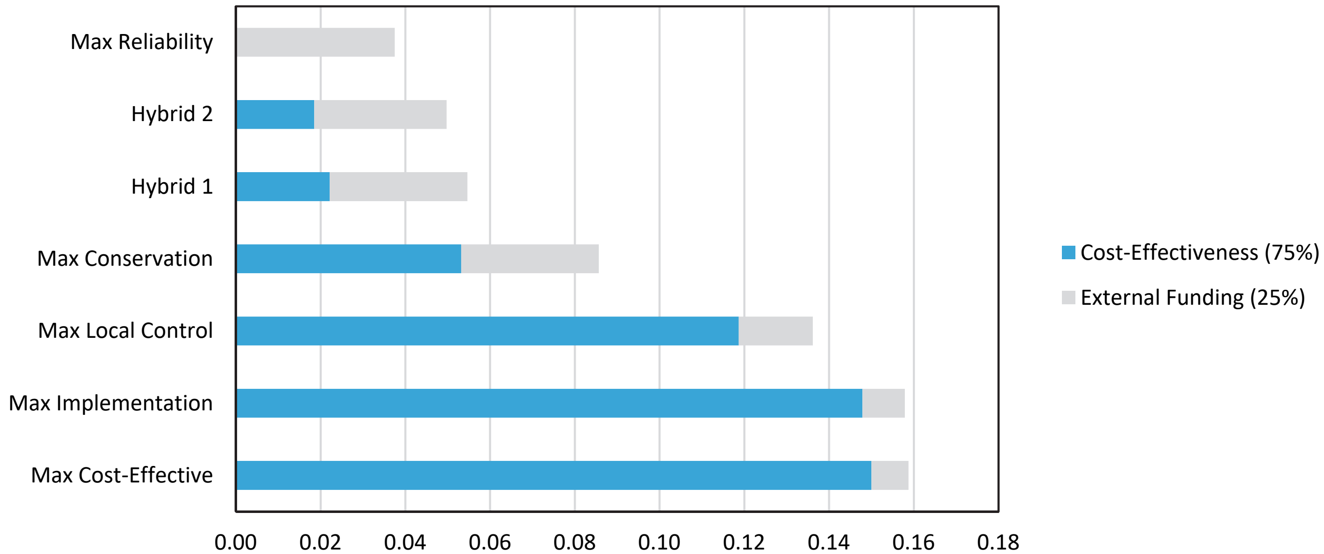

Figure L-2. Economic benefits standardized score output from CDP

L.3.1 Maximize Cost-Effectiveness

A standard method used by many water and power agencies across the country for assessing cost-effectiveness of projects is levelized unit cost (LUC). Central to the LUC method for water projects is an accounting of both fixed costs (such as construction) and variable costs (such as operations and maintenance) through the planning period, and a reflection of the actual supply need for new water rather than supply capacity. As opposed to the more commonly used capacity unit cost (CUC) method where annualized costs (both fixed and variable) are divided by supply capacity, the LUC method divides annualized costs by water supply need. Thus, the LUC method is more representative because it treats larger projects with greater economies of scale (which typically have a lower CUC) and smaller decentralized projects (which often have a larger CUC but can be developed incrementally over time) more accurately. For example, for a larger project that has a lower CUC but provides unused excess supply capacity, the LUC will be greater than the CUC and better reflect actual project use, because the denominator for estimating unit cost is based on supply need not supply capacity.

For the Water Forward evaluation process, a simplified LUC method was used based on the following steps:

1) For options that are assumed to be available and used on a near-constant basis, regardless of hydrological condition (i.e., all demand management options, centralized non-potable reuse, decentralized wastewater reuse, decentralized sewer mining, and community-scale stormwater and rainwater harvesting), the total unit cost was used as a basis to quantify cost-effectiveness. The option's total unit cost represents the annualized capital cost plus the annual operations and maintenance (O&M) cost, estimated using standard engineering methods and including financing costs. For each option, the unit cost was multiplied by the annual yield for each option, then those total costs were totaled for each planning horizon (2040, 2070, and 2115). Because escalating and discounting costs over 100 years is highly speculative, unit costs were not escalated or discounted,

and thus can be interpreted as current year dollars. The total unit cost for each constant-operation option is shown in **Table L-2** in the non-shaded rows.

2) For options that were assumed to be providing supply on an as-needed basis, particularly during drought periods (i.e., all storage options, indirect and direct potable reuse, brackish groundwater, imported seawater desalination, and imported groundwater), the modeled average annual water yield of the options from the WAM using Scenario B hydrology were multiplied by the annual O&M cost, while the maximum potential annual water supply yield for each option was multiplied by the annualized capital cost (with financing). These costs were then totaled for each planning horizon (2020, 2040, 2070, and 2115). The capital unit costs and O&M unit costs for these options are shown in grey in **Table L-2**.

3) Finally, the costs for each planning horizon (2020, 2040, 2070, and 2115) from steps (1) and (2) were totaled to get a total representative cost. This total representative cost should not be interpreted as a total aggregate cost for the portfolios for the 100-year planning period, as it only represents four planning horizons for the purpose of estimating the simplified LUC. The total representative water supply needs for the same four periods (2020, 2040, 2070, and 2115) were estimated based on the Water Forward Water Availability Model using hydrologic scenario B (period of record hydrology with climate change). As with costs, this total representative supply need should not be interpreted as the total aggregate supply need for the entire 100-year planning period, as it was only used for estimating the simplified LUC for portfolio evaluation. The total representative cost was then divided by the total representative supply need to estimate the simplified LUC for each portfolio. The components of this calculation are shown in **Table L-3**.

Table L-2. Total, capital, and O&M unit cost for options (Hybrid 1 decentralized representative costs)

Options	Total Unit Cost ($/AF)	Capital Unit Cost ($/AF)	O&M Unit Cost ($/AF)
Advanced Metering Infrastructure	$2,800		
Water Loss Control Utility Side	$3,690		
CII Ordinances for Cooling Towers and Steam Boilers	$71		
Water Use Benchmarking and Budgeting	$21		
Landscape Transformation Ordinance	$23		
Landscape Transformation Incentives	$96		
Irrigation Efficiency Incentives	$202		
Stormwater Harvesting (Lot-Scale)	$6,470		
Rainwater Harvesting (Lot-Scale)	$2,864		
Graywater Harvesting (Lot-Scale)	$9,797		
Building Scale Wastewater Reuse (Lot-Scale)	$11,726		
AC Condensate Reuse (Lot-Scale)	$2,702		
Aquifer Storage and Recovery		$1,174	$318
Brackish Groundwater Desalination		$1,883	$807
Direct Non-Potable Reuse (Centralized Reuse – Purple Pipe)	$1,229		

Options	Total Unit Cost ($/AF)	Capital Unit Cost ($/AF)	O&M Unit Cost ($/AF)
Direct Potable Reuse		$1,455	$749
Indirect Potable Reuse with Capture Lady Bird Lake Inflows		$284	$321
Additional Supply from LCRA		$73[2]	$353
Off-Channel Reservoir w/ Lake Evaporation Suppression		$499	$347
Imported Option Category - Seawater Desalination		$1,555	$1,477
Imported Option Category - Conventional Groundwater		$845	$274
Community-Scale Distributed Wastewater Reuse	$1,295		
Community-Scale Wastewater Scalping (Sewer Mining)	$2,906		
Community-Scale Stormwater Harvesting	$4,261		
Community-Scale Rainwater Harvesting	$11,666		

Scoring Method: Quantitative

Note: Options with no table background shading are assumed to be available on a near-constant basis and use the total unit cost. Options in gray shading are used when needed or available and use capital unit cost for potential yield but only O&M cost for average modeled need. Some option costs may vary from costs presented in Appendix J due to further refinement during portfolio evaluation.

Table L-3. Simplified life-cycle unit cost calculation by portfolio

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Representative Cost Using Years 2020, 2040, 2070, and 2115 ($M)	$587	$738	$596	$1,346	$1,040	$1,190	$1,207
Representative Supply Need Using Years 2020, 2040, 2070, and 2115 (AF)	388,143	385,756	387,003	392,097	377,625	377,625	377,625
Simplified Levelized Unit Cost ($/AFY)	$1,513	$1,914	$1,540	$3,434	$2,753	$3,150	$3,197

Scoring Method: Quantitative

L.3.2 Maximize Advantageous External Funding

The score for maximizing advantageous funding considers two metrics: (1) the potential that a project owned and operated by Austin Water could receive outside funding (e.g. loans, grants, or other), and (2) the potential for project costs to be borne by customers/developers rather than the utility. For the outside funding component (1), each option was scored on a scale of one to five with a score of one indicating a low potential for a project to be owned and operated by Austin Water or low potential for project that would be owned and operated by Austin Water to receive outside funding, and a score of five indicating a high potential for the same situations. The score for each option is provided in **Table L-4**. Each portfolio's score for (1) was then the average of the costs weighted by the 2115 yield of each option, with results shown in **Table L-5.**

[2] For this option, this fixed cost corresponds to a reservation fee for the water

Table L-4. Qualitative scores for potential that a project owned and operated by Austin Water could receive outside funding (e.g. loans, grants, or other)

Project Options	Score	Note
Demand Side Options		
Advanced Metering Infrastructure	5	Owned by AW. Approved for SWIFT funding (low interest loans) by TWDB
Water Loss Control Utility Side	4	Owned by AW. Potential for SWIFT funding (low interest loans) from TWDB
CII Ordinances for Cooling Towers and Steam Boilers	2	Likely not owned by AW. Cost borne by customer/developer
Water Use Benchmarking and Budgeting	2	Likely not owned by AW. Cost largely borne by customer/developer (would require city staff program implementation costs)
Landscape Transformation Ordinance	2	Likely not owned by AW. Cost largely borne by customer/developer (would require city staff program implementation costs)
Landscape Transformation Incentives	1	Cost for incentive borne by AW, less likely to receive outside funding.
Irrigation Efficiency Incentives	1	Cost for incentive borne by AW, less likely to receive outside funding.
Stormwater Harvesting (Lot-Scale)	2	Likely not owned by AW. Cost potentially borne largely by customer/developer (may require city staff program implementation costs)
Rainwater Harvesting (Lot-Scale)	2	
Graywater Harvesting (Lot-Scale)	2	
Building Scale Wastewater Reuse	2	
AC Condensate Reuse (Lot-Scale)	2	
Supply Side Options		
Aquifer Storage and Recovery	3	Owned by AW and most likely AW funded. Higher potential for outside funding, for example SWIFT funding (low interest loans) from TWDB
Brackish Groundwater Desalination	1	Owned by AW and most likely AW funded. Potential for SWIFT funding (low interest loans) from TWDB.
Direct Non-Potable Reuse	5	Owned by AW. Approved for SWIFT funding (low interest loans) by TWDB for some existing projects, potential for SWIFT funding for additional components
Direct Potable Reuse	1	Owned by AW and most likely AW funded. Potential for SWIFT funding (low interest loans) from TWDB.
Indirect Potable Reuse with Capture Lady Bird Lake Inflows	1	Owned by AW and most likely AW funded. Potential for SWIFT funding (low interest loans) from TWDB.
Additional Supply from LCRA	1	Contracted by AW and most likely AW funded.
Off-Channel Reservoir w/ Lake Evaporation Suppression	1	Owned by AW and most likely AW funded. Potential for SWIFT funding (low interest loans) from TWDB.
Seawater Desalination	1	Owned by AW and most likely AW funded. Potential for SWIFT funding (low interest loans) from TWDB.
Distributed Wastewater Reuse	4	Owned by AW and most likely AW funded. Potential for SWIFT funding (low interest loans) from TWDB
Wastewater Scalping (Sewer Mining)	2	Cost potentially borne largely by customer/developer (may require city staff program implementation costs)
Community Stormwater Harvesting	2	
Community Rainwater Harvesting	2	
Conventional Groundwater	1	Owned by AW and most likely AW funded. Some project components may have potential for SWIFT funding (low interest loans) from TWDB.

Note: Future supply option implementation may consider regional partnership approaches.

Table L-5. Score for potential that a project owned and operated by Austin Water could receive outside funding (e.g. loans, grants, or other) metric

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Qualitative Score for Potential that a Project Owned and Operated by Austin Water Could Receive Outside Funding Metric	2.63	3.10	2.84	2.50	2.97	2.89	2.79

Scoring Method: Purely Qualitative

The metric for (2) potential customer/developer contribution was found by summing the unit costs of options that may have a potential for customer/developer contribution. These options were lot-scale stormwater, lot-scale rainwater, lot-scale greywater harvesting, building-scale wastewater reuse, and sewer mining. This calculated cost for each portfolio was then converted to a score of one to five where the portfolio with the highest total potential for developer contribution received a five, the portfolio with the lowest potential for customer/developer contribution received a one, and the other scores fall in between, as shown in **Table L-6.**

Table L-6. Score for cost borne by developer metric

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Total Cost from Options with the Potential for Developer Contribution ($M)	$0 (lowest)	$79	$13	$358 (highest)	$272	$272	$272
Qualitative Score Based on Potential for Developer Contribution (above)	1.00	1.88	1.15	5.00	4.04	4.04	4.04

Scoring Method: Qualitative Informed by Quantitative

The final score for advantageous external funding was then determined as 40% of the score for the potential that a project owned and operated by Austin Water could receive outside funding (e.g. loans) and 60% of the score for the potential for developer contribution. The sub-component and final scoring for this sub-objective is provided in **Table L-7**.

Table L-7. Score for maximize advantageous external funding sub-objective

Scoring Element	% of Sub-Objective Score	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Qualitative Score Based on Potential that Project Owned and Operated by AW Could Receive Outside Funding	40%	2.63	3.10	2.84	2.50	2.97	2.89	2.79
Qualitative Score Based on Potential for Developer Contribution	60%	1.00	1.88	1.15	5.00	4.04	4.04	4.04
Final Maximize Advantageous External Funding Score		**1.65**	**2.37**	**1.82**	**4.00**	**3.61**	**3.58**	**3.54**

L.4 Environmental Benefit Scores

The environmental benefit score was based on portfolio performance for three sub-objectives: minimizing ecosystem impacts, minimizing net energy use and maximizing water use efficiency. The minimize ecosystem impact sub-objective was based on the volume of net diversions in each portfolio and the volume of rainwater/stormwater harvesting in each portfolio. The net energy use sub-objective looked at the annual energy use of each of each portfolio, while the water use efficiency sub-objective looked at the per-capita water use of each portfolio. The scores for each sub-objective were inputted to CDP, which produced the overall standardized environmental benefit scores shown in **Figure L-3**. More detail on how each sub-objective score was calculated is presented in the following sub-sections.

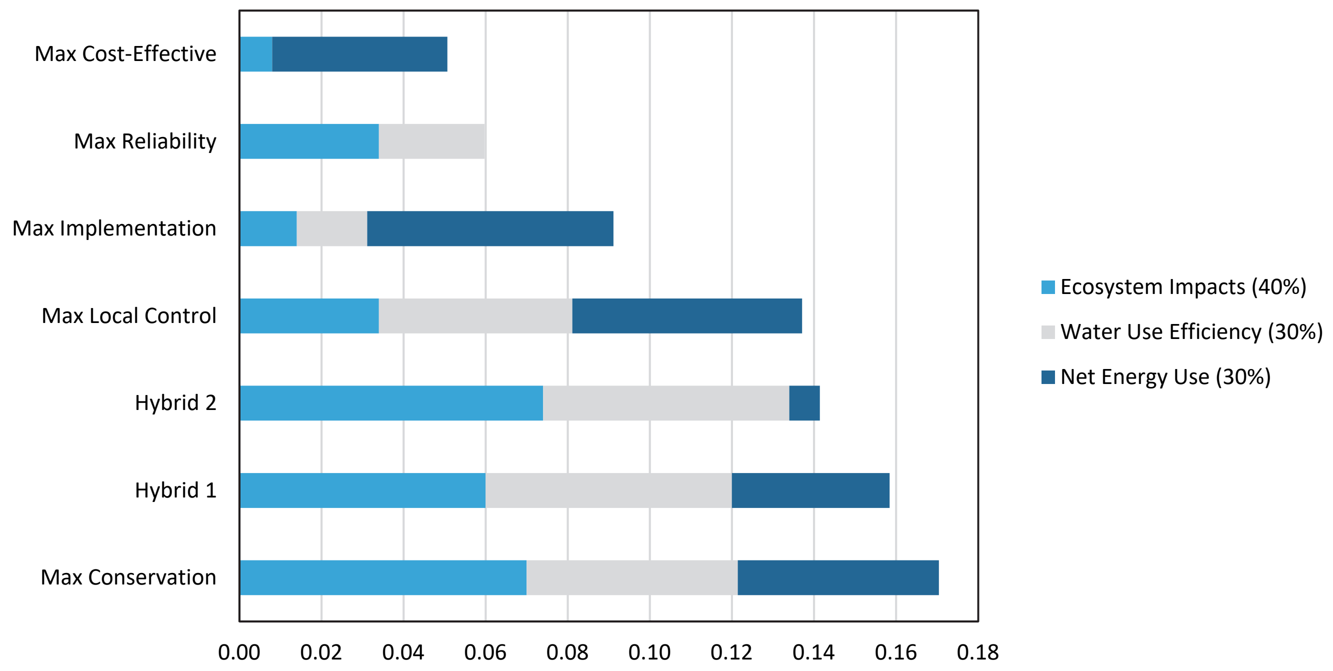

Figure L-3. Environmental benefits standardized score output from CDP

L.4.1 Minimize Ecosystem Impacts

The ecosystem impact score was based on two metrics: net diversions from the Colorado River and the volume of stormwater/rainwater harvesting in each portfolio. The net diversions volume is based on Water Forward WAM output and is equal to the total volume of modeled City of Austin diversion from the river minus the return flow from the City of Austin to the river. Therefore, a higher net diversions score means the portfolio performs more poorly for that subobjective. To score portfolios based on net diversions, an estimated annual volume of net diversions was derived for each portfolio based on the average monthly net diversion amount from WAM modeling using Scenario B for the 2040, 2070, and 2115 planning horizons and Scenario A for the 2020 planning horizon and the geometric mean of all planning horizons was calculated. The portfolio with the greatest net diversions received a score of one, the lowest received a score of five, and the other portfolios were ranked in between. The results of this method are shown in **Table L-8.**

Table L-8. Net diversions volume and score

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Net Diversions (AFY)	65,684	62,843	68,268	57,851	56,962	60,453	56,179
Net Diversion Scaled Score	1.85	2.80	1.00	4.45	4.74	3.59	5.00

Scoring Method: Qualitative Informed by Quantitative

For the stormwater/rainwater capture portion of the minimize ecosystem impacts sub-objective, the volume of stormwater/rainwater capture was calculated as amount of demand offset by the stormwater and rainwater harvesting options in each portfolio. Portfolios were scored along a linear scale with zero stormwater/rainwater capture receiving a score of one and a top bound amount of stormwater/rainwater capture receiving a five (the top bound was set at 14,357 AF, which represented the largest volume of stormwater/rainwater harvesting possible due to end-use demand constraints), as shown in **Table L-9**.

Table L-9. Stormwater and rainwater harvesting volume and score

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Stormwater/Rainwater Harvesting Volume (AFY)	0	5,717	4,887	0	12,029	12,029	12,029
Stormwater/Rainwater Harvesting Volume Converted Score	1.00	2.59	2.36	1.00	4.35	4.35	4.35

Scoring Method: Qualitative Informed by Quantitative

The final minimize ecosystem impacts sub-objective score was then calculated as 50% of the net diversion score and 50% of the stormwater/rainwater harvesting score. The results of the sub-objective scoring are shown in **Table L-10**.

Table L-10. Score for minimize ecosystem impacts

Scoring Element	% Sub-Obj. Score	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Net Diversion Converted Score	50%	1.85	2.80	1.00	4.45	4.74	3.59	5.00
Stormwater/Rainwater Converted Score	50%	1.00	2.59	2.36	1.00	4.35	4.35	4.35
Final Minimize Ecosystem Impacts Score		**1.43**	**2.70**	**1.68**	**2.72**	**4.55**	**3.97**	**4.68**

L.4.2 Minimize Net Energy Use

For the minimize net energy use sub-objective, the incremental change in energy use from baseline use attributed to each portfolio was used as the scoring metric. The incremental change in energy use considers the additional energy required to operate each option as well as energy savings from not having to treat water that would have been used if not for the demand offset provided by the demand management options. **Table L-11** shows the additional energy use or energy savings for each option in kWh/AF. These values were determined using the energy costs developed as part of option characterization. Some of the decentralized options show a range of energy usages, as the energy use is different depending on the scope of the option included in the portfolio. For example, lot-scale rainwater harvesting targeting just outdoor use takes less energy than rainwater harvesting targeting both indoor and outdoor uses.

Table L-11. Additional energy use or savings per options

Project Options	Energy Use (kWh/AF)
Demand Side Options	
Advanced Metering Infrastructure	-649
Water Loss Control Utility Side	-582
CII Ordinance for Cooling Towers and Steam Boilers	-817
Water Use Benchmarking and Budgeting	-747
Landscape Transformation Ordinance	-582
Landscape Transformation Incentives	-580
Irrigation Efficiency Incentives	-574
Stormwater Harvesting (Lot-Scale)	925
Rainwater Harvesting (Lot-Scale)	463 – 1,850
Graywater Harvesting (Lot-Scale)	1,080 – 1,850
Building Scale Wastewater Reuse	1,850
AC Condensate Reuse	-581
Supply Side Options	
Aquifer Storage and Recovery	1,222
Brackish Groundwater Desalination	1,222
Direct Non-Potable Reuse	207
Direct Potable Reuse	250
Indirect Potable Reuse with Capture Lady Bird Lake Inflows	45
Additional Supply from LCRA	0
Off-Channel Reservoir w/ Lake Evaporation Suppression	145
Seawater Desalination	2,976
Distributed Wastewater Reuse	109
Wastewater Scalping (Sewer Mining)	68-77
Community Stormwater Harvesting	121-139
Community Rainwater Harvesting	0
Conventional Groundwater	1,833

A portfolio's net energy use score was then calculated as the summation of additional energy use or savings from each option in millions of kWh per year, which was determined using the unit energy cost in kWh/AF, the yield of the portfolio options, and the unit cost of energy. Since the sub-objective was to *minimize* net energy use, a lower score is relatively better for this performance measure. The final score for the minimize net energy use sub-objective are shown in **Table L-12.**

Table L-12. Final minimize net energy use score

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Final Minimize Net Energy Use Score (millions of kWh/yr)	**124**	**66**	**48**	**315**	**97**	**144**	**282**

Scoring Method: Quantitative

L.3.3 Maximize Water Use Efficiency

The sub-objective to maximize water use efficiency was scored as the potable water use of the portfolio measured in gallons per capita per day (GPCD). To calculate GPCD, projected 2115 climate-adjusted potable water demands (based on average demands taken from the Disaggregated Demand Model –

described further in Appendix A) for each portfolio were converted to treated potable water pumpage to align with standard methods for GPCD calculation. Pumpage is an estimate of how much treated potable water is pumped from the water treatment plants, so it does not include losses incurred between the diversion point and leaving the plant. Both demand and pumpage values are shown in the following table. Once pumpage values were obtained, that volume was divided by the projected 2115 population and the number of days in a year to find the projected average city-wide total GPCD for each portfolio in 2115. For this performance measure, a lower score is better since it indicates more efficient use of potable water. The scoring for this performance metric is shown in **Table L-13**.

Table L-13. Score for maximize water use efficiency (based on 2115 projections)

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Projected 2115 Potable Water Demands (AFY)	363,983	313,595	345,181	336,090	306,797	296,197	296,197
Estimated 2115 Pumpage (AFY)	354,005	304,999	335,718	326,877	298,387	288,078	288,078
Final Maximize Water Use Efficiency Score (Projected GPCD)	**79**	**68**	**75**	**73**	**67**	**65**	**65**

Scoring Method: Quantitative
Note: Projected AW served population in 2115 is 3,977,380.

L.5 Social Benefit Scores

The social benefit objective score was based on scores for three sub-objectives: maximizing multi-benefit infrastructure, maximizing net benefits to the local economy, and maximizing social equity and environmental justice. The scores for each of these sub-objectives are based on metrics that measure relative portfolio performance and which are described in more detail in the following sub-sections. The raw scores for each social benefit sub-objective were inputted to CDP, and the standardized total social benefits score output from CDP is shown in **Figure L-4**.

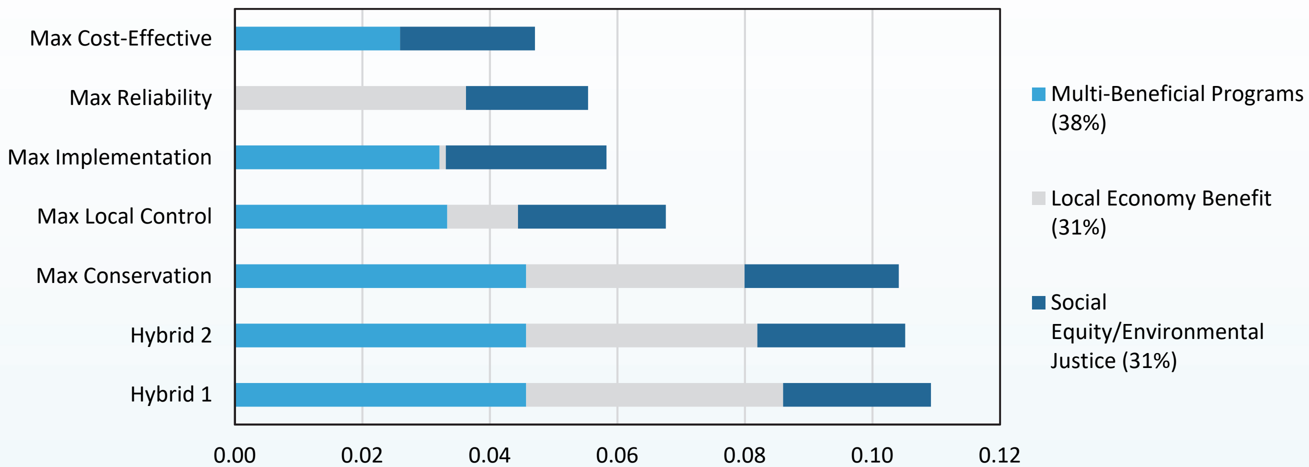

Figure L-4. Social benefits standardized score output from CDP

L.4.1 Maximize Multi-Benefit Infrastructure / Programs

Stormwater harvesting, rainwater harvesting, and options that provide landscape transformation benefits were used as a proxy for representing multi-benefit infrastructure. The total demand reduction or supply yield of these options was summed for each portfolio, and then assigned a score of one through five. A score of one indicated that a portfolio had no demand reduction or supply coming from multi-benefit infrastructure proxies, while a score of five indicated a portfolio which fully utilized all the multi-benefit infrastructure proxies (resulting in a demand-constrained yield of 30,336 AFY in 2115). The scoring for this performance metric is shown in **Table L-14**.

Table L-14. Score for Multi-Benefit Infrastructure

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Total Yield from Options that Focus on Stormwater, Rainwater, Landscaping (Proxies for Multi-Benefit Infras.) (AFY)	15,979	20,767	19,937	0	28,009	28,009	28,008
Final Score for Multi-Benefit Infrastructure	**3.11**	**3.74**	**3.63**	**1.00**	**4.69**	**4.69**	**4.69**

Scoring Method: Qualitative Informed by Quantitative

L.4.2 Maximize Net Benefits to Local Economy

While all options characterized for Water Forward would likely contribute some benefit to the local economy, this sub-objective focused on those options with the highest potential to generate local economic activity. This could be through options having significant locally-based construction and ongoing operations, or through the development of new and innovative water-focused industries. Options considered to bring significant benefit to the local economy are listed in **Table L-15**.

Table L-15. Relative Levels of Potential Benefit to the Local Economy

Project Options	Potential Level of Impact to Local Economy
Demand Side Options	
Advanced Metering Infrastructure	Some Benefit
Water Loss Control Utility Side	Some Benefit
CII Ordinance for Cooling Towers and Steam Boilers	Some Benefit
Water Use Benchmarking and Budgeting	Some Benefit
Landscape Transformation Ordinance	Some Benefit
Landscape Transformation Incentives	Some Benefit
Irrigation Efficiency Incentives	Some Benefit
Stormwater Harvesting (Lot)	**Significant Benefit**
Rainwater Harvesting (Lot)	**Significant Benefit**
Graywater Harvesting (Lot)	**Significant Benefit**
Building Scale Wastewater Reuse	**Significant Benefit**
AC Condensate Reuse	**Significant Benefit**
Supply Side Options	
Aquifer Storage and Recovery	**Significant Benefit**
Brackish Groundwater Desalination	**Significant Benefit**
Direct Non-Potable Reuse	Some Benefit
Direct Potable Reuse	**Significant Benefit**
Indirect Potable Reuse with Capture Lady Bird Lake Inflows	Some Benefit
Additional Supply from LCRA	Some Benefit
Off-Channel Reservoir w/ Lake Evaporation Suppression	**Significant Benefit**
Seawater Desalination	Some Benefit
Distributed Wastewater Reuse	**Significant Benefit**

Project Options	Potential Level of Impact to Local Economy
Wastewater Scalping (Sewer Mining)	**Significant Benefit**
Community Stormwater Harvesting	Some Benefit
Community Rainwater Harvesting	Some Benefit
Conventional Groundwater	Some Benefit

The demand reduction or supply yield from each of the options that have the highest potential for providing significant benefit to the local economy was multiplied by its unit cost and then the totals were summed for each portfolio. These total dollar figures were then converted to a one to five scale, with a score of one going to the lowest total, a score of five going to the highest total, and the other portfolios falling in between as shown in **Table L-16**.

Table L-16. Score for Net Benefits to the Local Economy

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Potential Contributions to Economic Benefit ($M)	$143	$245	$157	$480	$462	$523	$485
Final Score for Net Benefits to the Local Economy	**1.00**	**2.07**	**1.14**	**4.55**	**4.36**	**5.00**	**4.60**

Scoring Method: Qualitative Informed by Quantitative

L.4.3 Maximize Social Equity and Environmental Justice

The social equity score is based on an Equity Analysis Worksheet provided by the City of Austin Equity Office. This worksheet is an adaptation of the Equity Assessment Tool, which lays out a process and a set of questions to guide city departments in evaluating policies, practices, budget allocations, and programs and begin addressing their role and impacts on equity. This worksheet was created to assist the City in thinking through the potential impact on equity of a specific project. As with the Equity Assessment Tool, this worksheet leads with race, as it is currently the primary predictor of access, outcomes, and opportunities for quality of life indicators. The adapted Equity Analysis Worksheet is shown in **Table L-18**.

In the future, Austin Water will continue to work with other City departments to strengthen the tools and datasets needed to perform this type of evaluation. Austin Water has also engaged in broad public outreach (attending and presenting at over 80 outreach events) and will continue to work with the community during subsequent phases of the Water Forward initiative to incorporate a social equity lens into project implementation.

Each option is scored within each category and then summed into a total composite score. The lowest composite score is converted to a score of one and the highest converted to a five, with the portfolios falling in between assigned relative scores rounded to the nearest integer. This scoring is shown in **Table L-19**. The portfolios are then assigned a final score based on a water yield-weighted average of their options, as shown below in **Table L-17.**

Table L-17. Score for maximize social equity and environmental justice

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Final Scaled Score for Social Equity and Environmental Justice	**3.07**	**3.31**	**3.49**	**2.85**	**3.36**	**3.30**	**3.30**

Scoring Method: Qualitative Informed by Quantitative

Table L-18. Detailed score for net benefits to the local economy

Score	Alignment	History	Data	Community Engagement	Advancing Equity	Unintended Outcomes	Impact	Access to Benefits
1	No connection between the option and desired outcomes	There are needed strategies and resources to ensure equity to marginalized populations	Option is not supported by disaggregated data on racial inequities	Communities of color have not been engaged or have not been engaged appropriately or effectively	These categories were scored up to six points based on the number of Council strategic outcomes that were either positively or negatively impacted by each option. • Economic Opportunity • Mobility • Safety • Health • Cultural and Learning Opportunities • Government that Works		Potential negative impacts for people of color	Low potential for people of color to access benefits from the option
2	Unclear if there is a connection between the option and desired outcomes	No historical events have caused racial disparities or social exclusion to marginalized communities	Data reflect no impact on equity; not a racial issue	Communities of color are not affected by the option			Neutral impacts for people of color	Medium potential for people of color to access benefits from the option
3	Clear connection between the option and desired outcomes	Option identifies and will address unintended consequences to communities of color	Option addresses inequities validated by disaggregated racial disparity data	Communities of color have been actively and effectively engaged			Potential positive impacts for people of color	High potential for people of color to access benefits from the option
Notes	All options received a score of three based on an assumption that option implementation would seek to align clearly with desired outcomes.	All options received a score of two based on an assumption that option implementation would at least seek to have no historical racial impact.	No scores were added for this category due to lack of data.	All options scored as a three based on assumption was that this score applies to the plan development process. There will be additional community engagement to follow during the plan implementation phase.				This was a new category added to the Water Forward social equity scoring framework to address those options that had a limited spatial reach.

Table L-19. Social equity and environmental justice option scoring

Project Option	Alignment	History	Data	Community Engagement	Advancing Equity*	Unintended Outcomes*	Impact	Access to Benefits	Total Composite Score	Converted Score
Demand Side Options										
Advanced Metering Infrastructure	3	2	-	3	3 (Health, GTW, C&LO)	6	3	3	23	**5**
Water Loss Control Utility Side	3	2	-	3	3 (Health, GTW, Safety)	6	3	3	23	**5**
CII Ordinances for Cooling Towers and Steam Boilers	3	2	-	3	2 (Health, EO)	5 (EO)	3	2	20	**3**
Water Use Benchmarking and Budgeting	3	2	-	3	3 (Health GTW, EO)	5 (EO)	3	3	22	**4**
Landscape Transformation Ordinance	3	2	-	3	2 (Health, EO)	5 (EO)	3	3	21	**4**
Landscape Transformation Incentives	3	2	-	3	2 (Health, EO)	6	3	3	22	**4**
Irrigation Efficiency Incentives	3	2	-	3	2 (Health, EO)	6	3	3	22	**4**
Stormwater Harvesting (Lot)	3	2	-	3	3 (Health, EO, C&LO)	5 (Safety)	2	2	20	**3**
Rainwater Harvesting (Lot)	3	2	-	3	3 (Health, EO, C&LO)	5 (Safety)	2	2	20	**3**
Graywater Harvesting (Lot)	3	2	-	3	3 (Health, EO, C&LO)	5 (Safety)	2	2	20	**3**
Building Scale Wastewater Reuse	3	2	-	3	3 (Health, EO, C&LO)	5 (Safety)	2	2	20	**3**
AC Condensate Reuse	3	2	-	3	3 (Health, EO, C&LO)	5 (Safety)	2	2	20	**3**
Supply Side Options										
Aquifer Storage and Recovery	3	2	-	3	2 (Health, Safety)	6	3	3	22	**4**
Brackish Groundwater Desalination	3	2	-	3	1 (Health)	5 (Safety)	2	3	19	**2**
Direct Non-Potable Reuse	3	2	-	3	2 (Health, C&LO)	5 (Safety)	3	2	20	**3**
Direct Potable Reuse	3	2	-	3	1 (Health)	5 (Safety)	2	2	18	**2**
Indirect Potable Reuse with Capture Lady Bird Lake Inflows	3	2	-	3	1 (Health)	5 (Safety)	2	3	19	**2**
Additional Supply from LCRA	3	2	-	3	1 (Health)	6	3	3	21	**4**
Off-Channel Reservoir w/ Lake Evaporation Suppression	3	2	-	3	2 (Health, Safety)	6	1	3	20	**3**
Seawater Desalination	3	2	-	3	2 (Health, Safety)	5 (Safety)	2	3	20	**3**
Distributed Wastewater Reuse	3	2	-	3	2 (Health, C&LO)	5 (Safety)	1	2	18	**2**
Wastewater Scalping (Sewer Mining)	3	2	-	3	2 (Health, EO)	5 (Safety)	1	2	18	**2**
Community Stormwater Harvesting	3	2	-	3	2 (Health, EO)	5 (Safety)	2	2	19	**2**
Community Rainwater Harvesting	3	2	-	3	2 (Health, EO)	5 (Safety)	2	2	19	**2**
Conventional Groundwater	3	2	-	3	2 (Health, EO)	5 (Safety)	1	2	17	**1**

* EO = Economic Opportunity; C&LO = Cultural and Learning Opportunities; GTW = Government That Works

L.6 Implementation Benefit Scores

The implementation benefit objective scores were based on input from two sub-objectives: the potential risk associated with a portfolio of options and what volume of demand reduction or water supply is considered to be under local control or a local resource. Metrics for these sub-objectives were inputted to CDP, which produced the final standardized implementation benefit scores shown in **Figure L-5**. More detail is presented in the sub-sections below.

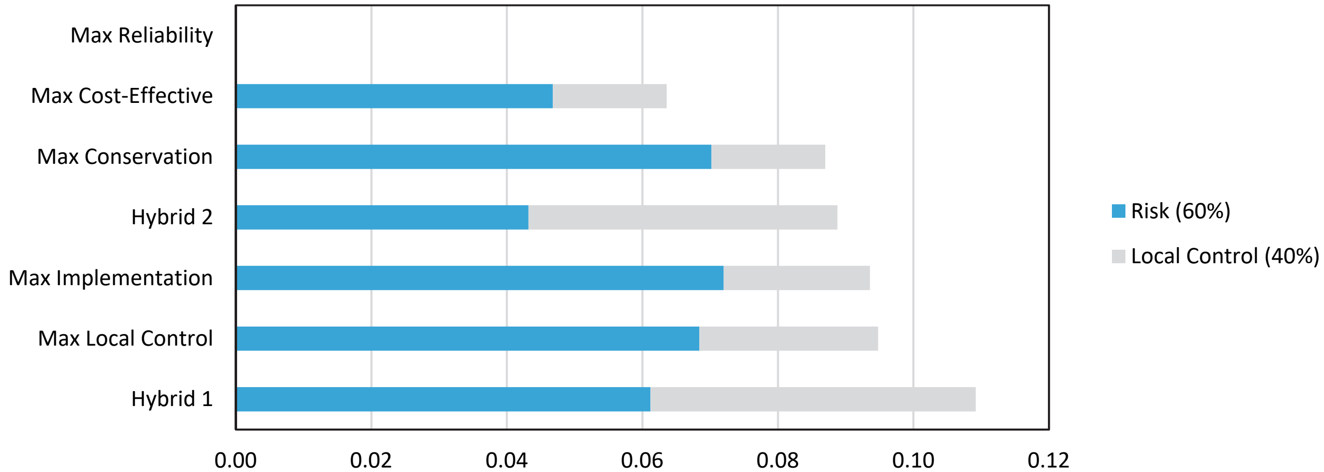

Figure L-5. Implementation benefits standardized score output from CDP

L.5.1 Risk Potential

The risk potential sub-objective score is based on the percentage of a portfolio's demand reduction or supply yield coming from higher-risk options. For each option, ten different risk types were considered, and a point was awarded for each type of risk the option may experience. The risks included: institutional challenges, public/developer opposition, scalability issues after initial construction, geographic/distribution limitations, permitting/regulatory difficulties, potential for infrastructure failure, supply/saving uncertainties, operations and maintenance (O&M) challenges, siting/land acquisition challenges, and emerging technology challenges. **Table L-21** shows the risk scoring for each option. Nine options received a risk score of four through seven and were considered the higher-risk options.

The percentage of yield coming from the higher-risk options was calculated for each portfolio and was then converted into a score of one to five, with a score of five going to the portfolio with the lowest percentage of higher-risk options, and a score of one being assigned to the portfolio with the highest percentage. The scoring for the risk potential performance metric is shown in **Table L-20**.

Table L-20. Score for risk potential

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Yield from Higher-Risk Options (AFY)	65,000	27,255	20,000	157,189	23,662	49,662	93,662
Higher-Risk Option Yield as % of Portfolio Total Yield	23%	10%	7%	54%	9%	14%	26%
Final Scaled Score for Risk Potential	**3.64**	**4.74**	**5.00**	**1.00**	**4.83**	**4.40**	**3.38**

Scoring Method: Qualitative Informed by Quantitative

Table L-21. Risk scores used to determine higher-risk options

	Project Option	Institutional Challenge	Public / Developer Opposition	Scalability Issue After Initial Const.	Geographic / Distribution Limitations	Permitting / Regulatory Difficulty	Infrastructure Failure	Supply / Saving Uncertainty	O&M Challenges	Siting / Land Acquisition	Emerging Technology	Total Risk Score
S8a	Imported Option Category – Seawater Desalination	1	0	1	0	1	1	0	1	1	1	**7**
S8b	Imported Option Category – Conventional Groundwater	1	1	0	0	1	1	1	1	1	0	**7**
S4	Direct Potable Reuse	1	1	0	0	1	0	0	1	1	1	**6**
D11	Building Scale Wastewater Reuse	0	1	0	1	1	0	0	1	0	1	**5**
S12	Community Rainwater Harvesting	1	1	0	1	0	0	1	1	0	0	**5**
S2	Brackish Groundwater Desalination	1	0	0	0	1	0	0	1	1	0	**4**
S5	Indirect Potable Reuse with Capture Lady Bird Lake Inflows	0	1	0	0	1	0	0	0	1	1	**4**
S11	Community Stormwater Harvesting	1	0	0	1	0	0	1	1	0	0	**4**
S10	Wastewater Scalping (Sewer Mining)	0	0	0	1	1	0	0	1	0	1	**4**
D4	Water Use Benchmarking/Budgeting	1	0	0	0	0	0	1	0	0	1	**3**
D8	Stormwater Harvesting (Lot)	0	1	0	0	0	0	1	1	0	0	**3**
D9	Rainwater Harvesting (Lot)	0	1	0	0	0	0	1	1	0	0	**3**
D10	Graywater Harvesting (Lot)	0	1	0	1	0	0	0	1	0	0	**3**
S1	Aquifer Storage and Recovery	0	0	0	0	0	0	0	1	1	1	**3**
S6	Additional Supply from LCRA	1	0	1	0	0	0	1	0	0	0	**3**
S7	Off-Channel Reservoir w/ Lake Evap. Suppression	0	0	1	0	1	0	0	0	1	0	**3**
S9	Distributed Wastewater Reuse	0	0	0	1	1	0	0	1	0	0	**3**
D1	Advanced Metering Infrastructure	0	0	0	0	0	0	0	1	0	1	**2**
D2	Water Loss Control Utility Side	0	0	0	0	0	0	0	1	0	1	**2**
D5	Landscape Transformation Ordinance	0	1	0	0	0	0	1	0	0	0	**2**
S3	Direct Non-Potable Reuse	0	1	0	1	0	0	0	0	0	0	**2**
D6	Landscape Transformation Incentives	0	0	0	0	0	0	1	0	0	0	**1**
D7	Irrigation Efficient Incentives	0	0	0	0	0	0	1	0	0	0	**1**
D12	AC Condensate Reuse	0	0	0	0	0	0	0	1	0	0	**1**
D3	CII Ordinance for Cooling Towers and Steam Boilers	0	0	0	0	0	0	0	0	0	0	**0**

Note: Options in light gray were considered the higher-risk options.

L.5.2 Local Control / Local Resource

The local control/local resource score was based on two components: (1) yield from options where AW will control the implementation and operation (local control), and (2) yield from options sited locally (local resource). The options which were considered a part of these two groups are shown in **Table L-22**.

Table L-22. Options considered under Austin Water control and as a local resource

Project Options	Option Projected to be Implemented and Operated by Austin Water?	Option Considered a Local Water Resource?
Demand Side Options		
Advanced Metering Infrastructure	Yes	Yes
Water Loss Control Utility Side	Yes	Yes
CII Ordinances for Cooling Towers and Steam Boilers	Yes	Yes
Water Use Benchmarking and Budgeting	Yes	Yes
Landscape Transformation Ordinance	Yes	Yes
Landscape Transformation Incentives	Yes	Yes
Irrigation Efficiency Incentives	Yes	Yes
Stormwater Harvesting (Lot)		Yes
Rainwater Harvesting (Lot)		Yes
Graywater Harvesting (Lot)		Yes
Building Scale Wastewater Reuse		Yes
AC Condensate Reuse		Yes
Supply Side Options		
Aquifer Storage and Recovery	Yes	Yes
Brackish Groundwater Desalination	Yes	
Direct Non-Potable Reuse	Yes	Yes
Direct Potable Reuse	Yes	Yes
Indirect Potable Reuse with Capture Lady Bird Lake Inflows	Yes	Yes
Additional Supply from LCRA		Yes
Off-Channel Reservoir w/ Lake Evaporation Suppression	Yes	Yes
Seawater Desalination	Yes	
Distributed Wastewater Reuse	Yes	Yes
Wastewater Scalping (Sewer Mining)		Yes
Community Stormwater Harvesting		Yes
Community Rainwater Harvesting		Yes
Conventional Groundwater	Yes	

The total yield or demand management savings for options anticipated to be under AW control and for local resources was determined for each portfolio and the two values were summed. This total demand management and supply yield volume for each portfolio was then converted to a score of one to five, with five being assigned to the portfolios with the highest totals. The final scoring for the local control / local resource sub-objective is shown in **Table L-23**.

Table L-23. Detailed score for local control / local resource

Scoring Element	Max Cost-Effectiveness	Max Control	Max Implem.	Max Reliability	Max Conserv.	Hybrid 1	Hybrid 2
Yield from Options that AW will Control (AFY)	233,065	282,537	281,629	195,118	267,979	328,579	302,752
Yield from Options that are Local Water Resources (AFY)	247,088	234,978	215,765	242,147	209,148	275,748	319,748
Sum of Yields from Local Control/Local Resource (AFY)	480,153	517,515	497,395	437,264	477,127	604,327	622,500
Final Scaled Local Control / Local Resource Score	**1.93**	**2.73**	**2.30**	**1.00**	**1.86**	**4.61**	**5.00**

Scoring Method: Qualitative Informed by Quantitative

Table L-24. Water Forward Integrated Water Resources Plan objectives

Primary Objective	Objective Weight	Sub-Objective	Defining Question	Performance Measure	Sub-Objective Weight
Water Supply Benefits	35%	Minimize Water Supply Vulnerability	How does the portfolio perform in terms of how large are shortages under various hydrologic conditions, including climate change scenarios?	Percent of shortage compared to demand during drought based on WAM modeling results	28%
		Maximize Water Supply Reliability	How does the portfolio perform in terms of how often is there a shortage under various hydrologic conditions, including climate change scenarios?	Percent of time a shortage occurs based on WAM modeling results	7%
Economic Impacts	20%	Maximize Cost-Effectiveness	What is the total capital (construction) and operations/maintenance costs of all projects/programs in the portfolio over the lifecycle, divided by the sum of all water yield produced by the portfolio?	Unit cost ($/AF) expressed as a present value sum of all costs over the lifecycle, including utility and customer costs.	15%
		Maximize Advantageous External Funding	Does the portfolio have an opportunity for advantageous external funding from Federal, State, local, and private sources?	External Funding Score (1-5), where 1 = low potential and 5 = high potential	5%
Environmental Impacts	20%	Minimize Ecosystem Impacts	To what extent does the portfolio positively or negatively impact receiving water quality (e.g., streams, river, lakes), terrestrial and aquatic habitats throughout Austin, and net streamflow effects both upstream and downstream from Austin?	Ecosystem Impact Score (1-5), where 1 = high combined negative impacts and 5 = high combined positive impacts	8%
		Minimize Net Energy Use	What is the net energy requirement of the portfolio, considering energy generation?	Incremental net change in kWh	6%
		Maximize Water Use Efficiency	What is the reduction in potable water use from water conservation, reuse and rainwater capture for the portfolio?	Potable per capita water use (gallon/person/day)	6%
Social Impacts	13%	Maximize Multi-Benefit Infrastructure/Programs	To what extent does the portfolio provide secondary benefits such as enhanced community livability/beautification, increased water ethic, ecosystem services, or others?	Multiple Benefits Score (1-5), where 1 = low benefits and 5 = high benefits	5%
		Maximize Net Benefits to Local Economy	To what extent does the supply reliability and water investments of the portfolio protect and improve local economic vitality, including permanent job creation?	Local Economy Score (1-5), where 1 = high negative impact and 5 = high positive impact	4%
		Maximize Social Equity and Environmental Justice	To what extent does the portfolio support social equity and environmental justice, with emphasis on underserved communities? (see accompanying reference slide)	Social Equity and Environmental Justice Score (1-5), where 1 = significant support and 5 = minimal support	4%
Implementation Impacts	12%	Minimize Risk	What major implementation and operational risks and uncertainties will the portfolio face?	Risk Score (1-5), where 1 = high combined risks and uncertainties and 5 = low combined risks and uncertainties	7%
		Maximize Local Control	To what extent does AW have control over the quantity and storage of water and operation of options (especially during drought periods) included in the portfolio?	Measured by assessing both AW's control over operations of resource and whether resource resides within the local area	5%

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L.7 Portfolio Composition Summary

	#	Options	Decentralized Option Parameters							Maximize Conservation and Environmental Stewardship							
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)	2115 Unit Cost ($/AF/Yr)
Demand Management Options	D1	AMI								✔	2020		596	3,882	5,766	9,371	$ 2,799
	D2	Water Loss Control								✔	2020		3,108	9,326	10,918	13,064	$ 5,187
	D3	CII Ordinances								✔	2020		1,063	1,063	1,063	1,063	$ 73
	D4	Benchmarking								✔	2020		-	5,953	11,670	25,228	$ 19
	D5	Landscape Ordinance								✔	2020		-	3,038	7,428	15,050	$ 19
	D6	Landscape Incentive								✔	2020		-	321	633	929	$ 825
	D7	Irrigation Incentive								✔	2020		42	205	427	394	$ 833
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All	✔	2020	20%	-	180	496	1,391	$ 6,858
			Outdoor			Y		IRR	All	✔	2020	20%	-	149	373	885	$ 5,861
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All	✔	2020	40%	-	937	2,410	5,088	$ 3,293
			Outdoor		Y			IRR	All	✔	2020	10%	-	54	151	425	$ 2,200
			Outdoor			Y		IRR	All	✔	2020	10%	-	82	209	498	$ 1,945
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL	All	✔	2020	20%	-	195	556	1,562	$ 2,451
			Dual pipe			Y		IRR TL HVC	All	✔	2020	20%	-	281	706	1,678	$ 2,386
			Potable	Y				ALL	All				-	-	-	-	
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All	✔	2020	10%	-	244	631	1,336	$ 4,546
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All	✔	2020	10%	-	571	1,461	2,860	$ 12,258
			Dual pipe		Y			IRR TL CW	All	✔	2020	20%	-	991	2,702	6,832	$ 9,887
			Dual pipe			Y		IRR TL	All	✔	2020	15%	-	321	823	1,638	$ 9,402
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All	✔	2020	20%	-	1,323	3,672	7,875	$ 11,726
	D12	AC Condensate Reuse								✔	2020		100	1,084	2,711	5,150	$ 2,702
Supply Options	S1	Aquifer Storage and Recovery								✔	2040		-	30,000	30,000	60,000	$ 1,053
	S2	Brackish Groundwater Desal								✔	2070		-	-	5,000	10,000	$ 2,690
	S3	Direct Non-Potable Reuse								✔	2020		4,000	12,000	24,000	44,000	$ 1,229
	S4	Direct Potable Reuse											-	-	-	-	
	S5	Indirect Potable Reuse											-	-	-	-	
	S6	LCRA Additional Supply											-	-	-	-	
	S7	Off Channel Reservoir								✔	2070		-	-	25,827	25,827	$ 846
	S8a	Seawater Desal (Import Option)											-	-	-	-	
	S8b	Conventional Groundwater (Import Option)															
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW	Greenfield	✔	2040	70%	-	3,154	14,467	30,049	$ 1,251
	S10	Sewer Mining	Outdoor				Y	IRR	NA	✔	2040	40%	-	-	-	-	$ -
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield	✔	2040	30%	-	1,000	2,211	5,284	$ 2,725
	S11	Community Stormwater	Outdoor				Y	IRR	NA	✔	2040	30%	-	48	48	48	$ 1,754
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield	✔	2040	30%	-	109	188	455	$ 1,476
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield				-	-	-	-	
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield				-	-	-	-	

	#	Options	Decentralized Option Parameters							Maximize Local Control							
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)	2115 Unit Cost ($/AF/Yr)
Demand Management Options	D1	AMI								✔	2020		596	3,882	5,766	9,371	$ 2,799
	D2	Water Loss Control								✔	2020		3,108	9,326	10,918	13,064	$ 5,187
	D3	CII Ordinances								✔	2020		1,063	1,063	1,063	1,063	$ 73
	D4	Benchmarking								✔	2020		-	5,953	11,670	25,228	$ 19
	D5	Landscape Ordinance								✔	2020		-	3,038	7,428	15,050	$ 19
	D6	Landscape Incentive											-	-	-	-	
	D7	Irrigation Incentive											-	-	-	-	
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All				-	-	-	-	
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All	✔	2040	20%	-	917	2,350	4,819	$ 3,398
			Dual pipe		Y			IRR TL	All				-	-	-	-	
			Dual pipe			Y		IRR TL HVC	All				-	-	-	-	
			Potable	Y				ALL	All				-	-	-	-	
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All				-	-	-	-	
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All	✔	2040	10%	-	495	1,351	3,416	$ 9,887
			Dual pipe			Y		IRR TL	All	✔	2040	10%	-	214	549	1,092	$ 9,402
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D12	AC Condensate Reuse								✔	2020		100	1,084	2,711	5,150	$ 2,702
Supply Options	S1	Aquifer Storage and Recovery								✔	2040		-	30,000	30,000	60,000	$ 1,053
	S2	Brackish Groundwater Desal											-	-	-	-	
	S3	Direct Non-Potable Reuse								✔	2020		4,000	12,000	25,000	59,600	$ 1,229
	S4	Direct Potable Reuse											-	-	-	-	
	S5	Indirect Potable Reuse								✔	2070		-	-	10,000	20,000	$ 605
	S6	LCRA Additional Supply											-	-	-	-	
	S7	Off Channel Reservoir								✔	2070		-	-	25,827	25,827	$ 846
	S8a	Seawater Desal (Import Option)											-	-	-	-	
	S8b	Conventional Groundwater (Import Option)															
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW I	Greenfield	✔	2040	90%	-	3,391	15,144	31,602	$ 1,295
	S10	Sewer Mining	Outdoor				Y	IRR	NA				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield	✔	2040	50%	-	1,255	2,673	6,357	$ 2,906
	S11	Community Stormwater	Outdoor				Y	IRR	NA	✔	2040	70%	-	73	73	73	$ 2,980
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield	✔	2040	80%	-	21	43	101	$ 1,757
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield	✔	2040	80%	-	174	324	700	$ 4,757
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield	✔	2040	100%	-	16	17	24	$ 11,666

	#	Options	Decentralized Option Parameters							Maximize Water Supply Reliability and Climate Resiliency							
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)	2115 Unit Cost ($/AF/Yr)
Demand Management Options	D1	AMI								✔	2020		596	3,882	5,766	9,371	$ 2,799
	D2	Water Loss Control								✔	2020		3,108	9,326	10,918	13,064	$ 5,187
	D3	CII Ordinances								✔	2020		1,063	1,063	1,063	1,063	$ 73
	D4	Benchmarking											-	-	-	-	
	D5	Landscape Ordinance											-	-	-	-	
	D6	Landscape Incentive											-	-	-	-	
	D7	Irrigation Incentive											-	-	-	-	
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All				-	-	-	-	
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL	All				-	-	-	-	
			Dual pipe			Y		IRR TL HVC	All				-	-	-	-	
			Potable	Y				ALL	All				-	-	-	-	
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All	✔	2040	20%	-	488	1,262	2,672	$ 4,546
			Outdoor		Y			IRR	All	✔	2040	20%	-	334	925	2,524	$ 1,134
			Outdoor			Y		IRR	All	✔	2040	20%	-	229	665	1,558	$ 1,120
			Dual pipe	Y				IRR TL CW	All	✔	2040	10%	-	571	1,461	2,860	$ 12,258
			Dual pipe		Y			IRR TL CW	All	✔	2040	20%	-	991	2,702	6,832	$ 9,887
			Dual pipe			Y		IRR TL	All	✔	2040	20%	-	428	1,098	2,185	$ 9,402
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All	✔	2040	10%	-	585	1,637	4,209	$ 13,827
			Dual pipe			Y		IRR TL CW HVC	All	✔	2040	30%	-	1,985	5,509	11,812	$ 11,726
	D12	AC Condensate Reuse								✔	2020		100	1,084	2,711	5,150	$ 2,702
Supply Options	S1	Aquifer Storage and Recovery											-	-	-	-	
	S2	Brackish Groundwater Desal								✔	2040		-	5,000	5,000	10,000	$ 2,690
	S3	Direct Non-Potable Reuse								✔	2020		4,000	12,000	25,000	54,600	$ 1,229
	S4	Direct Potable Reuse								✔	2040		-	20,000	20,000	20,000	$ 2,204
	S5	Indirect Potable Reuse								✔	2040		-	10,000	10,000	20,000	$ 605
	S6	LCRA Additional Supply											-	-	-	-	
	S7	Off Channel Reservoir											-	-	-	-	
	S8a	Seawater Desal (Import Option)								✔	2070		-	-	40,000	84,000	$ 3,032
	S8b	Conventional Groundwater (Import Option)															
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW	Greenfield	✔	2070	70%	-	3,154	14,467	30,049	$ 1,251
	S10	Sewer Mining	Outdoor				Y	IRR	NA				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield	✔	2040	50%	-	1,417	3,012	7,168	$ 2,934
	S11	Community Stormwater	Outdoor				Y	IRR	NA				-	-	-	-	
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield				-	-	-	-	
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield				-	-	-	-	

	#	Options	Decentralized Option Parameters							Minimize Cost							
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)	2115 Unit Cost ($/AF/Yr)
Demand Management Options	D1	AMI								✓	2020		596	3,882	5,766	9,371	$ 2,799
	D2	Water Loss Control								✓	2020		3,108	9,326	10,918	13,064	$ 5,187
	D3	CII Ordinances								✓	2020		1,063	1,063	1,063	1,063	$ 73
	D4	Benchmarking								✓	2020		-	5,953	11,670	25,228	$ 19
	D5	Landscape Ordinance								✓	2020		-	3,038	7,428	15,050	$ 19
	D6	Landscape Incentive								✓	2020		-	321	633	929	$ 825
	D7	Irrigation Incentive								✓	2040		-	205	427	394	$ 833
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All				-	-	-	-	
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL	All				-	-	-	-	
			Dual pipe			Y		IRR TL HVC	All				-	-	-	-	
			Potable	Y				ALL	All				-	-	-	-	
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All				-	-	-	-	
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL	All				-	-	-	-	
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D12	AC Condensate Reuse								✓	2020		100	1,084	2,711	5,150	$ 2,702
Supply Options	S1	Aquifer Storage and Recovery								✓	2070		-	-	30,000	60,000	$ 1,053
	S2	Brackish Groundwater Desal											-	-	-	-	
	S3	Direct Non-Potable Reuse								✓	2020		4,000	8,000	16,000	40,000	$ 1,229
	S4	Direct Potable Reuse											-	-	-	-	
	S5	Indirect Potable Reuse								✓	2040		-	10,000	10,000	20,000	$ 605
	S6	LCRA Additional Supply								✓	2020		-	-	-	-	$ 352
	S7	Off Channel Reservoir								✓	2040		-	25,827	25,827	25,827	$ 846
	S8a	Seawater Desal (Import Option)								✓	2040		0	0	0	0	$ 3,032
	S8b	Conventional Groundwater (Import Option)											-	10,000	20,000	45,000	
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW	Greenfield	✓	2040	20%	-	1,055	8,025	16,989	$ 1,069
	S10	Sewer Mining	Outdoor				Y	IRR	NA				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield				-	-	-	-	
	S11	Community Stormwater	Outdoor				Y	IRR	NA				-	-	-	-	
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield				-	-	-	-	
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield				-	-	-	-	

	#	Options	Decentralized Option Parameters							Minimize Implementation Challenges							
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)	2115 Unit Cost ($/AF/Yr)
Demand Management Options	D1	AMI								✔	2020		596	3,882	5,766	9,371	$ 2,799
	D2	Water Loss Control								✔	2020		3,108	9,326	10,918	13,064	$ 5,187
	D3	CII Ordinances								✔	2020		1,063	1,063	1,063	1,063	$ 73
	D4	Benchmarking								✔	2020		-	5,953	11,670	25,228	$ 19
	D5	Landscape Ordinance								✔	2020		-	3,038	7,428	15,050	$ 19
	D6	Landscape Incentive											-	-	-	-	
	D7	Irrigation Incentive								✔	2040		-	207	434	401	$ 833
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All	✔	2040	20%	-	468	1,205	2,544	$ 3,293
			Outdoor		Y			IRR	All	✔	2040	20%	-	107	302	850	$ 2,200
			Outdoor			Y		IRR	All	✔	2040	30%	-	247	626	1,493	$ 1,945
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL	All				-	-	-	-	
			Dual pipe			Y		IRR TL HVC	All				-	-	-	-	
			Potable	Y				ALL	All				-	-	-	-	
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All				-	-	-	-	
			Outdoor		Y			IRR	All				-	-	-	-	
			Outdoor			Y		IRR	All				-	-	-	-	
			Dual pipe	Y				IRR TL CW	All				-	-	-	-	
			Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL	All				-	-	-	-	
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All				-	-	-	-	
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-	
	D12	AC Condensate Reuse								✔	2020		100	1,084	2,711	5,150	$ 2,702
Supply Options	S1	Aquifer Storage and Recovery								✔	2040		-	30,000	30,000	60,000	$ 1,053
	S2	Brackish Groundwater Desal											-	-	-	-	
	S3	Direct Non-Potable Reuse								✔	2020		4,000	12,000	25,000	54,600	$ 1,229
	S4	Direct Potable Reuse											-	-	-	-	
	S5	Indirect Potable Reuse								✔	2070		-	-	10,000	20,000	$ 605
	S6	LCRA Additional Supply								✔	(95,720)		-	-	-	30,000	$ 352
	S7	Off Channel Reservoir								✔	2070		-	-	25,827	25,827	$ 846
	S8a	Seawater Desal (Import Option)											-	-	-	-	
	S8b	Conventional Groundwater (Import Option)															
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW	Greenfield	✔	2070	20%	-	1,055	8,025	16,989	$ 1,069
	S10	Sewer Mining	Outdoor				Y	IRR	NA				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield				-	-	-	-	
	S11	Community Stormwater	Outdoor				Y	IRR	NA				-	-	-	-	
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield				-	-	-	-	
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield				-	-	-	-	
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield				-	-	-	-	

	#	Options	Decentralized Option Parameters							Hybrid 1						
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)
Demand Management Options	D1	AMI								✔	2020		596	3,882	5,766	9,371
	D2	Water Loss Control								✔	2020		3,108	9,326	10,918	13,064
	D3	CII Ordinances								✔	2020		1,063	1,063	1,063	1,063
	D4	Benchmarking								✔	2020		-	5,953	11,670	25,228
	D5	Landscape Ordinance								✔	2020		-	3,038	7,428	15,050
	D6	Landscape Incentive								✔	2020		-	321	633	929
	D7	Irrigation Incentive								✔	2020		42	205	427	394
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All	✔	2020	20%	-	180	496	1,391
			Outdoor			Y		IRR	All	✔	2020	20%	-	149	373	885
			Dual pipe		Y			IRR TL CW	All				-	-	-	-
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All	✔	2020	40%	-	937	2,410	5,088
			Outdoor		Y			IRR	All	✔	2020	10%	-	54	151	425
			Outdoor			Y		IRR	All	✔	2020	10%	-	82	209	498
			Dual pipe	Y				IRR TL CW	All				-	-	-	-
			Dual pipe		Y			IRR TL	All	✔	2020	20%	-	195	556	1,562
			Dual pipe			Y		IRR TL HVC	All	✔	2020	20%	-	281	706	1,678
			Potable	Y				ALL	All				-	-	-	-
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All	✔	2020	10%	-	244	631	1,336
			Outdoor		Y			IRR	All				-	-	-	-
			Outdoor			Y		IRR	All				-	-	-	-
			Dual pipe	Y				IRR TL CW	All	✔	2020	10%	-	571	1,461	2,860
			Dual pipe		Y			IRR TL CW	All	✔	2020	20%	-	991	2,702	6,832
			Dual pipe			Y		IRR TL	All	✔	2020	15%	-	321	823	1,638
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All				-	-	-	-
			Dual pipe			Y		IRR TL CW HVC	All	✔	2020	20%	-	1,323	3,672	7,875
	D12	AC Condensate Reuse								✔	2020		100	1,084	2,711	5,150
Supply Options	S1	Aquifer Storage and Recovery								✔	2040		-	60,000	60,000	90,000
	S2	Brackish Groundwater Desal								✔	2070		-	-	5,000	16,000
	S3	Direct Non-Potable Reuse								✔	2020		*4,000*	12,000	25,000	54,600
	S4	Direct Potable Reuse											-	-	-	-
	S5	Indirect Potable Reuse								✔	2040		-	11,000	20,000	20,000
	S6	LCRA Additional Supply											-	-	-	-
	S7	Off Channel Reservoir								✔	2070		-	-	25,000	25,000
	S8a	Seawater Desal (Import Option)											-	-	-	-
	S8b	Conventional Groundwater (Import Option)											-	-	-	-
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW	Greenfield	✔	2040	70%	-	3,154	14,467	30,049
	S10	Sewer Mining	Outdoor				Y	IRR	NA	✔	2040	40%	-	-	-	-
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield	✔	2040	30%	-	1,000	2,211	5,284
	S11	Community Stormwater	Outdoor				Y	IRR	NA	✔	2040	30%	-	48	48	48
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield	✔	2040	30%	-	109	188	455
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield				-	-	-	-
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield				-	-	-	-

	#	Options	Decentralized Option Parameters							Hybrid 2						
			Sub-Option / Scenario	SFR	MFR	COM	COA	End Uses	Type of New Development Option Applies To	On?	Implement. Year	Decent. Saturation Rate	2020 Yield (AF/Yr)	2040 Yield (AF/Yr)	2070 Yield (AF/Yr)	2115 Yield (AF/Yr)
Demand Management Options	D1	AMI								✓	2020		596	3,882	5,766	9,371
	D2	Water Loss Control								✓	2020		3,108	9,326	10,918	13,064
	D3	CII Ordinances								✓	2020		1,063	1,063	1,063	1,063
	D4	Benchmarking								✓	2020		-	5,953	11,670	25,228
	D5	Landscape Ordinance								✓	2020		-	3,038	7,428	15,050
	D6	Landscape Incentive								✓	2020		-	321	633	929
	D7	Irrigation Incentive								✓	2020		42	205	427	394
	D8	Lot Scale Stormwater Harvesting	Outdoor		Y			IRR	All	✓	2020	20%	-	180	496	1,391
			Outdoor			Y		IRR	All	✓	2020	20%	-	149	373	885
			Dual pipe		Y			IRR TL CW	All				-	-	-	-
			Dual pipe			Y		IRR TL CW HVC	All				-	-	-	-
	D9	Lot Scale Rainwater Harvesting	Outdoor	Y				IRR	All	✓	2020	40%	-	937	2,410	5,088
			Outdoor		Y			IRR	All	✓	2020	10%	-	54	151	425
			Outdoor			Y		IRR	All	✓	2020	10%	-	82	209	498
			Dual pipe	Y				IRR TL CW	All				-	-	-	-
			Dual pipe		Y			IRR TL	All	✓	2020	20%	-	195	556	1,562
			Dual pipe			Y		IRR TL HVC	All	✓	2020	20%	-	281	706	1,678
			Potable	Y				ALL	All				-	-	-	-
	D10	Gray Water Harvesting	Outdoor	Y				IRR	All	✓	2020	10%	-	244	631	1,336
			Outdoor		Y			IRR	All				-	-	-	-
			Outdoor			Y		IRR	All				-	-	-	-
			Dual pipe	Y				IRR TL CW	All	✓	2020	10%	-	571	1,461	2,860
			Dual pipe		Y			IRR TL CW	All	✓	2020	20%	-	991	2,702	6,832
			Dual pipe			Y		IRR TL	All	✓	2020	15%	-	321	823	1,638
	D11	Building Scale Wastewater Reuse	Dual pipe		Y			IRR TL CW	All				-	-	-	-
			Dual pipe			Y		IRR TL CW HVC	All	✓	2020	20%	-	1,323	3,672	7,875
	D12	AC Condensate Reuse								✓	2020		100	1,084	2,711	5,150
Supply Options	S1	Aquifer Storage and Recovery								✓	2040		-	45,000	90,000	90,000
	S2	Brackish Groundwater Desal								✓	2040		-	5,000	5,000	10,000
	S3	Direct Non-Potable Reuse								✓	2020		*4,000*	12,000	25,000	54,600
	S4	Direct Potable Reuse											-	-	-	-
	S5	Indirect Potable Reuse								✓	2040		-	20,000	20,000	20,000
	S6	LCRA Additional Supply											-	-	-	-
	S7	Off Channel Reservoir											-	-	-	-
	S8a	Seawater Desal (Import Option)								✓	2115		-	-	-	50,000
	S8b	Conventional Groundwater (Import Option)											-	-	-	-
	S9	Distributed WW Reuse	Dual pipe	Y	Y	Y	Y	IRR TL CW	Greenfield	✓	2040	70%	-	3,154	14,467	30,049
	S10	Sewer Mining	Outdoor				Y	IRR	NA	✓	2040	40%	-	-	-	-
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Mainly Brownfield	✓	2040	30%	-	1,000	2,211	5,284
	S11	Community Stormwater	Outdoor				Y	IRR	NA	✓	2040	30%	-	48	48	48
			Outdoor	Y	Y	Y	Y	IRR	Green & Brownfield	✓	2040	30%	-	109	188	455
			Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Green & Brownfield				-	-	-	-
	S12	Community Rainwater	Dual pipe	Y	Y	Y	Y	IRR TL CW HVC	Greenfield				-	-	-	-

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APPENDIX M: WATER FORWARD ADAPTIVE MANAGEMENT PLAN AND IMPLEMENTATION OUTLOOK

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Water Forward

Implementation Outlook and Adaptive Management Plan

AW will continue implementation of Advanced Metering Infrastructure and Water Loss Control utility initiatives.
AW will continue to monitor AC Condensate Reuse and CII Ordinances that have recently been adopted into code.
NOTE: All process steps are not included on this informational visual.

	Row No.	Option No.	Task Name	Description
Planning Cycles	1		**Integrated Water Resource Plan Development and Update Process**	
	2		Scope of Work and Project Schedule Development	
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	4		Data Gathering and Preliminary Analyses	
	5		Plan Development Process	
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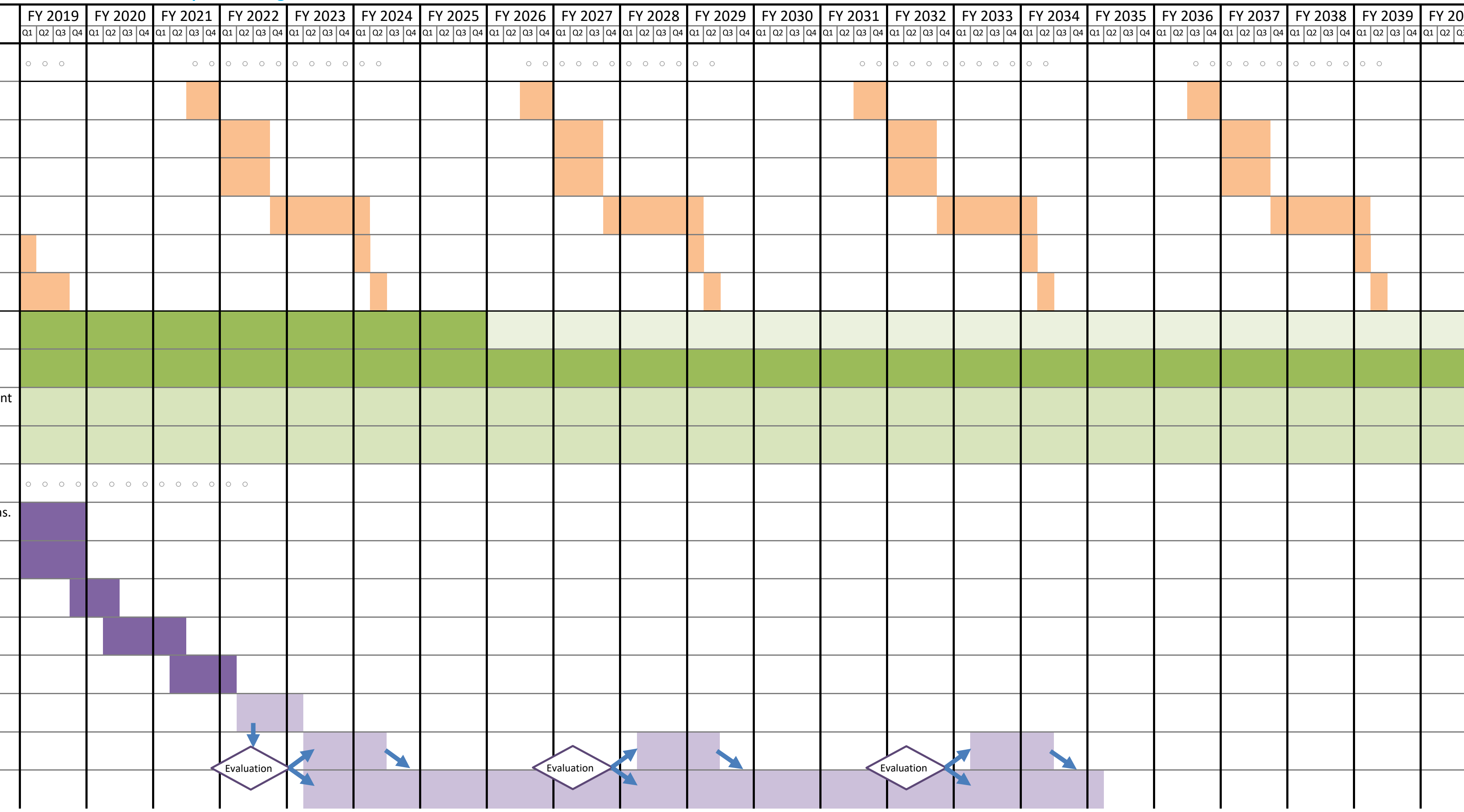
	7		Implementation Plan Development	
Ongoing Utility Initiatives	8	D1	**Advanced Metering Infrastructure**	Implement customer facing programs that provide real-time water use information. Savings achieved through identification of customer-side leaks, behavior modification, etc.
	9	D2	**Water Loss Control - Utility Side**	Leak detection, correction, and prevention program to reduce the Infrastructure Leakage Index (ILI) to 2.7 by 2020 and further reduce and sustain a 2.0 ILI from 2040 to 2115.
	10	D3	**Commercial, Institutional, and Industrial (CII) Ordinances**	Already in Code - Require older cooling towers to meet water efficiency benchmarks and use efficient equipment and require efficiency standards for steam boilers in new development.
	11	D12	**AC Condensate Reuse**	Already in Code - Require collection and reuse of condensate water from Air Handling Units (AHUs) for cooling systems from new development with cooling capacity over 200 tons.
	12		**Expansion of Current Centralized Reclaimed Water Connection Requirements**	Stakeholder process will explore expanding existing centralized reclaimed water connection requirements.
	13		Evaluation of potential implementation approaches	Evaluation to include refinement of ordinance scope, applicability, location in code, enforcement considerations.
	14		Preliminary stakeholder outreach	
	15		Develop draft ordinance language	
	16		Stakeholder outreach and draft code language changes as needed	
	17		Boards and Commissions and Council action	
	18		Implementation and monitoring	
	19		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	20		Maintain approach and continue monitoring	



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Implementation Outlook and Adaptive Management Plan

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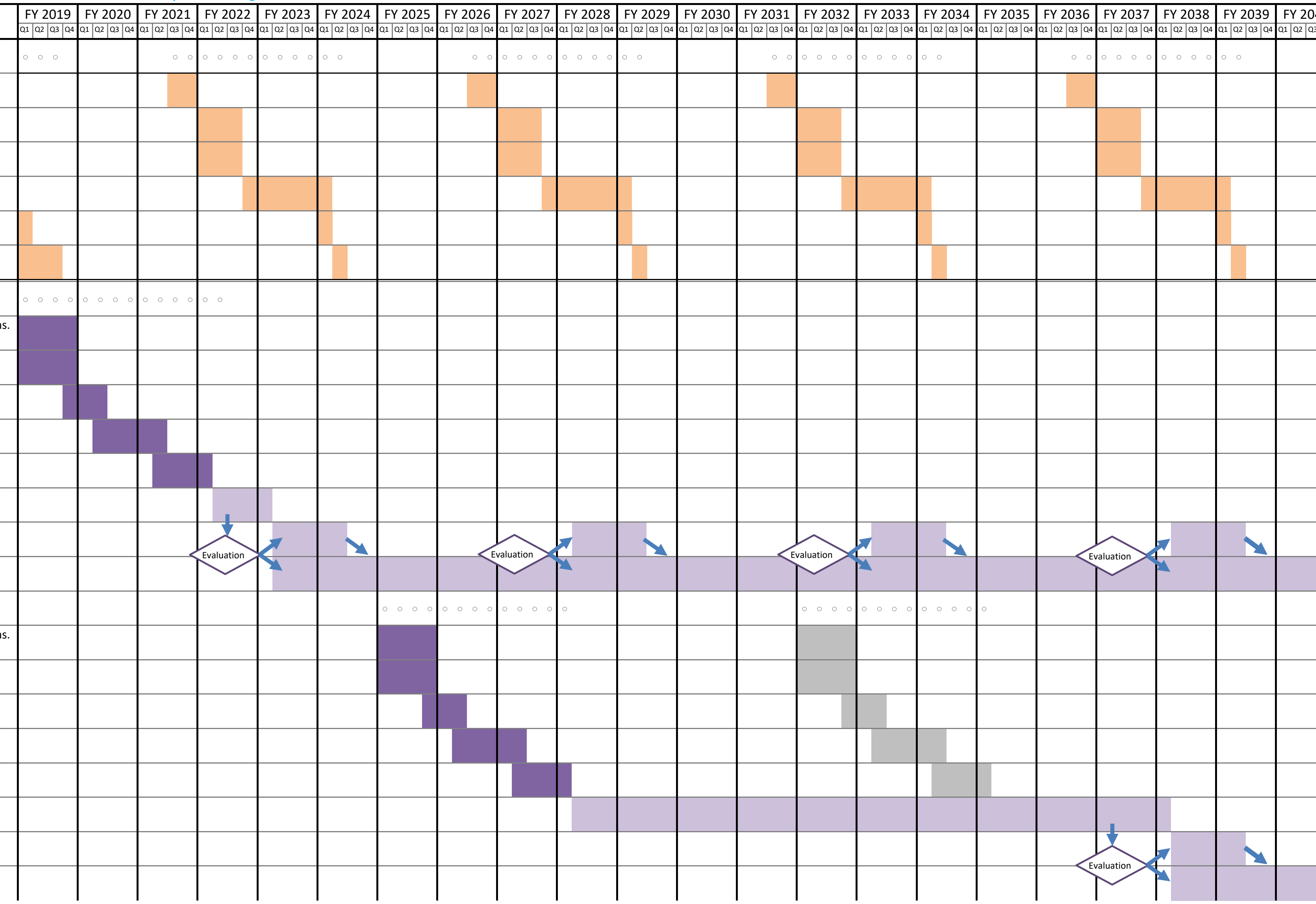
	21	D8, D9, D10, D11, S11	**Phase 1 Dual Plumbing Ordinance Development**	Stakeholder process will explore requiring dual plumbing for new large Commercial and Multifamily development (with a potable backup).
	22		Evaluation of potential implementation approaches	Evaluation to include refinement of ordinance scope, applicability, location in code, enforcement considerations.
	23		Preliminary stakeholder outreach	
	24		Develop draft ordinance language	
	25		Stakeholder outreach and draft code language changes as needed	
	26		Boards and Commissions and Council action	
	27		Implementation and monitoring	
	28		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	29		Maintain approach and continue monitoring	
	30		**Phase 2 Dual Plumbing Ordinance Development**	Stakeholder process will explore expanding ordinance's applicability to potentially include mid-size new commercial and multifamily (with a potable back-up required).
	31		Evaluation of potential implementation approaches	Evaluation to include refinement of ordinance scope, applicability, location in code, enforcement considerations.
	32		Preliminary stakeholder outreach	
	33		Develop draft ordinance language	
	34		Stakeholder outreach and draft code language changes as needed	
	35		Boards and Commissions and Council action	
	36		Implementation and monitoring	
	37		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	38		Maintain approach and continue monitoring	



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Implementation Outlook and Adaptive Management Plan

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Planning Cycles	1		**Integrated Water Resource Plan Development and Update Process**	
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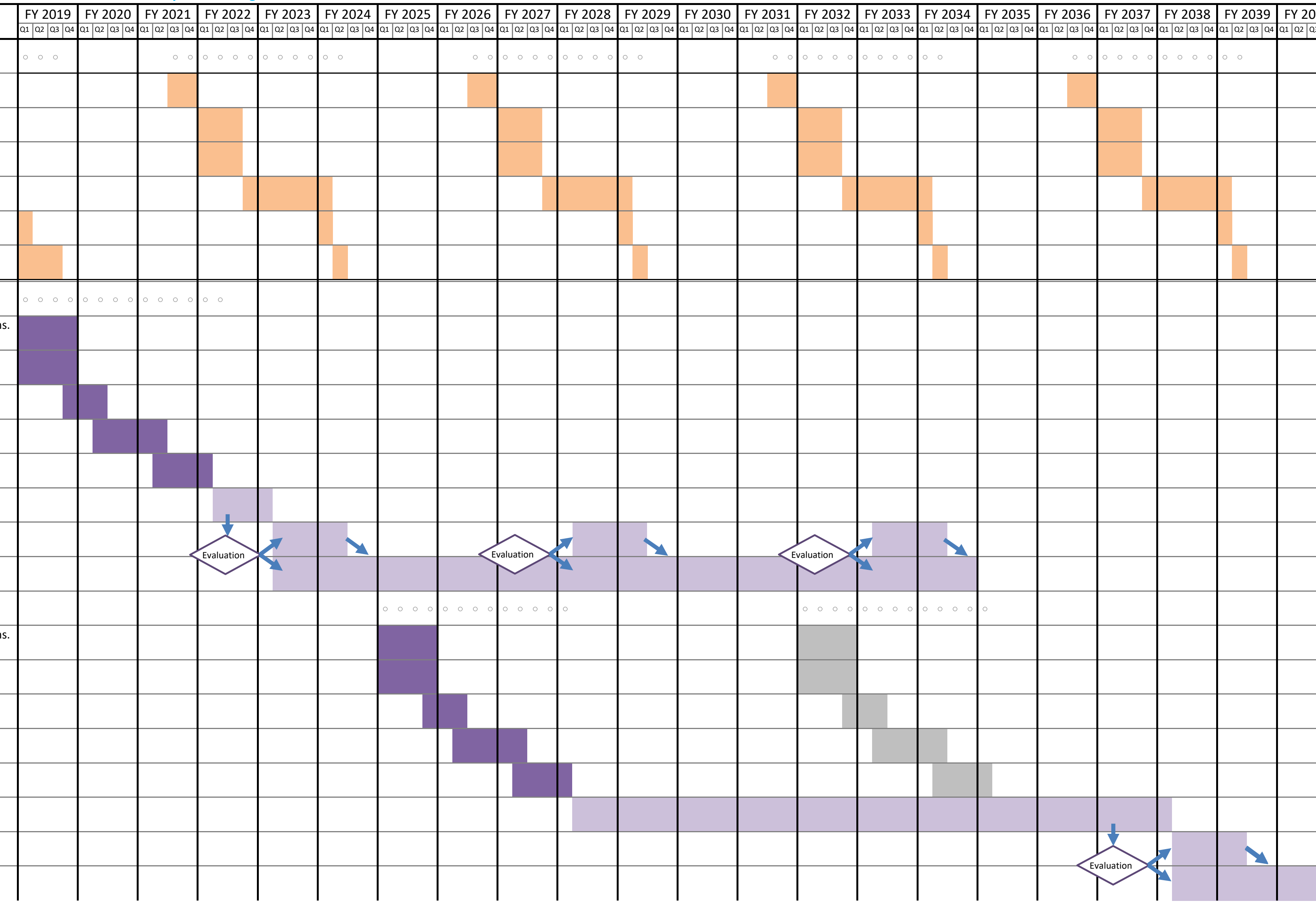
	4		Data Gathering and Preliminary Analyses	
	5		Plan Development Process	
	6		Target Final Plan Presentation To and Adoption By Council	
	7		Implementation Plan Development	
	39	D8, D9, D10, D11, S11	**Phase 1 Alternative Water Ordinance Development**	Stakeholder process will explore requiring use of alternative waters for new large Commercial and Multifamily development (with a potable backup).
	40		Evaluation of potential implementation approaches	Evaluation to include refinement of ordinance scope, applicability, location in code, enforcement considerations.
	41		Preliminary stakeholder outreach	
	42		Develop draft ordinance language	
	43		Stakeholder outreach and draft code language changes as needed	
	44		Boards and Commissions and Council action	
	45		Implementation and monitoring	
	46		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	47		Maintain approach and continue monitoring	
	48		**Phase 2 Alternative Water Ordinance Development**	Stakeholder process will explore expanding ordinance's applicability to potentially include mid-size new commercial and multifamily (with a potable back-up required).
	49		Evaluation of potential implementation approaches	Evaluation to include refinement of ordinance scope, applicability, location in code, enforcement considerations.
	50		Preliminary stakeholder outreach	
	51		Develop draft ordinance language	
	52		Stakeholder outreach and draft code language changes as needed	
	53		Boards and Commissions and Council action	
	54		Implementation and monitoring	
	55		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	56		Maintain approach and continue monitoring	



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Implementation Outlook and Adaptive Management Plan

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AW will continue to monitor AC Condensate Reuse and CII Ordinances that have recently been adopted into code.
NOTE: All process steps are not included on this informational visual.

	Row No.	Option No.	Task Name	Description
Planning Cycles	1		**Integrated Water Resource Plan Development and Update Process**	
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	4		Data Gathering and Preliminary Analyses	
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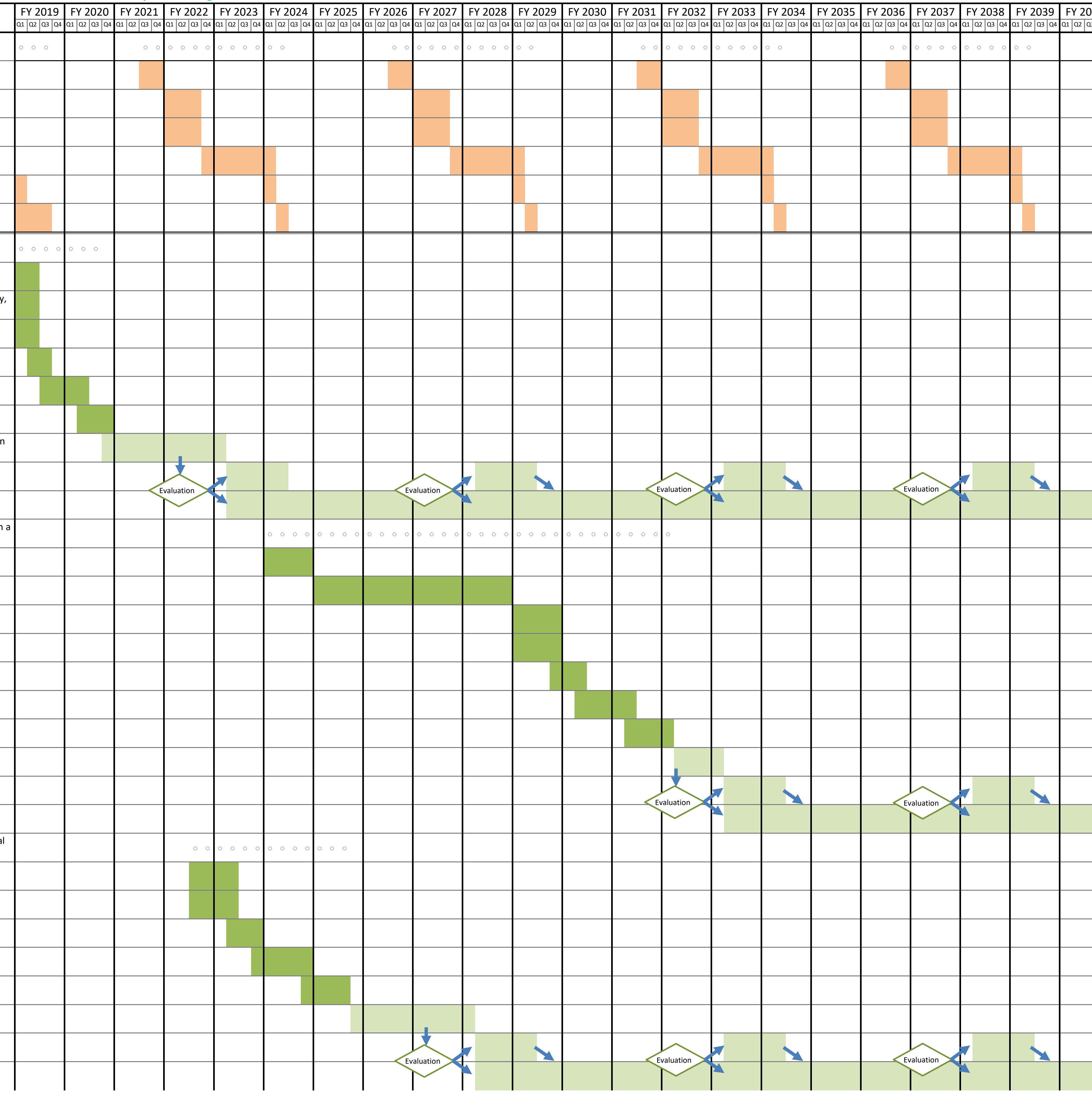
	7		Implementation Plan Development	
Developer or customer installed, owned, and operated	57	D4	**Phase 1 Development-focused Water Use Benchmarking and Budgeting - Submittal Process Development**	Stakeholder process to explore requiring submittal of water use estimates for new development.
	58		Development of water usage calculator	
	59		Evaluation of potential implementation approaches	Determination if an ordinance is needed - If so, process will include refinement of ordinance scope, applicability, location in code, enforcement considerations
	60		Preliminary stakeholder outreach	
	61		Develop draft ordinance language if needed	
	62		Stakeholder outreach and draft code language changes as needed	
	63		Boards and Commissions and Council action	
	64		Implementation	City staff will provide potential water use efficiency and alternative water recommendations and information on available incentive and rebate programs.
	65		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	66		Maintain approach and continue monitoring	
	67		**Phase 2 Development-focused Water Use Benchmarking and Budgeting Ordinance Development**	Stakeholder process will explore requiring new development to submit a water usage estimate and comply with a water budget - compliance mechanism to be determined.
	68		Public stakeholder process in advance of benchmark development	Stakeholder process will explore development of benchmarks to be applied to buildings developed post-2025.
	69		Data gathering and development of water usage database	
	70		Evaluation of potential implementation approaches (refinement of ordinance scope, applicability, location in	
	71		Preliminary stakeholder outreach	
	72		Develop draft ordinance language	
	73		Stakeholder outreach and draft code language changes as needed	
	74		Boards and Commissions and Council action	
	75		Implementation and monitoring	Starting in FY 2032, water budgets will be applied to development built post-2025.
	76		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	77		Maintain approach and continue monitoring	
	78	D5	**Landscape Transformation Ordinance**	Stakeholder process will explore requiring single-family residential to limit turf-grass area and include additional requirements for existing COM and MFR ordinance
	79		Evaluation of potential implementation approaches (refinement of ordinance scope, applicability, location in	
	80		Preliminary stakeholder outreach	
	81		Develop draft ordinance language	
	82		Stakeholder outreach and draft code language changes as needed	
	83		Boards and Commissions and Council action	
	84		Implementation and monitoring	
	85		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	86		Maintain approach and continue monitoring	



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Water Forward

Implementation Outlook and Adaptive Management Plan

AW will continue implementation of Advanced Metering Infrastructure and Water Loss Control utility initiatives.
AW will continue to monitor AC Condensate Reuse and CII Ordinances that have recently been adopted into code.
NOTE: All process steps are not included on this informational visual.

	Row No.	Option No.	Task Name	Description
Planning Cycles	1		**Integrated Water Resource Plan Development and Update Process**	
	2		Scope of Work and Project Schedule Development	
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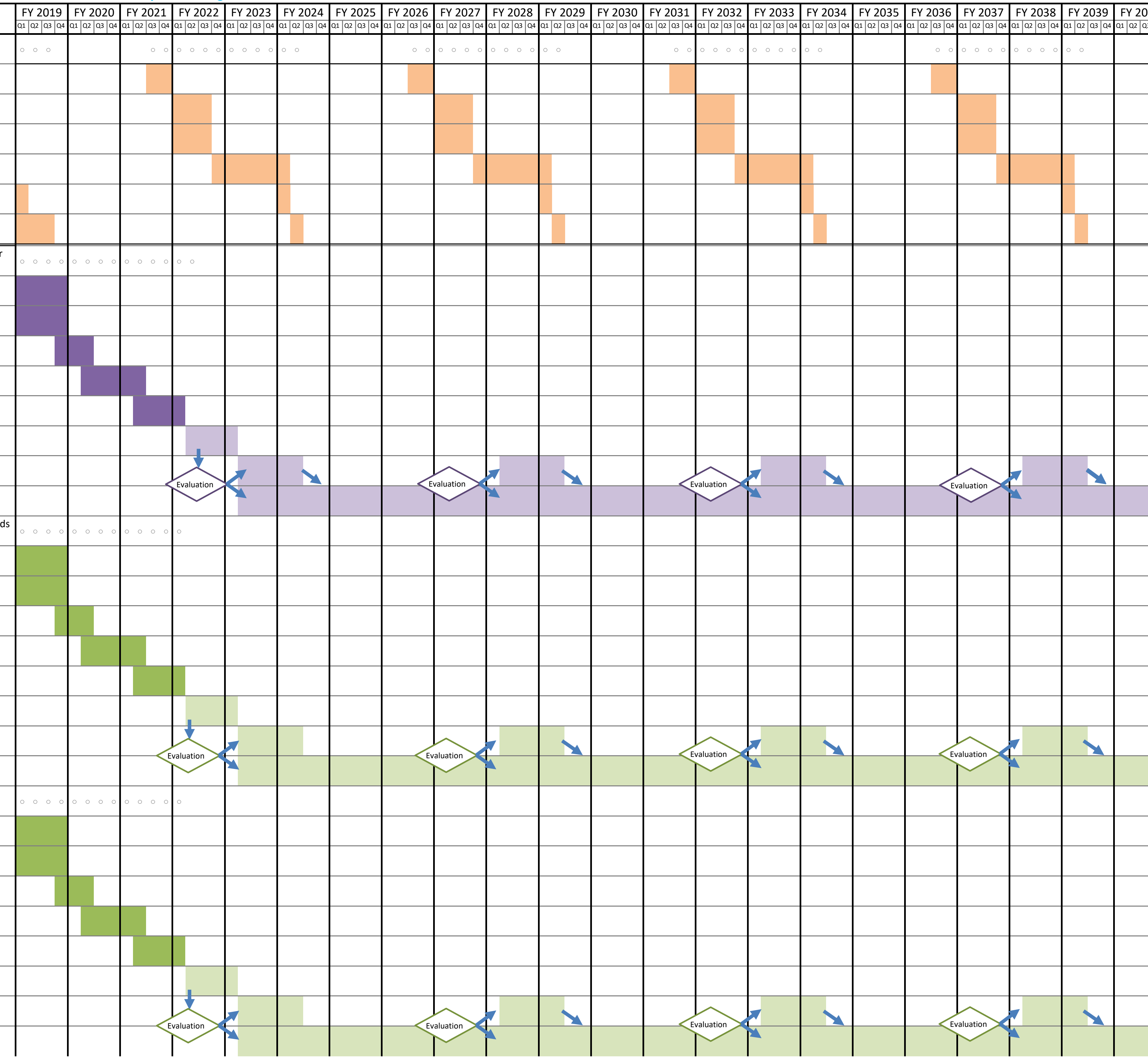
	4		Data Gathering and Preliminary Analyses	
	5		Plan Development Process	
	6		Target Final Plan Presentation To and Adoption By Council	
	7		Implementation Plan Development	
	87	D8, D9, D10, D11, S11	**Alternative Water Incentive**	Expansion of existing rebate program - incentive would encourage the use of rainwater harvesting, stormwater harvesting, graywater reuse, and blackwater reuse.
	88		Evaluation of potential implementation approaches	Evaluation to potentially include amount and/or type of incentive to offer.
	89		Preliminary stakeholder outreach	
	90		Program development and cost-benefit analysis	
	91		Stakeholder outreach and incentive program refinement as needed	
	92		Boards and Commissions Input	
	93		Program implementation and monitoring	
	94		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	95		Maintain approach and continue monitoring	
	96	D6	**Landscape Transformation Incentive**	Expansion of existing rebate program - incentive would encourage water use efficiencies and reduce water needs for outdoor irrigation through regionally appropriate landscapes
	97		Evaluation of potential implementation approaches	Evaluation to potentially include amount and/or type of incentive to offer.
	98		Preliminary stakeholder outreach	
	99		Program development and cost-benefit analysis	
	100		Stakeholder outreach and incentive program refinement as needed	
	101		Boards and Commissions Input	
	102		Program implementation and monitoring	
	103		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	104		Maintain approach and continue monitoring	
	105	D7	**Irrigation Efficiency Incentive (Expand existing rebate program)**	Expansion of existing rebate program - incentive would encourage use of include irrigation system controllers.
	106		Evaluation of potential implementation approaches	Evaluation to potentially include amount and/or type of incentive to offer.
	107		Preliminary stakeholder outreach	
	108		Program development and cost-benefit analysis	
	109		Stakeholder outreach and incentive program refinement as needed	
	110		Boards and Commissions Input	
	111		Program implementation and monitoring	
	112		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	113		Maintain approach and continue monitoring	



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Water Forward

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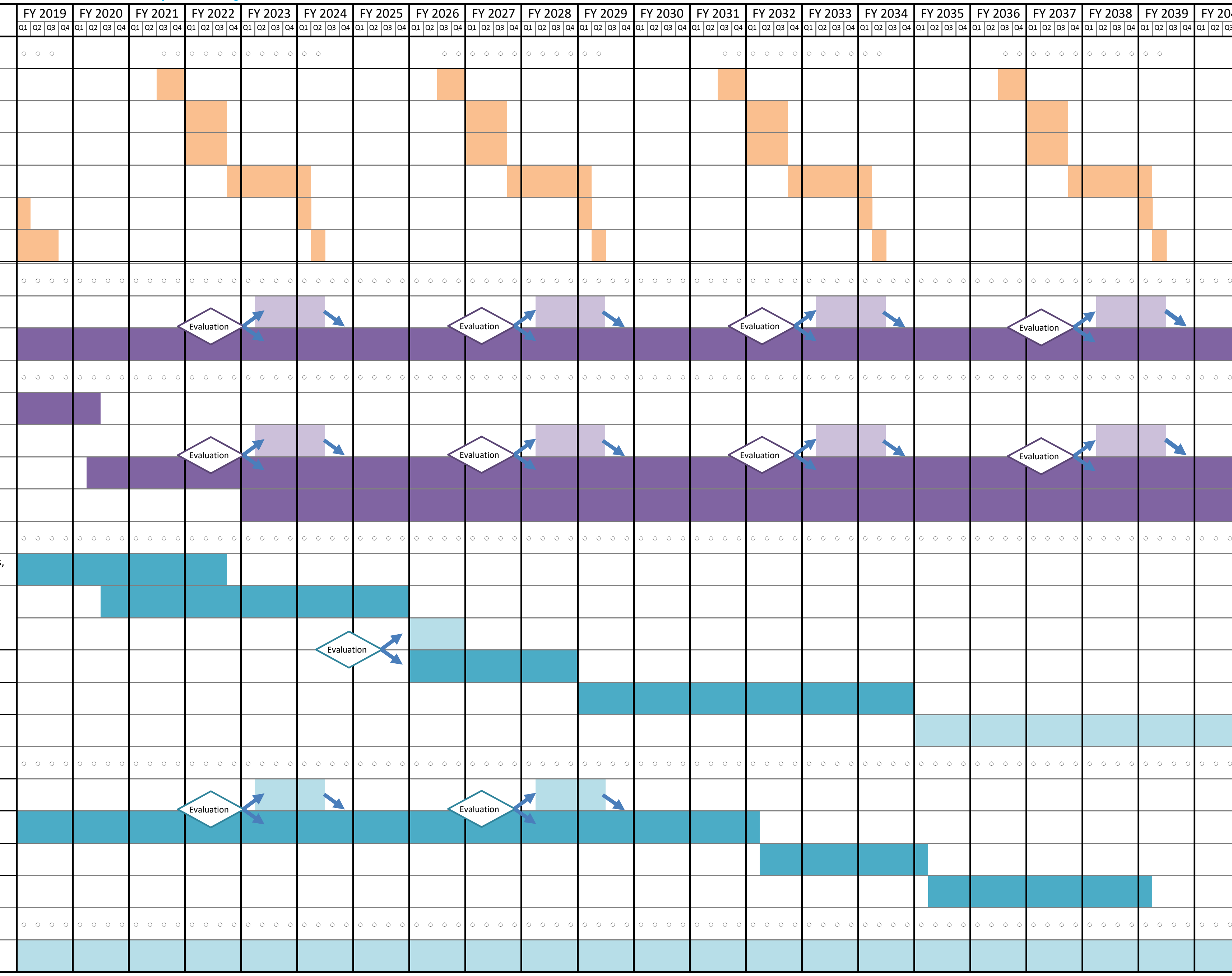
AW will continue implementation of Advanced Metering Infrastructure and Water Loss Control utility initiatives.
AW will continue to monitor AC Condensate Reuse and CII Ordinances that have recently been adopted into code.
NOTE: All process steps are not included on this informational visual.

	Row No.	Option No.	Task Name	Description
Planning Cycles	1		**Integrated Water Resource Plan Development and Update Process**	
	2		Scope of Work and Project Schedule Development	
	3		Consultant Procurement	
	4		Data Gathering and Preliminary Analyses	
	5		Plan Development Process	
	6		Target Final Plan Presentation To and Adoption By Council	
	7		Implementation Plan Development	
Potentially a combination	114	S3	**Centralized Reclaimed System (Direct Non-Potable Reuse)**	Implementation to focus on Reclaimed Master Plan through 2040.
	115		Approach refinement and/or implementation of other option(s) identified in plan update cycle	
	116		Maintain approach and continue implementation	
	117	S9, S10	**Decentralized Reclaimed (Community Scale Distributed Wastewater Reuse and Sewer Mining)**	
	118		Refinement of decentralized option analysis	
	119		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	120		Future additional decentralized reclaimed project identification	
	121		Decentralized reclaimed project design and construction	Implementation will consider timing and location of new development opportunities.
Utility constructed, owned and operated	122	S1	**Aquifer Storage and Recovery**	
	123		Further Study and Modeling, Permitting, Land Acquisition	Initial steps will include further study for pilot and full project, further modelling for operational considerations, land acquisition, legal and permitting considerations, and piloting
	124		Pilot Design, Construction, and Testing	
	125		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	126		Design of full-scale ASR facility	
	127		Construction of full-scale ASR facility	
	128		ASR fill/refill cycles	
	129	S5	**Indirect Potable Reuse (IPR) through Lady Bird Lake Capture Local Inflows to Lady Bird Lake**	Note: IPR option could be accelerated if required in a drought situation.
	130		Approach refinement and/or implementation of other option(s) in subsequent plan update cycle	
	131		Alternatives Analysis, Permitting, and Public Outreach	
	132		Design	
	133		Construction	
	134	S7, S2	**New Off Channel Reservoir and Brackish Groundwater Desalination**	
	135		Continued study and refinement of option	This phase to include public outreach and possible exploratory land acquisition efforts.



APPENDIX N: WATER FORWARD PLAN APPROVAL AND COUNCIL DIRECTION

Water Forward, Austin's Integrated Water Resource Plan, was recommended for approval by the Water Forward Task Force on October 9, 2018 and by the Water and Wastewater Commission on October 10, 2018. Austin's City Council unanimously approved adoption of Water Forward (with Council Member Troxclair off the dais) on November 29, 2018.

As a component of adoption, Council provided direction on Water Forward. This direction was captured in the meeting minutes, which can be found in the meeting minutes on page 10 at the following link: https://www.austintexas.gov/edims/document.cfm?id=312502. Excerpts from the minutes regarding Water Forward direction are included as follows for reference.

DISCUSSION ITEMS

3. Approve adoption of Water Forward, Austin's Integrated Water Resource Plan.

The motion approving adoption of Water Forward, Austin's Integrated Water Resource Plan with the following direction to staff was approved on Mayor Pro Tem Tovo's motion, Council Member Flannigan's second on a 10-0 vote. Council Member Troxclair was absent.

The following direction was given to staff by Mayor Pro Tem Tovo and Council Member Kitchen and accepted without objection.

1. **The City Manager is directed to work with city staff and the Water Forward Task Force to accelerate, to the greatest extent feasible, the implementation timeline for these specific strategies:**
    - **Dual Plumbing**
    - **Landscape Transformation**
    - **Development-Focused Water Benchmarking and Budgeting, and**
    - **Alternative Water Ordinances.**
2. **The City Manager is also directed to work with staff to ensure substantive stakeholder outreach and involvement regarding the location of any future Aquifer Storage and Recovery Facility.**
3. **The City Manager is further encouraged to explore the benefit of coordinated stakeholder outreach for the development of multiple ordinances, both to maximize staff time and resources as well as to expedite the timeline for implementation.**

The following direction was given to staff by Council Member Alter and accepted without objection.

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- Council directs the City Manager to have Austin Water coordinate an effort for each City of Austin Department to assess its building and structures, including city pools, with a goal to reduce or eliminate water loss due to leaks and inefficiencies.
- Council directs the City Manager to consider using cost-saving Texas Water Development Board funding options, or other outside funding sources such as loans or grants for water projects whenever possible.
- Concurrent to ordinance development, consider advancing educational materials, training and facilitation of demonstration projects, particularly with regard to dual plumbing.
- Council directs the City Manager to consider a stage in the City's permitting process to discuss with large developments how to incorporate water conservation strategies early in the design phase.
- Council directs the City Manager to consider methods for interdepartmental collaboration to work to help ensure we have a skilled and developed workforce, including but not limited to plumbing professionals, ready to implement alternative water strategies for buildings and development and to identify whatever resources the City may need to bring to bear to support the necessary training.

The following direction was given to staff by Mayor Adler and accepted without objection.

- The City Manager should expedite the timeline of all codes and ordinances recommended by Water Forward, where feasible, to increase the City's resilience to the next drought.
- The City Manager and Austin Water should consider orienting impact fees and rates to promote Water Forward so that any change to fees and rates is done with the lens of advancing of Water Forward.
- The City Manager should align Austin Water and Watershed Protection Department to advance Water Forward through reporting structures and performance metrics to drive continued and enhanced integrated water management between the Utility and Watershed Protection.
- When considering ordinances related to on-site strategies, the City Manager should consider opportunities to extend these strategies to entire master planned developments, including PUDs and other special districts.
- The City Manager should consider creating a Research & Development unit with the water utility to advance business model innovations, leveraging new developments as an opportunity to test and deploy new technologies, operational strategies, and revenue structures.

The following direction was given to staff by Council Member Pool and accepted without objection.

- To the extent possible, to find other sources other than the Carrizo-Wilcox Aquifer that would be closer to Austin.