



2017 Water Management Plan



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Revised 11/7/17

ON THE COVER: San Antonio Water System's commitment to the community's water future is exemplified by new water supply projects such as the Vista Ridge public-private partnership (top), conservation outreach efforts such as its annual Spring Bloom gardening festival (middle), and innovative technology such as its new brackish groundwater desalination plant (bottom).

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Executive Summary

As San Antonio approaches a celebration of its 300th founding anniversary, and as San Antonio Water System celebrates its 25th anniversary, it's important to note how water was a critical factor in the founding of the city and continues to be the cornerstone of its vitality and development.

In its relatively short history, SAWS is now one of the largest municipal water utilities in the country providing water and wastewater services for more than 1.8 million people in San Antonio and surrounding areas. Nationally recognized for sustainable and responsible management, SAWS oversees existing water supplies while developing new water sources for the future – helping diversify its water supply and ensuring sustainable, affordable water services for generations.

The Water Management Plan serves as a guide to meet San Antonio's future water needs. SAWS' first Water Management Plan was developed in 1998, introducing projected water demands and identifying the framework of future water sources to meet these demands. Since that first plan, SAWS has continuously produced updates incorporating changes in population, water demand patterns, regulations, and water supply options providing a clear direction for implementation. Significant changes required updates to the Water Management Plan in 2005, 2009, and 2012. The most extensive revision occurred in 2012, with the assumption of the former Bexar Metropolitan Water District and the incorporation of the Edwards Aquifer Habitat

Conservation Plan. Since the adoption of the 2012 Water Management Plan, SAWS has completed the Regional Carrizo (Gonzales County) and Brackish Groundwater Desalination (Bexar County) projects, participated in successful implementation of the Edwards Aquifer Habitat Conservation Plan, exceeded GPCD expectations, and navigated through the worst drought since the 1950's drought of record. The 2017 Water Management Plan further refines and improves on the 2012 Water Management Plan utilizing better modeling tools, greater operational knowledge of diversified supplies through drought, disaggregated customer demands, risk management, as well as an improved understanding of climatic conditions. This plan is the starting point for securing San Antonio's water future.

On the local level, implementing this plan will require incorporation into annual operations and capital improvement budgets and may require revisions to various City of San Antonio ordinances as well as SAWS policies and procedures. The plan will also be incorporated into the State of Texas Water Plan through the regional planning process. The 2017 Water Management Plan continues the long-standing tradition of planning for and implementing a balanced mix of water supply projects and progressive water conservation programs.

Diversified Water Supply

SAWS boasts the largest direct recycled water system in the country, the largest groundwater based Aquifer Storage & Recovery (ASR) facility in the nation, and several innovative infrastructure-sharing arrangements with regional partners. In addition, SAWS recently opened the Brackish Desalination Plant at H₂Oaks Center with the capacity to produce 12 million gallons of drinking water daily.

Since the 2012 Water Management Plan, several significant events have occurred to secure San Antonio's water future:

- Regional Carrizo Water Project was brought on line in 2013, providing more than 10,000 acre-feet of water in both 2015 and 2016 from the Carrizo Aquifer in Gonzales County to San Antonio.
- The SAWS H₂Oaks Desalination Plant and water center began operations in January 2017.
- SAWS ASR at H₂Oaks has reached a record storage volume of more than 143,000 acre-feet, which is over half a year's potable demand.

With plans to be on line in early 2020, SAWS is actively working on the 142-mile Vista Ridge project – the newest water resource to continue diversifying the city's water

supply. As one of the largest water Public-Private Partnerships (P3), this project is being led on the private company side by Garney Construction. Design for the project is well advanced, well drilling has begun and pipe is being put in the ground. When it comes on line, this game-changing project will satisfy 20 percent of SAWS demand, and serve as added protection for the Edwards Aquifer during drought conditions.

With the addition of the Vista Ridge project, SAWS' already robust water supply inventory will be increased to feature 16 different water supply projects from nine different water sources. By continuing to develop non-Edwards Aquifer supplies, SAWS will continue to reduce its reliance on the Edwards Aquifer throughout the planning period. This dedication to diversification and commitment to strategic water planning ensures San Antonio will have plentiful water for generations to come.

Figure 1-1: SAWS will continue to reduce reliance on the Edwards Aquifer by bringing in new supplies, as seen in its planned inventory during drought years.



World Class Water Conservation

San Antonio's long-standing commitment and investment in water conservation and infrastructure improvements has yielded its largest water supply. SAWS' total per capita water consumption has decreased significantly from 225 gallons per capita per day (GPCD) in 1982 to 117 GPCD in 2016, which has resulted in approximately 3.2 million acre-feet of cumulative savings. Using today's larger population, a total per capita of 225 GPCD would require an additional 215,000 acre-feet of water per year. SAWS has successfully cultivated an ethic of conservation and invested in infrastructure over the past 35 years and effectively reduced GPCD by approximately 50 percent, all while SAWS' service area population has grown by approximately 150 percent.

Water conservation continues to be a strategy for long-term water supply. New water conservation investments are projected to result in approximately 4.3 million acre-feet of cumulative water savings by 2070, and will replace the need for approximately 132,000 acre-feet per year of new water projects.

Figure 1-2: SAWS conservation events such as Spring Bloom educate thousands of people each year on the many benefits of drought-tolerant landscaping.



Over the last five years, many initiatives have contributed to SAWS' progress in extending San Antonio's water supplies through conservation.

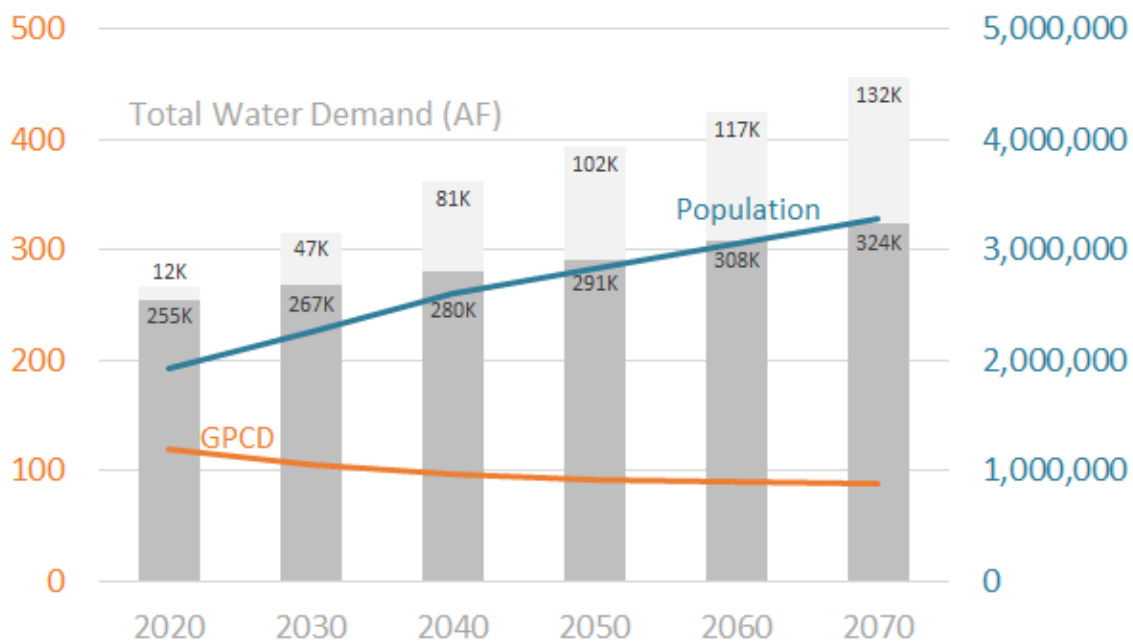
Highlights of newer programs include:

- Over 2 million square feet of water-intensive grass has been replaced with low water-use plants or permeable patios through WaterSaver Landscape Coupon programs.
- WaterSaver Irrigation Consultations providing home irrigation and landscape education visits have reduced household usage by 84 million gallons every year.
- The GardenStyleSA.com website and e-newsletter providing timely San Antonio-focused low water use landscape information to reduce outdoor watering.
- SAWS has partnered with The University of Texas at Austin based Pecan Street to develop an integrated conservation platform that will expand water conservation opportunities in the future.

SAWS' 2017 Water Management Plan assumes a total demand in 2070 that is approximately 75,000 acre-feet per year less than the 2012 Water Management Plan.

SAWS' 2017 Water Management Plan strives for a reduction of residential consumption to 55 GPCD by 2070, and a total consumption (to include commercial, industrial and non-revenue water) of 88 GPCD by 2070.

Figure 1-3: SAWS aims to achieve a total GPCD of 88 by 2070 for a total demand of 324,000 AFY. If SAWS were to remain at 124 GPCD through 2070, SAWS demand would be an additional 132,000 AFY, as identified in the light gray bars below.



Even with a significantly higher population projection than the 2012 Water Management Plan, the 2017 Water Management Plan assumes a total demand in 2070 that is approximately 74,000 acre-feet per year **less** than the 2012 Water Management Plan, as a result of SAWS' realized and anticipated water savings from conservation.

Visionary Planning

SAWS' 2017 Water Management Plan introduces a number of topics of growing public interest that are new to the document, although not new to SAWS planning. For the first time, SAWS customers will be able to see how SAWS projects demand by customer class (versus total demand), using its disaggregated demand model. One component of SAWS demand is how much water is accounted for as nonrevenue, which this document expands upon in Section 6.

Acknowledging that the climate may become more challenging in the future, the 2017 Water Management Plan includes comprehensive preparations for historic drought scenarios. In collaboration with the City of San Antonio (CoSA), SAWS has begun to

evaluate the potential challenges posed by more extreme weather conditions, and believes that it is uniquely well positioned to manage those challenges, as outlined in Section 13. One way that SAWS is incorporating these issues is by planning for a more severe, hybrid Drought of Record, which merges the duration of the drought of the 1950s with the intensity of the 2011-2014 drought. This hybrid model results in an additional cutback to SAWS Edwards Aquifer permit of one-half percent during three years of the nine-year drought period. Stated another way, SAWS permitted Edwards Aquifer inventory reduces during that nine-year drought period from 1,645,000 acre-feet, to 1,639,000 acre-feet. This is being done to add conservatism to this plan, and to account for changing climatic conditions. This hybrid Drought of Record is a layer of conservatism that is in addition to the layer of conservatism that SAWS has been using for its last two Water Management Plans: projecting supply and demand during a 108-month drought, versus the 77-month drought used in the State Water Plan.

Section 12 of this document addresses the increasingly important topic of water supply integration, as SAWS continues to diversify and grow its water supply portfolio. Finally, in order to convey all of these exciting new features, SAWS is leveraging technology and social media to inform customers and solicit input, as discussed in Section 17.

***Waterful* Solutions – One Regional Water Community**

Coined by the US Water Alliance, the One Water approach re-frames the urban water cycle as a single integrated system, in which all flows are recognized as potential resources. Within this system, the interconnectedness of surface water, groundwater, stormwater and wastewater is optimized. The One Water approach strives for greater coordination among diverse stakeholders, recognizing that water quantity and quality depends on multi-faceted collaborations. San Antonio leads the country in *Waterful* solutions – providing sustainable innovations for water management and developing holistic water solutions for the San Antonio area.

Sustainability

As a nationally recognized leader in water conservation, SAWS demonstrates its commitment to sustainability through significant investments in conservation programs. Early conservation efforts achieved significant reductions in indoor usage at homes and businesses. Newer programs are primarily aimed at achieving reductions in outdoor irrigation through a wide variety of education efforts, incentive programs, and development of reasonable regulations for both residences and businesses.

San Antonio is building resiliency via a number of different strategies, including but not limited to the following:

- SAWS helps businesses reclaim condensate water for use on-site as irrigation or other non-potable applications.
- Accomplishment of the trifecta in wastewater treatment:
 - Highly treated effluent water is reused in the largest direct recycled system in the U.S.
 - Methane gas is captured and sold on the natural gas market.
 - Solids are reused and sold as compost.
- Generating and saving energy:
 - Partnering with CPS Energy to develop a 20 MW solar panel field on SAWS property, among the largest solar fields in the state.
 - Implementing peak energy avoidance programs at SAWS' Water Recycling Centers.

Figure 1-4: Water Energy Nexus – CPS Energy utilizes SAWS property at Dos Rios Water Recycling Center to generate up to 20 megawatts of solar energy.

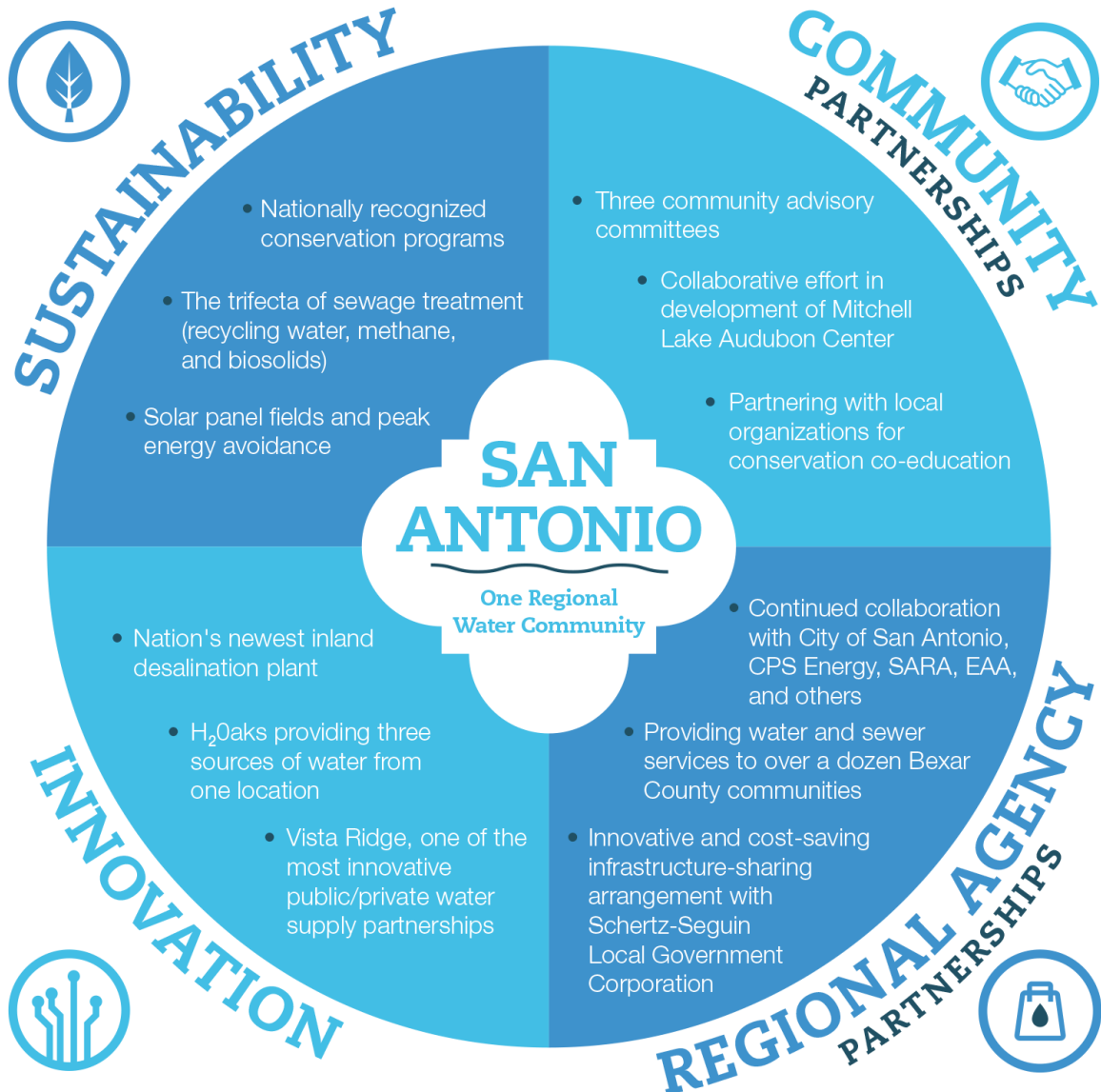


Community Partnerships

- Volunteer committees such as the Citizens Advisory Panel and Community Conservation Committee provide valuable customer insight to the SAWS Board of Trustees and management on water and conservation projects.
- Community and environmental groups worked with SAWS to develop Mitchell Lake Audubon Center, a natural wonder that attracts people from around the world and helps educate current and future generations on the environment.
- SAWS has seven programs to ease the burden of utility costs for customers who qualify: Project Agua, Affordability Discount, Disability Billing, Courtesy Notice, Senior Citizen Billing, Plumbers to People, and Laterals to People. These programs help ensure all residents have access to life-sustaining water and sewer services. SAWS works with CoSA Department of Human Services on several programs. SAWS has nearly 25,000 people enrolled in the Affordability Discount Program, as of August 2017. SAWS also allocates over \$200,000 annually to Project Agua, its payment assistance program. It is also worth noting

that SAWS water rates continue to utilize a tiered structure to incentivize lower water consumption, while striving to ensure that life essential uses of water are made as affordable as possible.

Figure 1-5: Waterful Solutions – Local and regional partnerships allow for a unified One Water approach to water management and conservation.



Regional Agency Partnerships

- Through coordination with the Edwards Aquifer Authority (EAA), San Antonio River Authority (SARA), and CoSA, SAWS' efforts help ensure high water quality and healthy waterways. SAWS assists customers in creating rain gardens through the WaterSaver Landscape Coupon program, as well as collaborating with SARA on this and many other sustainability initiatives.

- The Regional Carrizo Water Project was developed in coordination with the Schertz-Seguin Local Government Corporation, utilizing a shared pipeline to bring water pumped in Gonzales County to San Antonio, saving both entities millions of dollars.
- SAWS continues to participate in the very successful Edwards Aquifer Habitat Conservation Plan, the largest such plan in the country in terms of financial contributions, covered species and mitigation activities.
- Since 2003, SAWS has been proactive in identifying potentially impacted wells surrounding H₂Oaks. As of mid-2017, over \$6.4 million has been spent, mitigating 159 wells.
- SAWS supports local communities in Gonzales County to ensure any potential water supply impacts from the Regional Carrizo project will be mitigated, having spent \$1.8 million in communities in Gonzales County. These measures include executing separate agreements with the City of Nixon to rehabilitate existing wells and Gonzales County Water Supply Corporation to drill a new well. Additionally, SAWS participates in a well mitigation fund managed by the Gonzales County Underground Water Conservation District, which provides mitigation assistance to local landowners.
- The Vista Ridge project is located in Burleson and Milam Counties within the jurisdiction of the Post Oak Savannah Groundwater Conservation District. The District is developing a Groundwater Well Assistance Program for the purpose of ensuring uninterrupted water supply to District well owners.

Innovation

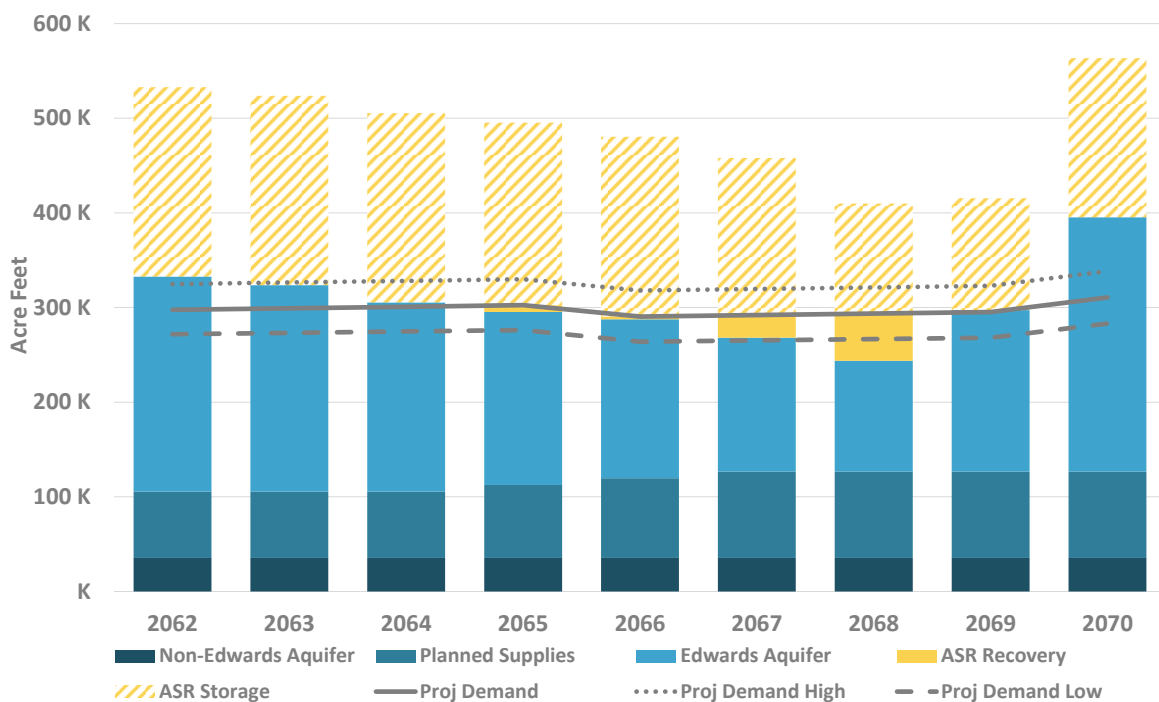
- The nation's newest inland desalination plant – H₂Oaks Center – is the only known place in the U.S. that maximizes efficiency by providing three different sources of water from one site:
 - Desalinated brackish water from deep underground Bexar County
 - Water stored in the ASR that was originally permitted from the Edwards Aquifer
 - Locally pumped Carrizo Aquifer water
- Vista Ridge, the newest water project currently under construction, is one of the most innovative water projects in the country, and has become a global model of public-private partnerships. Through unprecedented public contract negotiations, this privately developed, regionally based water project protects San Antonio ratepayers from development and regulatory risk during the 30-year contract term.

- CoSA's Office of the City Manager and Office of Innovation have initiated a forum to develop a community-wide vision for San Antonio as a Smart City. SAWS Department of Continuous Improvement and Innovation, among others, are participating in this important effort, along with virtually every major public and private stakeholder in the community.
- Through SAWS' participation in the state-wide Technology Approval Group, SAWS has been working with Isle, an independent technology and innovation consultant forum that facilitates connecting mature innovation opportunities with a utility's customized needs. Participating in these synergistic collaborations has numerous benefits, both for SAWS and its peer organizations.

Water for Generations

Through the development of diversified water supply projects, advanced water conservation efforts, and the efficient management and operation of its water supplies, SAWS will have water security in the driest of dry times through at least 2070.

Figure 1-6: SAWS ensures water for generations by setting progressive demand goals with stage 1 and 2 landscape watering restrictions, and then evaluating the need to develop future planned supplies. Scenario below represents a Drought of Record.



The SAWS Board of Trustees and management recognized significant changes that have occurred over the last five years. This began a new round of water supply planning, including critical review of supply, demand, conservation, nonrevenue water, integration, climatic conditions, risk management, financial impacts, and community perspectives. The task force that worked on developing the new plan consisted of:

- Robert R. Puente, President/CEO
- Mary Bailey, Vice President Accounting & Business Planning
- Andrea Beymer, Vice President Engineering & Construction
- Donovan Burton, Vice President Water Resources & Governmental Relations
- Steve Clouse, Senior Vice President & Chief Operating Officer
- Doug Evanson, Senior Vice President & Chief Financial Officer
- Steve Kosub, Esq., Senior Water Resources Counsel
- Gavino Ramos, Vice President Communications & External Affairs

2 Geography, Geology and Climate

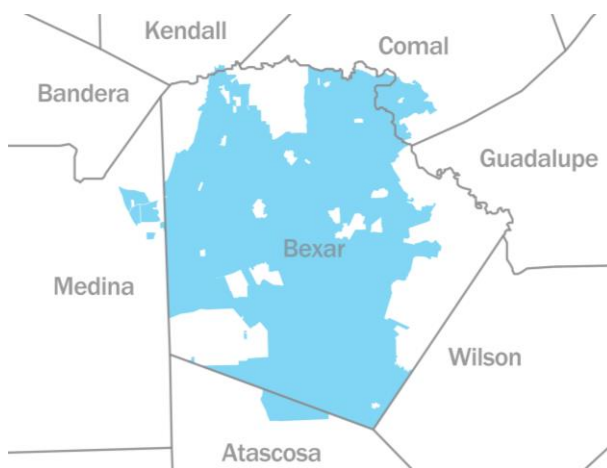
San Antonio's location provides unique water opportunities and challenges. Three areas key to water analysis and planning are: Geography; geology; and climate.

Geography

SAWS' service area encompasses 967 square miles in Bexar County and parts of four surrounding counties. SAWS' service area includes the city limits of San Antonio and several smaller incorporated cities, as well as surrounding unincorporated areas.

Elevations vary from about 500 feet above sea level in the southeast to more than 1,400

Figure 2-1: San Antonio Water System's service area encompasses 967 square miles in five counties.



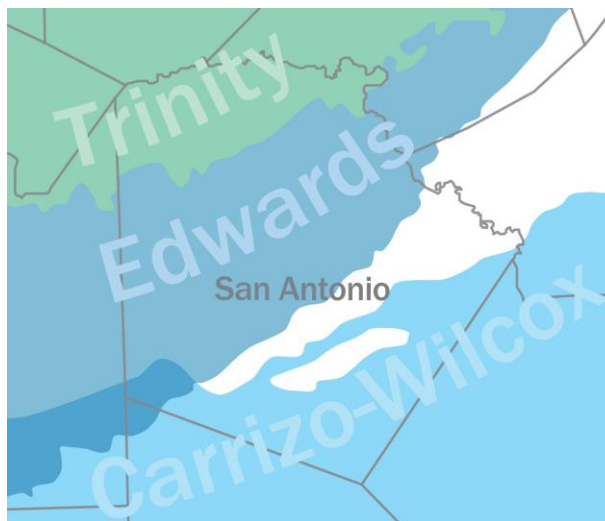
feet above sea level in the northwest.

The San Antonio Economic Development Foundation estimates that the 2016 population of the city of San Antonio was 1,440,900. The U.S. Census Bureau estimates the 2016 population of Bexar County to be 1,928,680. The estimated 2017 population projection for the SAWS service area is 1,817,387 people. The Bureau currently ranks San Antonio as the second largest city in Texas and the seventh largest city in the U.S.

Geology

The San Antonio region overlies portions of four major aquifers. The most notable is the Edwards Aquifer, a prolific karst limestone aquifer which has always served as San Antonio's cornerstone source of water supply. SAWS also utilizes to a lesser degree water resources from the Trinity Aquifer, the Carrizo Aquifer and the Wilcox Aquifer.

Figure 2-2: SAWS is fortunate to be in close proximity to four major aquifer systems.



Climate

San Antonio's climate is classified as modified humid subtropical. Its location between a semi-arid area to the west and a much wetter and more humid area to the east often results in large variations in monthly and annual precipitation amounts. The average high monthly temperatures range from 62 degrees in January to 95 degrees in July and August. The average low monthly temperatures range from 39 degrees in January to 74 degrees in July and August. The 30-year average (1981-2010) annual precipitation for San Antonio is 32 inches. Perhaps more significant than annual total rainfall is that rainfall is highly variable. Long dry periods can be punctuated by some of the highest rainfall intensities in the world.

Climate variability increases the difficulties in water management planning.

The combined impacts of geography, geology and climate impact both water supply and water demand in complex ways. Extreme weather can reduce availability of some water supplies, while concurrently increasing demand for water (or vice versa). SAWS deploys a variety of strategies to manage this challenge that include supply diversification, adding drought-firm

supplies, and reducing weather-related water demand through focused water conservation initiatives.

3

Current Water Supply Portfolio

SAWS has one of the most diversified and innovative water supply portfolios in the country. Over the last 20 years, SAWS has been a national leader in developing water supply for the purposes of reducing its reliance on the Edwards Aquifer and diversifying its portfolio, planning for one of the highest population growth corridors in the nation, and preparing for drought. San Antonio leadership has worked over these last 20 years to radically change the water supply situation, thereby sustaining a thriving economy.

In planning for future water supplies, SAWS applies Drought of Record (DOR) conditions to all water supplies in its current inventory to calculate firm yield. The drought of the 1950s in Texas is widely recognized as the Drought of Record for water resource planning purposes (SAWS plans for 108 months of drought and Texas Water Development Board (TWDB) plans for 77 months of drought). Firm yield is defined by SAWS as the volume of water which can be produced from a specific source during a repeat of the Drought of Record under existing regulatory, legal, contractual, hydrological or infrastructure constraints. An innovative feature of SAWS' 2017 Water Management Plan is that the hydrological and regulatory constraints experienced in the 2011-2014 drought and the 1950-1958 drought were merged, to create a more severe, hybrid Drought of Record which adds a level of conservatism to water supply planning.

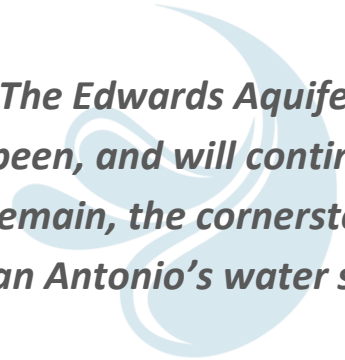
SAWS has numerous water supply contracts with various terms and expiration dates. Water supplies available by contract will not be accounted for after the term in which the current contract expires, unless an extension option for SAWS is unilateral. This

assumption by SAWS is not an evaluation of the merits of these contracts or supplies which are not assumed to be extended, but is simply an equitable methodology for planning purposes.

SAWS currently has access to the following supplies for providing water:

Edwards Aquifer Authority (EAA) Permit

The Edwards Aquifer has been, and will continue to remain, the cornerstone of San Antonio's water supply. SAWS currently holds permits issued by the EAA to produce approximately 292,000 acre-feet per year of Edwards Aquifer groundwater with approximately 88 percent of this amount owned and the remainder under lease to SAWS. Production under these permits is subject to regulatory cutbacks up to 44 percent during periods of drought. In addition to the regulatory cutbacks, SAWS has agreed to not produce approximately 8,000 acre-feet per year through 2027 for the benefit of the Edwards Aquifer Habitat Conservation Plan (EAHCP). In another agreement for the benefit of the EAHCP, SAWS has agreed to reduce (forebear) pumping by up to 46,300 acre-feet during any single year or 126,000 acre-feet aggregate during the term of the agreement under conditions replicating the 1950s Drought of Record. SAWS has conservatively planned for the continuation of this EAHCP commitment throughout the planning horizon. In order to successfully meet the needs of both SAWS customers and the EAHCP, SAWS will reduce its reliance on the Edwards Aquifer by approximately 11,000 acre-feet per year, through the non-renewal of yet-to-be-determined Edwards Aquifer lease agreements. The reduction in Edwards Aquifer inventory allows for a more successful implementation of the flow protection measures identified to fulfill the goals of the EAHCP. SAWS is to maintain approximately 281,000 acre-feet per year of EAA-permitted groundwater withdrawal rights, through a variety of procurement methods, including buying, leasing, and/or a potential dry year option.



The Edwards Aquifer has been, and will continue to remain, the cornerstone of San Antonio's water supply.

- **Edwards Aquifer Habitat Conservation Plan (EAHCP)** – Development and implementation of the nationally recognized EAHCP has been undertaken by a remarkably diverse set of stakeholders and interest groups from throughout the Edwards Aquifer region. The EAHCP will be in place until 2027; however, the necessity to balance the needs of the human users of the Edwards Aquifer and the federally-listed threatened and endangered species associated with it will remain. Some form of aquifer management for periods of record-breaking drought stress will be required to continue.

Figure 3-1: The Texas blind salamander is one of eight species in the Edwards Aquifer ecosystem that have been designated as either threatened or endangered.



While those future forms of aquifer management cannot be predicted, SAWS has chosen to continue to represent the EAHCP commitment on the water supply and demand charts beyond the expiration of the present EAHCP.

- **Water Quality - Protecting the Edwards Aquifer** – As previously mentioned, the Edwards Aquifer is San Antonio's cornerstone supply of water. Protecting the water quality of this resource is of the utmost importance to San Antonio and the surrounding region. As described in the Natural Resources and

SAWS' water quality protection program is one of the most aggressive in the state of Texas.

Environmental Sustainability planning element of the CoSA's SA Tomorrow Comprehensive Plan, SAWS' water quality protection program is one of the most aggressive in the state of Texas. SAWS implements a number of programs directed at protecting the watershed that provides source water to this wonderful resource by enforcement of regulatory requirements,

review and analysis of development plans over the recharge zone, monitoring of construction sites, utilizing an extensive sampling and monitoring network for water quality compliance, and stormwater education among others. SAWS along with the CoSA has made progress ensuring that this natural resource will always remain the cornerstone of San Antonio's water supply.

- Sensitive Land Acquisition Program
 - As a result of propositions in 2000, 2005, 2010, and 2015 elections, San Antonio citizens have overwhelmingly voted in support of a 1/8-of-a-cent addition to the sales tax, for purchasing conservation easements that will protect the sensitive land located over the Edwards Aquifer recharge zone and contributing zone. The Edwards Aquifer Protection Program (EAPP) has balanced growth with land and water stewardship by conserving approximately 146,000 acres, to date.
- Aquifer Protection
 - Implementing a series of programs comprising aquifer protection and evaluation including: groundwater resource protection, industrial compliance, construction compliance, sampling and monitoring, and fats, oils and grease abatement.
 - As part of these protection programs, SAWS reviews and analyzes development plans over the recharge zone of the Edwards Aquifer. Following the development of the properties, inspections and testing occur to ensure approved protections are maintained and functioning.
 - In partnership with the San Antonio Police Department and CoSA's Solid Waste Management Department, SAWS hosts Med Drop SA, a safe and easy way to dispose of unwanted medicines. Medications are accepted at no charge, and disposed of in a safe, legal way – keeping these drugs off San Antonio streets and out of the environment. Since the program's inception in 2009, over 40,000 pounds have been collected.
 - A water quality monitoring program is in place to assist in improving the quality of water flowing through streams ultimately providing beneficial recharge to the Edwards Aquifer.
 - Special care is given to ensure wastewater is safely transported across the Edwards Aquifer recharge zone without any adverse impacts. The wastewater collection system over the recharge is inspected every five years with mechanical components inspected annually. These inspections are designed to proactively identify threats before they occur.

SAWS will continue to work with CoSA and others to ensure the water quality of the Edwards Aquifer is protected for generations to come.

H₂Oaks Center

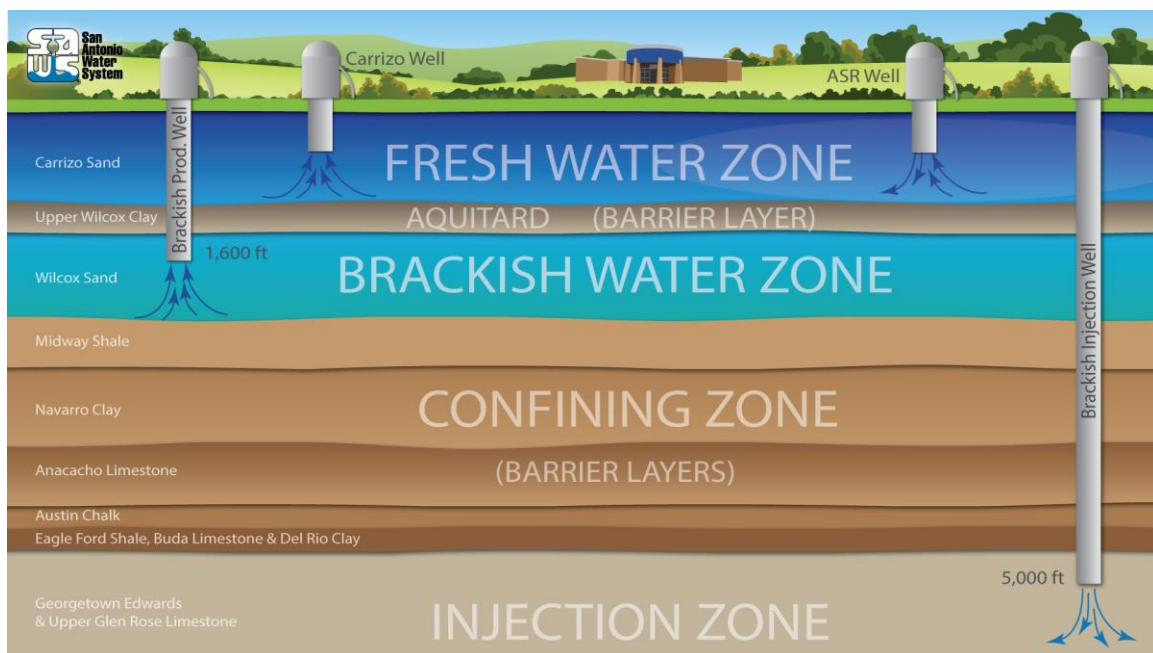
Located 20 miles south of downtown San Antonio in southern Bexar County, the SAWS H₂Oaks Center is the only known location in the U.S. where a utility produces three

SAWS desalination represents a wholly new, abundant, drought-proof water supply.

different water supplies at one location. With the H₂Oaks Center over the Carrizo-Wilcox formations, SAWS is able to serve the public through the production of freshwater from the Carrizo Aquifer, the production of brackish groundwater from the Lower Wilcox Aquifer at the Brackish Groundwater Desalination facility, and the recovery of stored Edwards Aquifer water from the Aquifer Storage and

Recovery project. In keeping with South Texas tradition, SAWS leases the land back to its original owners for continued agricultural use and cattle grazing.

Figure 3-2: Geologic cross section below the SAWS H₂Oaks Center (not to scale).



- **Aquifer Storage and Recovery (ASR) Facility** – The SAWS ASR has been an unquestioned success, and has become the largest groundwater-based ASR in the nation. This valuable asset allows SAWS to store Edwards Aquifer water during wet times or low demand seasons, and to recover that water during droughts, periods of peak usage, or other times when demand on the Edwards Aquifer is high. SAWS recovered over 50,000 acre-feet of stored Edwards Aquifer

water during the record-breaking drought between 2011 and 2014. Thanks to above average rainfall, SAWS was able to store nearly 20,000 acre-feet of Edwards Aquifer water in 2015, and more than 35,000 acre-feet in 2016. SAWS' trailblazing project has been so successful that it plays a prominent role in the EAHCP developed to withstand a recurrence of drought similar to the 1950s Drought of Record in the Edwards Aquifer region. SAWS has stored over 143,000 acre-feet of water in the facility, which is available for use. Over 70,000 acre-feet of the total storage volume has been contributed by the EAA to offset Edwards Aquifer pumping limitations imposed on SAWS by the EAHCP agreement during times of extraordinary drought, as discussed above. SAWS plans for a total storage volume of approximately 200,000 acre-feet. This level of storage has been supported by recent studies which have estimated total storage capacity of 200,000 acre-feet or more.

- **Carrizo Aquifer Groundwater in Bexar County** – SAWS has access to a total of 9,900 acre-feet per year of Carrizo Aquifer groundwater from property owned by SAWS in southern Bexar County. A portion of that access is derived from wells located on SAWS' H₂Oaks property, and a portion is derived from wells located proximal to that property.

- **Brackish Groundwater Desalination (BGD)**

Phase I – Development of this water resource in close proximity to San Antonio will diversify SAWS water resources portfolio with a wholly new, abundant, drought-proof supply. The BGD program involves the production of brackish (salty) groundwater

Figure 3-3: Racks of reverse osmosis membranes remove dissolved solids from brackish groundwater at the SAWS H₂Oaks Center desalination plant in southern Bexar County.



from the Lower Wilcox Aquifer in southern Bexar County, and reverse osmosis treatment to drinking water quality standards at the SAWS H₂Oaks Center. Phase I of the BGD program is fully constructed, consisting of new production wells, a conveyance pipeline, concentrate disposal wells and disposal pipeline, and a

reverse osmosis treatment plant. Phase I of this innovative water supply project provides up to 13,440 acre-feet per year of firm water supply. The facility is designed for expansion in two phases to produce up to an additional 20,000 acre-feet per year.

Trinity Aquifer

SAWS has three contracts to purchase groundwater from privately owned Trinity Aquifer projects and one SAWS-owned project in North Central San Antonio. By utilizing this water source, as opposed to pushing Edwards Aquifer water uphill, SAWS customers save on avoided operating and energy costs. In the 2012 Water Management Plan, SAWS considered its Trinity Aquifer supply to be firm at 2,000 acre-feet per year. As a result of both valuable experience gained during the recent drought, as well as thoughtful and sustainable management, SAWS now considers its supply from the Trinity Aquifer to be 16,100 acre-feet per year in average years, and firm at 4,000 acre-feet per year. For long-term planning purposes, SAWS assumes termination of its contract with Water Exploration Company (WECO) in 2027, termination of its contract with Bulverde Sneekner Ranch (BSR) in 2020, and extension of its contract with Oliver Ranch to 2035.

Canyon Lake

SAWS has a contract with the Guadalupe-Blanco River Authority to purchase between 4,000 and 9,000 acre-feet per year of stored water from Canyon Lake, delivered to North Central and Northwestern Bexar County. The contract expires in 2037. It includes an option to extend to 2077 under terms that SAWS currently considers financially uncertain. Thus, SAWS assumes termination of this contract in 2037.

Canyon Regional Water Authority (CRWA)

SAWS has a contract with CRWA to purchase up to 4,000 acre-feet per year of treated surface water from Lake Dunlap on the Guadalupe River near New Braunfels. SAWS has agreed to lease 500 acre-feet per year of this water to Springs Hill Water Supply Corporation through 2023. SAWS has an additional contract with CRWA to purchase 2,800 acre-feet per year of Carrizo Aquifer groundwater from sources in Gonzales and Guadalupe Counties. The Lake Dunlap contract expires in 2038 and the Wells Ranch contract expires in 2047. SAWS does not have unilateral control over the extension of the contracts and therefore assumes termination in those years.

Carrizo Aquifer Groundwater from Gonzales County

When this Carrizo Aquifer supply became operational in 2013, it provided SAWS customers with the largest non-Edwards Aquifer groundwater supply to-date through an innovative and cost-saving infrastructure-sharing arrangement with Schertz-Seguin Local

SAWS customers saved \$88 million thanks to an infrastructure-sharing arrangement with Schertz-Seguin Local Government Corporation.

Government Corporation (SSLGC). This plan includes the 11,688 acre-feet per year permit (minus losses) that SAWS is permitted to produce and export. SAWS has the option of whether or not to purchase surplus water made available by SSLGC, but as this amount is not firm, no surplus deliveries are included in this plan. SAWS is proud of the mutual benefits that this major public-public

partnership has made possible, eliminating the need to construct over 50 miles of pipeline, a new water treatment plant, and two pump stations, thereby saving SAWS customers \$88 million, and providing a back-up supply and debt payments to SSLGC. The term of this supply goes beyond the planning horizon of 2070.

Medina System

SAWS has a contract with the Bexar-Medina-Atascosa Water Control & Improvement District #1 (BMA) to purchase up to 19,974 acre-feet per year of stored water from Medina Lake delivered to a SAWS treatment plant via the Medina River. Medina Lake was virtually empty during the 2011-2014 drought. SAWS therefore considers the firm yield of this supply to be zero acre-feet per year during the worst six years of a Drought of Record. The contract expires in 2049, and SAWS assumes termination in that year.

Recycled Water

SAWS has the nation's largest direct recycled water system, with infrastructure capacity to deliver up to 35,000 acre-feet per year of treated recycled water through more than 130 miles of pipeline to commercial and industrial customers, golf courses, and parks throughout the city. The system was also designed to supplement flows in the San Antonio River and Salado Creek. In addition, recycled water supplies up to 50,000 acre-feet per year conveyed via bed and banks to CPS Energy for use in electrical generation.

SAWS has the nation's largest direct recycled water system.

SAWS is working to ensure that this resource that was once considered a liability is being valued correctly and provides the greatest public benefits. As part of this strategy,

Figure 3-4: SAWS began planning for the large-scale reuse of recycled wastewater in the 1990s as a sustainable way to reduce pumping from the Edwards Aquifer.



SAWS filed an application with the Texas Commission on Environmental Quality (TCEQ) to proactively convey this increasingly valuable water resource for downstream diversion and use. This strategy is also designed to support regional stakeholder goals for meeting Texas' Instream Flow Standards for the San Antonio River and freshwater inflows for San Antonio Bay. SAWS is working to ensure that future

plans may consider options for use of anticipated increases in treated effluent. Longer-term expansion of the current recycle program or direct potable reuse (DPR) are identified in Section 14.

Regional Regulations (Non-Edwards Aquifer Groundwater)

Groundwater Conservation Districts (GCDs) manage the aquifers within their jurisdiction. As part of this management, they are required to set a desired condition over a 50-year planning period — referred to as the Desired Future Condition (DFC) — for each aquifer. These desired future aquifer conditions are established through a policy-driven process within a larger group of conservation districts called Groundwater Management Areas (GMAs). The DFCs are then submitted by the districts to the Texas Water Development Board. TWDB then uses a computer model to calculate the Modeled Available Groundwater (MAG) in each GMA and GCD. The MAG is used by GCDs to assist in managing production.

The MAG is a calculation based on the policy-driven DFC process. It is not a representation of the amount of water that is physically available within an aquifer. The MAG is one of several factors that a GCD is required by law to consider in the management of total groundwater production. The DFCs are revisited every five years, and may change based on new policy and data.

The 2017 Water Management Plan is the first SAWS water management plan which addresses this regulatory process. All of SAWS non-Edwards Aquifer groundwater projects are affected by MAG determinations. As described above, GCDs must take the MAG into consideration in their regulatory decisions; however, they are afforded some flexibility in determining how DFCs will be achieved.

The Vista Ridge project (described in Section 7) is a non-Edwards Aquifer project influenced by the MAG. The project has been planned to deliver up to 50,000 acre-feet of groundwater per year from Burleson County throughout the 30-60 year term of the contract. Current DFCs adopted for groundwater projects in Burleson County result in a MAG of 23,249 acre-feet in 2020 increasing to 38,701 acre-feet in 2060. After accounting for existing production and other planned projects, 18,242 acre-feet of MAG are available for the Vista Ridge project in 2020 increasing to 33,694 acre-feet in 2060. TWDB is developing a revised groundwater availability model (GAM) for GMA 12 to better determine groundwater availability. The revised GAM, which includes the area of the Carrizo-Wilcox and Simsboro Aquifers that will be the source of the Vista Ridge project, is expected to be completed by mid-2018 and available for the next revision of DFCs.

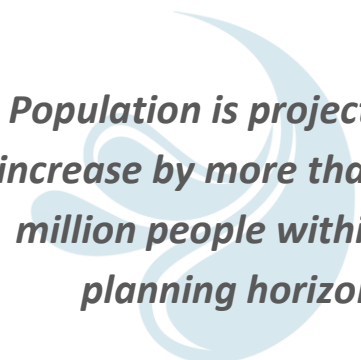
Other SAWS water supply projects sourced from the Carrizo and Wilcox Aquifers were not fully supported by MAG volumes during the first round of DFC planning. DFCs were later adjusted on the basis of additional data acquired during the actual operation of the water supply projects. These SAWS groundwater supply projects (with the exception of Vista Ridge) are now expected to be fully supported by MAG determinations from the most recently adopted DFCs.

Given recent experiences, impending changes to the groundwater models, and the fact that the issue is not yet ripe, for purposes of the 2017 Plan, SAWS has determined that MAG limitations reflected at this point are a manageable risk. The impact of this MAG will continue to be evaluated as the projects mature and the regulatory scheme of groundwater evolves.

4

Population Projections

The estimated 2017 population for the SAWS service area is approximately 1.8 million. By 2070, the population is projected to increase to approximately 3.3 million (see Figure 4-1). These projections are higher than the 2012 Water Management Plan population projections primarily because of the change in methodology from half-migration to full-migration. Texas State Data Center (TSDC) defines full-migration as the assumption that “trends in age, sex and race/ethnicity net migration rates of the post-2000 decade will characterize those occurring in the future of Texas.” In short, growth rates experienced since 2000 are predicted to continue in the future. SAWS has decided to align its 2017 population estimate with CoSA projections by adopting the specific full-migration growth rates consistent with the City’s SA Tomorrow initiative. The full-migration growth rates adopted by CoSA only extend to 2040. Based upon long term planning recommendations from the State Demographer, SAWS used the half-migration methodology beyond 2040.

A decorative graphic consisting of several overlapping, swirling blue lines that form a circular, organic shape, positioned behind the highlighted text.

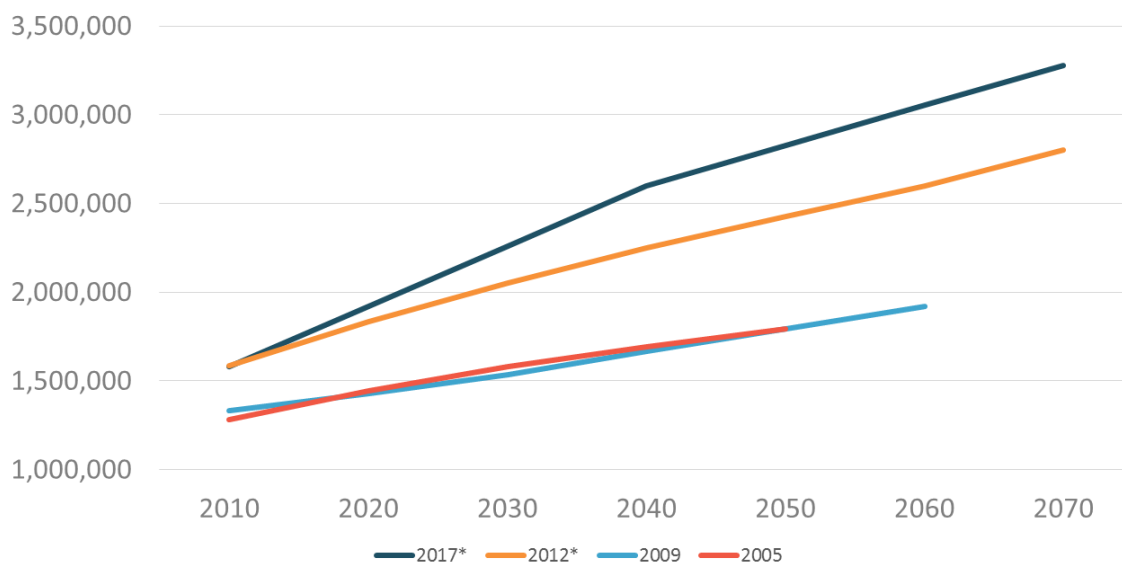
Population is projected to increase by more than 1.46 million people within the planning horizon.

The final combined growth rates for the 54-year period averaged out to 1.15 percent, with a 2017 growth rate of 1.83 percent, and ending the planning period in 2070 with a growth rate of 0.70 percent. This translates to approximately 35,000 more people per

year in the 2020s, and approximately 23,000 more people per year in the 2060s. This plan does not assume any significant expansion of existing SAWS service area.

In the graph below, SAWS 2005 and 2009 Water Management Plans did not plan for the population in areas that at that time were served by Bexar Metropolitan Water District, whereas the 2012 and 2017 Water Management Plans do. Additionally, SAWS 2012 Water Management Plan assumed a half-migration growth rate and SAWS 2017 Water Management Plan assumes a full-migration growth rate to 2040 (consistent with the City’s SA Tomorrow initiative), which explains the new higher population projections.

Figure 4-1: SAWS Water Management Plan population projections



* Includes population in areas formerly served by Bexar Metropolitan Water District.

5

Conservation and Demand Projections

San Antonio's long-standing commitment and investment in water conservation and infrastructure improvements has yielded its largest water supply. SAWS' total per capita water consumption has decreased significantly from 225 gallons per capita per day (GPCD) in 1982 to 117 GPCD in 2016, which has resulted in approximately 3.2 million acre-feet of cumulative savings. Using today's larger population, a total per capita of 225 GPCD would require an additional 215,000 acre-feet of water per year. Over the past 35 years, SAWS has reduced GPCD by approximately 50 percent by improving infrastructure and cultivating an ethic in conservation, all while population has grown by approximately 150 percent. If SAWS experienced a severe drought today and had not achieved the significant reductions in water usage and development of water supply projects that it has since 1982, SAWS would need several substantially sized water supply projects, resulting in higher current and future rates.

***Over the past 35 years,
SAWS has reduced GPCD by
approximately 50 percent,
while population has grown
by approximately 150
percent.***

Water Use Trending Downward

Recent analysis of SAWS residential and business customers shows both long term and short term water use is trending downward. SAWS uses these trends as well as our

extensive knowledge of water efficiency opportunities to project how quickly per capita usage may continue to drop. However, future water use forecasting is not an exact science because water use patterns can quickly. For example, during recent years a combination of drought conditions, restrictions on discretionary use, and periods of rainfall all contributed to a more rapid decline in consumption than was expected. If SAWS assumes this steeper drop will continue every year in the future, its forecast would likely be inaccurate because these conditions cannot always be expected. For this reason, SAWS suggests a range in potential consumption trend lines that reflect wet periods, normal weather and very dry periods. Per capita consumption will vary between these levels each year with a long-term trend downward.



SAWS analyzes water use patterns to suggest free irrigation consultations to customers who will most benefit from them. The average savings per household is between 2,000-4,000 gallons per month. In 2016, 2,495 consult services were provided to SAWS customers, resulting in savings of over 90 million gallons per year. Customers are left with custom rebate offers that reflect opportunities to make their irrigation systems more efficient. Fourteen percent of customers follow up and complete these improvements.

The trends from prior years are not the sole reason SAWS believes that consumption patterns will continue to drop. Success at getting customers to change their patterns of water use is also integral. There are clear opportunities to use incentives, education, and reasonable regulations to reduce water use among residential, business, and irrigation customers. Our knowledge of residential and commercial usage patterns informs our predictions of how low each class of customers may go in the future.

In the decades to come, proactive conservation programs will assist all water users in finding ways to be even more efficient. Success of conservation initiatives will continue to be measured by each class of customers to illustrate how each contributes to cost-

effective ways to manage the long-term usage of water. Water conservation continues to be a SAWS strategy for long-term water supply.

Residential

SAWS residential customers have enthusiastically embraced conservation both inside their homes and in how they manage their landscapes. During 2015, 2016 and 2017,

Over a three year period, San Antonio homeowners replaced the equivalent of 35 football fields with drought tolerant plants.

homeowners replaced over 2 million square feet of traditional grass with drought-tolerant landscape plants. Multi-family residential locations are also upgrading landscapes and improving irrigation efficiency. With these trends established, residential GPCD is projected to decline significantly over time. (see Figure 5-2). Higher water rates reflecting the cost of more expensive new water

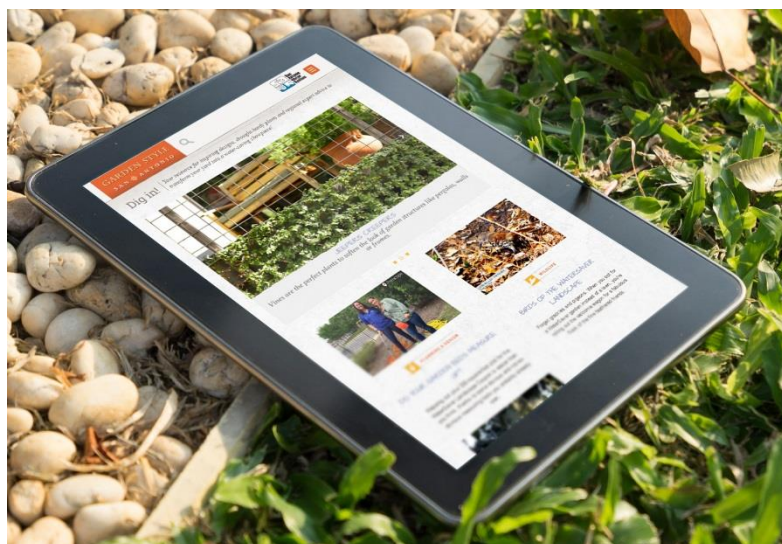
supplies are also expected to motivate efficiency resulting in conservation.

Residential consumption is the most variable of all customer groups served by SAWS. During wet winter months, the average usage declines significantly. In contrast, usage may increase quickly during hot summer months when there is little or no rainfall. The projections provided in Figure 5-2 illustrate the uncertainty associated with variable weather. Residential GPCD is expected to decline in the coming decades, but can fluctuate within the ranges identified in SAWS high, average, and low demand projections.

High demand is characterized by well above average temperatures, and/or well below average rainfall. Average demand is characterized by

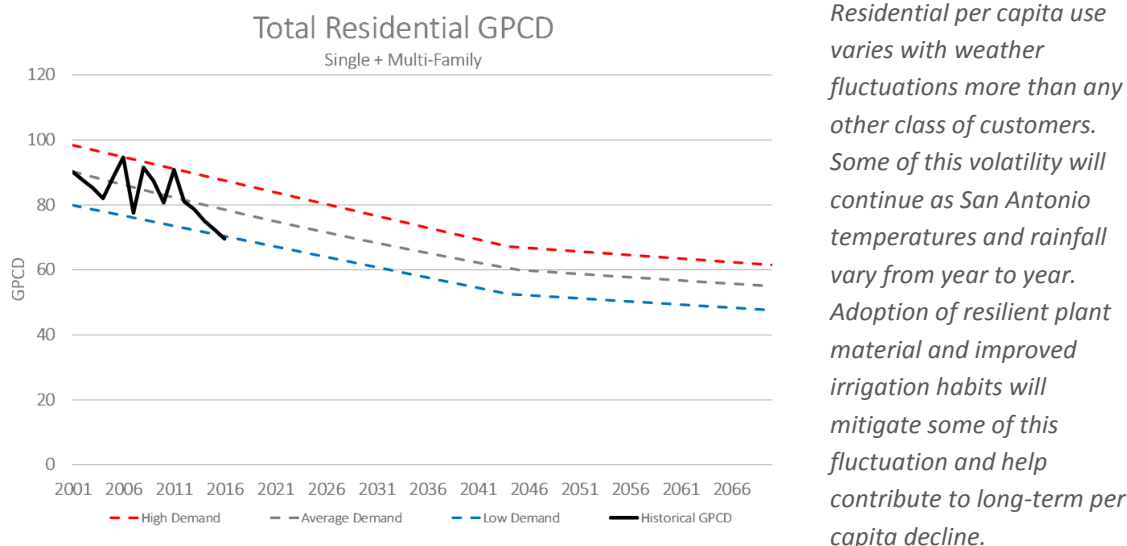
average temperatures, and/or average rainfall. Low demand is characterized by below

Figure 5-1: SAWS uses its GardenStyleSA.com website, along with a weekly email newsletter, to help residents keep their landscapes beautiful while using less water.



average temperatures, and/or above average rainfall. Outdoor watering restrictions will also reduce discretionary usage, impacting demand in all three demand scenarios.

Figure 5-2: Long-Term Conservation Projections for Residential Customers



Outdoor consumption varies greatly, but in some years, it may account for up to 50 percent of that year’s residential consumption. This will decline over time as landscape design trends continue to favor Texas natives and other drought-tolerant plants. As landscapes are less dominated by grass supported by irrigation systems, it will be possible to maintain attractive outdoor areas with less water. To decrease residential outdoor water use in general, and specifically address reductions in peak use during periods of extreme hot/dry weather conditions, SAWS will accelerate the adoption of new landscape design trends and better irrigation technology with continued education and incentive programs. Already many households are choosing less grass dominated landscapes. A recent survey of residential customers who have engaged in at least one of SAWS’ conservation programs demonstrated that conservation participants understand that the best way to reduce water use at home is through landscape transformation to a diverse and sustainable landscape reducing the need for use of in-ground irrigation systems.

Indoor water use at homes and multifamily settings is not dependent on weather fluctuations and is expected to continue to drop. Analysis from the 2012 Residential End Use Study indicates that San Antonio has not yet reached complete indoor water use efficiency. Some high flow water fixtures still remain and others that were replaced may be in need of regular maintenance and repairs to operate at full efficiency. SAWS’

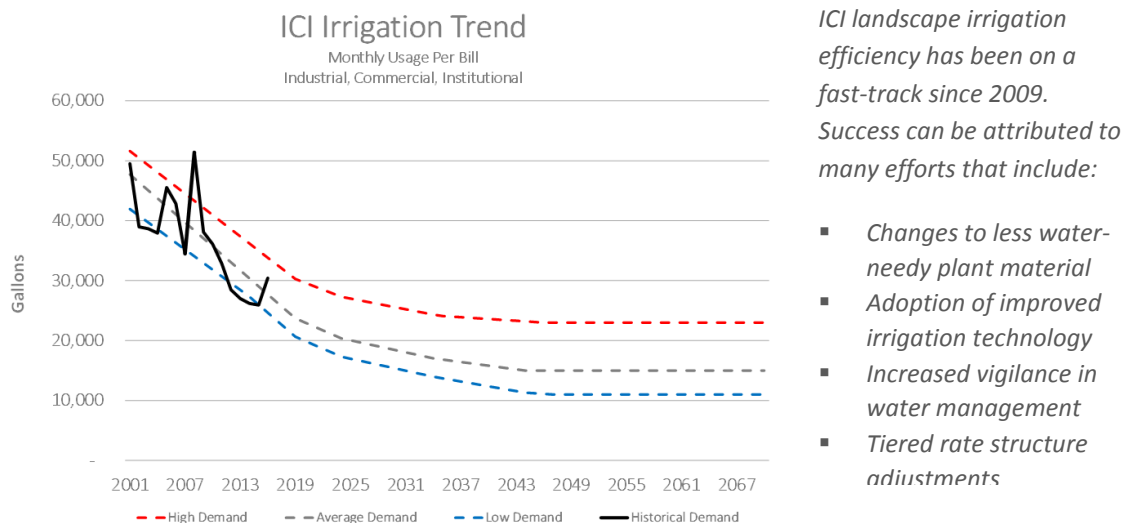
indoor single family GPCD in 2012 was 47 gallons. In 2004, new homes that had the most efficient fixtures and no leaks had an indoor GPCD of 36 gallons.

To address indoor efficiencies, SAWS will focus its efforts on promoting the repair of leaks. The few high flow fixtures that remain will naturally be replaced over time with new fixtures, all of which meet the federal high efficiency standards. Average consumption by single family households during winter months also continues to decline. While winter average does not perfectly reflect indoor only use, it is a reliable indicator of the trend.

Industrial, Commercial, and Institutional (ICI) Irrigation

Landscape water use patterns at San Antonio businesses have changed remarkably in recent years. There has been a significant decrease in the average use per bill since 2011. While drought restrictions have been a component in driving the long-term investments leading to this change, there is more to the trend than simply restricting the use of commercial irrigation systems. A combination of changes in habit, improved water management with the help of new irrigation technologies, changes in water price, and pricing structure have all been important factors in the decline. Several factors lead SAWS conservation staff to believe the declines will continue in the future.

Figure 5-3: Long-Term Conservation Projections for ICI Landscape Water Use



Continued Technology Improvements: New landscape irrigation management systems now available make it possible to more effectively manage vast commercial landscapes. SAWS has worked with several properties that have over 100 acres of land under irrigation, to assess how cloud-based data delivery, real-time flow indicators, and control systems can combine to enhance water efficiency. The results have been



While commercial and nonresidential accounts only represent six percent of SAWS' customer base, these customers account for forty-one percent of SAWS' annual water sales. There is a tremendous potential for water conservation efforts within these customer classes. Commercial and industrial customers use water in diverse ways that are not easily captured by standard rebate options. Many potential water-saving innovations are tabled because investments in water savings compete against other investments that may have a better-perceived rate of return. The custom rebate incentive is designed to overcome this barrier to water conservation with an effective but not overly generous financial incentive.

For example, NuStar Energy has installed an HVAC condensation and reclamation system to water their drought tolerant landscaping and supply a 10,000 gallon Koi fish pond. Additionally, a rain catchment system was constructed to provide over 42,000 gallons of stored rainwater per year for all the water features on the campus.

impressive. SAWS has seen sites achieve water use declines of 30-50 percent through the use of this new technology that allows the facility managers to effectively manage these landscapes by quickly detecting leaks, cutting off irrigation with rainfall, and managing settings appropriate to the season. These changes have improved the health of landscapes and reduced water use tremendously. It should be noted that while the technology is key, it is an engaged property manager keeping their eyes on the system that results in the most water savings. Developing incentives to encourage a more engaged property managers will result in significant water savings independent of technology adoption.

Changing Landscape Styles:

Many businesses and Home Owner Associations (HOAs) are realizing that grass-dominated landscapes are

expensive to water and maintain. Grass located in parking lot islands or in road medians has no functional purpose and is challenging keep trimmed and watered so that it is attractive. They are realizing there are alternative plant choices that lead to more interesting and resilient landscapes needing less water and maintenance. Lower

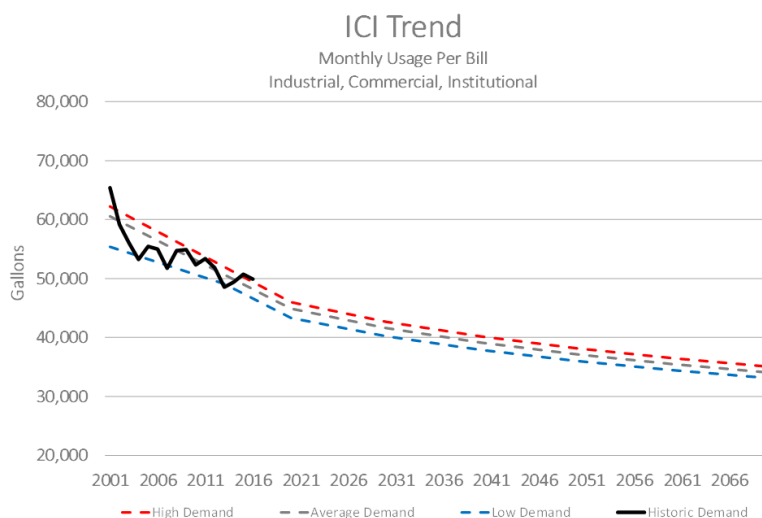
maintenance costs are attractive to business owners and HOA members alike. This focus on financial efficiency is an opportunity to promote water-saving landscapes and irrigation system upgrades, leading to a more overall sustainable community without sacrificing an attractive environment for our community.

Irrigation Checkup Report Follow Up: Large landscape sites in San Antonio are required by CoSA City Code (Ch. 34 – Water & Sewer, Art. 4 – Water Conservation & Reuse) to complete Irrigation Checkup analyses each year to demonstrate that irrigation systems are properly functioning and fully repaired. The reports also document what the professional irrigator maintaining the irrigation system believes is the maximum summer peak consumption for each irrigation meter. SAWS conservation staff are using data from these reports to alert commercial sites when their use goes up higher than expected. The reports have also provided information on where SAWS incentives can help properties change their landscapes and irrigation to use less water.

Industrial, Commercial, and Institutional (ICI)

ICI business customers continue to find innovative ways to be productive while using less water. Each year their efforts account for approximately 30 percent of the annual water savings achieved through conservation programs. Business water efficiency is expected to continue for many years (see Figures 5-3 and 5-4).

Figure 5-4: Long-Term Conservation Projections for ICI Usage



ICI customers contribute half of the water savings achieved each year through innovation, vigilance, and reasonable regulation:

- Adoption of new water efficient practices
- Installation of new equipment that requires less water
- Compliance with reasonable regulations

SAWS' goal is to help businesses use water as efficiently as possible. Custom incentives, cooperative education efforts, and enforcement of reasonable regulations all contribute to reduce water use at ICI sites today and into the future.

Predicting future business water use is not easy due to the nature of different ICI operations. SAWS expects business water use to continue on its trend to efficiency, but that does not guarantee that total sales in this category will decline. If more businesses come to San Antonio, total use could increase, even with water efficiency efforts. Increased production at industrial sites, increased occupancy at commercial buildings, and even increased enrollment at educational institutions are all wild cards in predicting total ICI water sales.

There are reasons to believe that even with accelerated economic activities and increased enrollment in San Antonio educational institutions, SAWS could see business water use decline at a slow, but steady rate over the next few decades. Each year new technological advances that greatly reduce water use for specific business purposes are developed. Hospitals can now sterilize medical equipment with a fraction of the water needed previously. Water-cooled equipment is rapidly being phased out. Additionally, water-intensive processes that were standard are being replaced with more efficient ones. These innovations are likely to continue.

Nevertheless, water is challenging to manage at very large sites. It is common for businesses to have single meters for large operations and to have little data available to help assess where leaks or inefficiencies could be unnecessarily using millions of gallons. This situation is changing rapidly as flow sensors and cloud-based technology are advancing. Over time, the technical challenges will be solved, and more properties will have information available in real time to monitor water use.

SAWS 2017 Water Management Plan assumes a total demand in 2070 that is approximately 75,000 acre-feet per year less than the 2012 Water Management Plan.

The cost of water and sewer services has increased for businesses across the country. This has changed the business proposition for efficiency measures that might have had a longer than acceptable return on investment in the past. SAWS will capitalize on these trends. SAWS is also working to enhance its ability to analyze business customers in greater detail to better identify opportunities for improvement more rapidly. The reductions achieved from these efforts are expected to contribute to lower total per capita demand for decades.

Growth and Development

The tremendous population growth, described in Section 4, will change the look and feel of San Antonio. The CoSA's SA Tomorrow Comprehensive Plan outlines a new and progressive approach to ensure San Antonio grows and develops in ways that benefit existing and future residents, the business community, and the environment. As SAWS strives to meet the water demand targets described in this section, a more densely populated city with greater efficiency in design and permanent landscape behavioral changes will lend itself to lower per capita consumption. SAWS will continue to work with developers and builders to incorporate more water efficient technologies. Efficient growth and development not only benefit conservation but also support CoSA's and SAWS' commitment to protecting water quality and the Edwards Aquifer recharge zone (Section 3). SAWS views its role as one of support for CoSA policies and planning activities relating to growth and development, and will work to ensure its policies and pricing support the overall community's objectives.

While not intended to direct growth, SAWS' impact fees are one example of the intersection of development and water/wastewater services. An impact fee is a charge for capital improvements or expansions attributable to new development that is governed by state law. Impact fees are generally based on the cost of the infrastructure associated with the pumping, treatment, and transmission of water and wastewater. Because it is generally more costly to provide new water and wastewater service in the northern portion of the SAWS service area, the impact fees are generally higher in these areas. In addition to lower impact fees for development closer to city center and further south, CoSA also established an impact fee waiver program to encourage inner city and infill development within the priority areas identified by CoSA Center City Development & Operations department.

Drought Restrictions

Drought demand strategies such as Stage 1 and 2 drought restrictions will further reduce the GPCD and total demand projections (found in Figures 5-5 and 5-6). It is projected that demand can be reduced by approximately 4.5% for each stage. Those reductions are built into the hybrid Drought of Record planning in this 2017 WMP. Although the supply and demand scenarios only include Stage 1 and 2 reductions, SAWS has the ability to implement deeper demand restrictions if an occurrence of a drought worse than the hybrid Drought of Record or in a circumstance where planned water sources are insufficient to meet customer demand. Both Stage 3 and 4 restrictions include once every other week watering from an irrigation system or sprinkler. Stage 4

restrictions include the addition of a drought surcharge and the discretion by CoSA City Council to establish additional restrictions if warranted. The projected savings from implementing Stages 3 and 4 is approximately 5% and 3.5% respectively. SAWS does not anticipate the need to utilize the more aggressive drought restrictions due to the amount of diversified water supplies both on hand and under construction but the ability to implement does exist.

Additional policy discussions on year-round once per week watering will continue among the SAWS Board of Trustees, CoSA City Council, and community organizations. Year-round once per week watering has been analyzed by SAWS as well as an independent consultant and was found to have minimal impact on SAWS' supply and demand outlook during drought, but could have some impact outside of drought during normal weather conditions. Permanent Stage 1 restrictions are appealing to various community and elected leaders for a range of policy reasons. This document plans for drought, and therefore already assumes Stage 1 and 2 restrictions throughout the 9-year hybrid Drought of Record, resulting in a reduction in demand in the appropriate years. As these demand reductions are already incorporated into the model, no additional changes to this WMP would occur if this policy were enacted. While not a specific recommendation in this Plan, a community-wide discussion on this topic is likely.

Total GPCD Projections

Reductions in usage from all types of customers and improvements in nonrevenue water (see Section 6) will result in a long-term total per capita water use decline. SAWS projects total per capita water use to reach a low of 88 GPCD by the year 2070. Fluctuations of plus or minus 8-11 GPCD are expected annually with impacts from weather. By 2070, conservation investments will result in approximately 4.3 million acre-feet of cumulative water savings since 2017, and would replace the need for an additional water supply project of approximately 132,000 acre-feet per year.

Figure 5-5: Long-Term Total Demand Projections for All Customer Classes

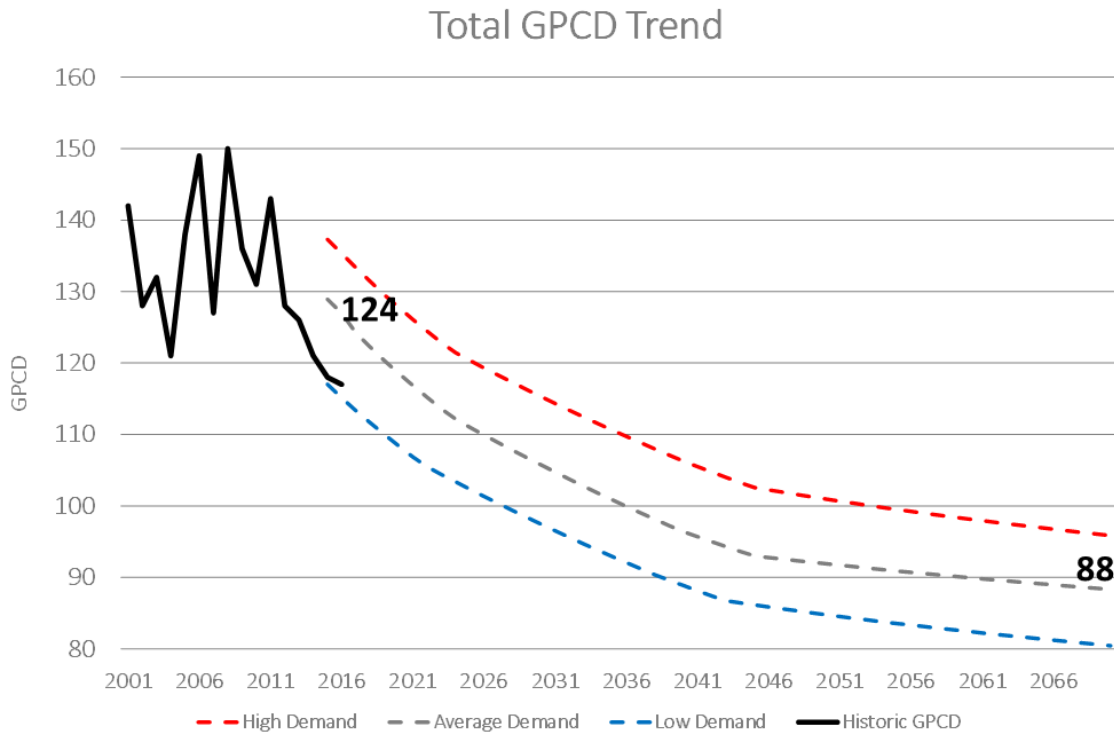
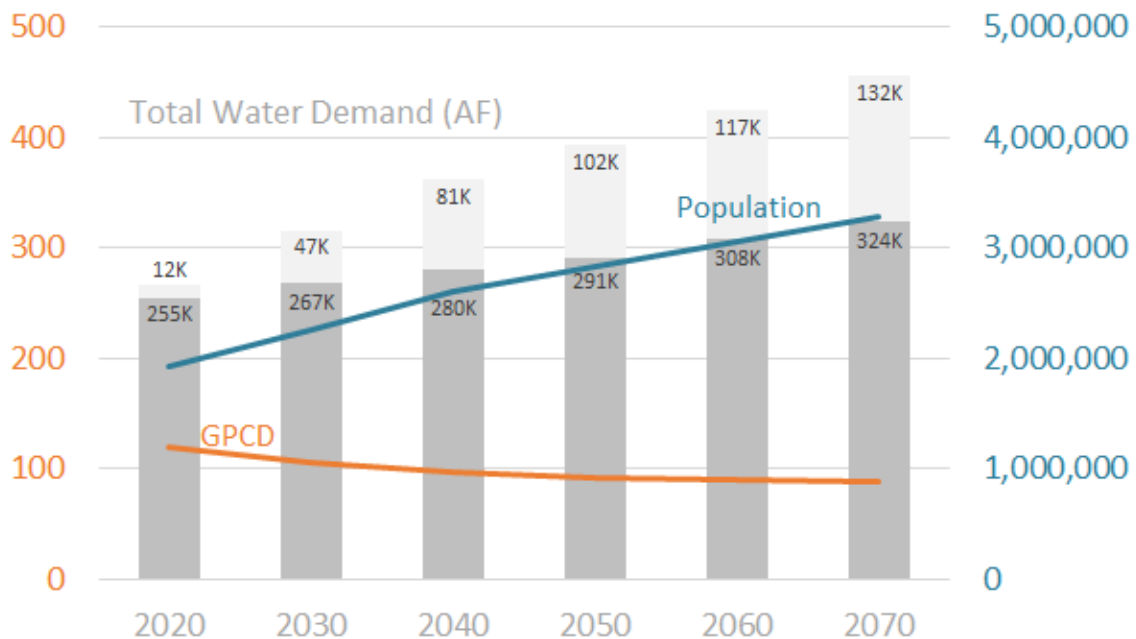


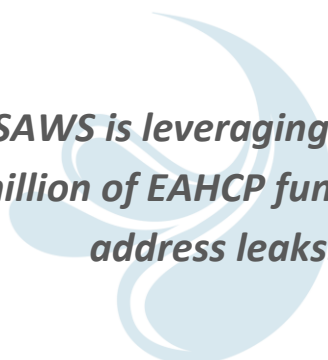
Figure 5-6: SAWS population projections, total GPCD projections, and total demand projections.
 Total Water Demand = GPCD x Population. If SAWS were to remain at 124 GPCD through 2070, SAWS demand would be an additional 132,000 AFY, as identified in the light gray bars below.



6 Nonrevenue Water Program

Nonrevenue water is the water for which SAWS does not receive payment. Nonrevenue water is not composed solely of water leaks and main breaks (real loss). It also includes business uses such as firefighting and flushing water mains to meet water quality regulations (authorized use), and paper losses such as meter under-registration and undetected theft (apparent loss). Determining and addressing the factors contributing to nonrevenue water requires specialized knowledge, funding, accurate measurements/quality data, dedication, and use of standardized audit tools to ensure detailed accounting.

The average nonrevenue water percent by total production nationally and in Texas is approximately 17 percent. SAWS' nonrevenue percentage in 2016 was 16.9 percent, slightly below the average. Of that 17 percent, approximately 2 percent is attributed to authorized use, approximately 1-3 percent is attributed to apparent loss, and the remaining 12-14 percent is attributed to real loss.



SAWS is leveraging \$18.6 million of EAHCP funding to address leaks.

SAWS is implementing cost-effective activities to reduce nonrevenue water and focusing on near-term opportunities that can result in a reduction in real and apparent loss of 5,000-7,000 acre-feet per year by 2025, growing to 7,000-10,000 acre-feet per

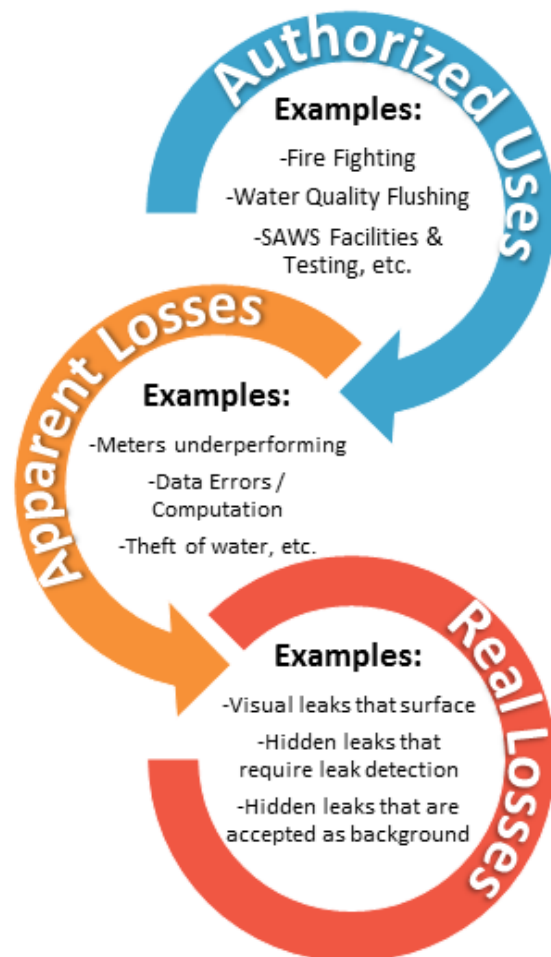
year long term. This assumption translates to approximately 14 percent nonrevenue water by total production volume by 2025, real loss under 10 percent, and contributes to SAWS' total GPCD reduction goals. Reducing SAWS nonrevenue percentage to 14 percent and maintaining that level will require significant, strategically targeted investment in its potable water infrastructure. SAWS is dedicated to continuously improving infrastructure and reducing nonrevenue water throughout the planning horizon.

SAWS is working with nationally recognized loss control professionals in order to evaluate additional opportunities and sustain improvements. SAWS is proactively taking steps to reduce nonrevenue water, which include:

- Implementing detailed leak surveys to further identify hidden leaks.
- Leveraging \$18.6 million of EAHCP funding, committed between 2016 and 2020, to augment existing leak repair activities.
- Evaluating efficiencies of field operations.
- Maintaining a more detailed accounting for regulated system wide flushing
- Reviewing production and customer metering annually to ensure effective measurement and management.
- Performing annual water balance audits using industry standard approach.
- Conducting internal and external education, with the aid of professional consultants to help guide SAWS loss control programming.

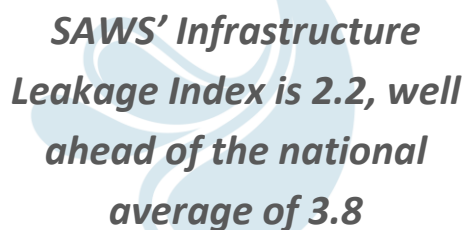
SAWS has committed efforts on nonrevenue water recovery, and has increased expenditures related to nonrevenue water

Figure 6-1: Quantifying nonrevenue water starts with adding up estimates for all known authorized uses, then evaluating apparent losses. The remainder of losses are considered real losses.



management. SAWS will be increasing the amount of service area that it inspects for leaks every year from one quarter to one half year. In addition, SAWS is looking into Advanced Metering Infrastructure (AMI), a technology that could enable SAWS to optimize its ability to manage water. Through enhanced analytics and reporting, improved resiliency and security, and enhanced customer service, AMI could make SAWS smarter, stronger, and greener. AMI, however, also comes with a steep price tag that could be well over \$100 Million. Further assessment of the benefits and the anticipated return on investment will accompany future recommendations to be considered by the SAWS Board of Trustees and any required rate requests from City Council. Nonrevenue water recovery will remain a priority to SAWS, as the cost of supply diversification continues to increase. Some challenges to reducing nonrevenue water include non-SAWS contractors damaging SAWS' water lines while performing cable installation or other subsurface construction, as well as continued regulations requiring line flushing.

Percentage-based measurements, however, may not be the best indicator to measure the utility's nonrevenue water status and should not be used to compare one utility to another. Moreover, while some water utilities have a single or very few points of water supply delivery, SAWS has over a hundred Edwards Aquifer wells and over a dozen different water supply projects. This gives SAWS tremendous integration and water supply redundancy, however it creates more nonrevenue water complications as compared to other entities.



***SAWS' Infrastructure
Leakage Index is 2.2, well
ahead of the national
average of 3.8***

The Infrastructure Leakage Index (ILI) has been found to be a better tool for utilities in similar regions, as it compares a ratio of current annual real loss to a system's theoretical real loss. This measurement takes into account a utility's specific operational challenges, such as system pressure, connection density, and distance of customer meter to street, to name a few. For the State of Texas, a unit-less measure between 1 and 3 is deemed acceptable. SAWS ILI has improved from 2.9 in 2010 to 2.2 in 2016, thanks in part to improved standardized auditing over that period. The drop in ILI to 2.2 pushes SAWS well ahead of the national average of 3.8. The ultimate goal of an ILI is to be as close to 1 as possible, as long as implementation activities are cost-effective.

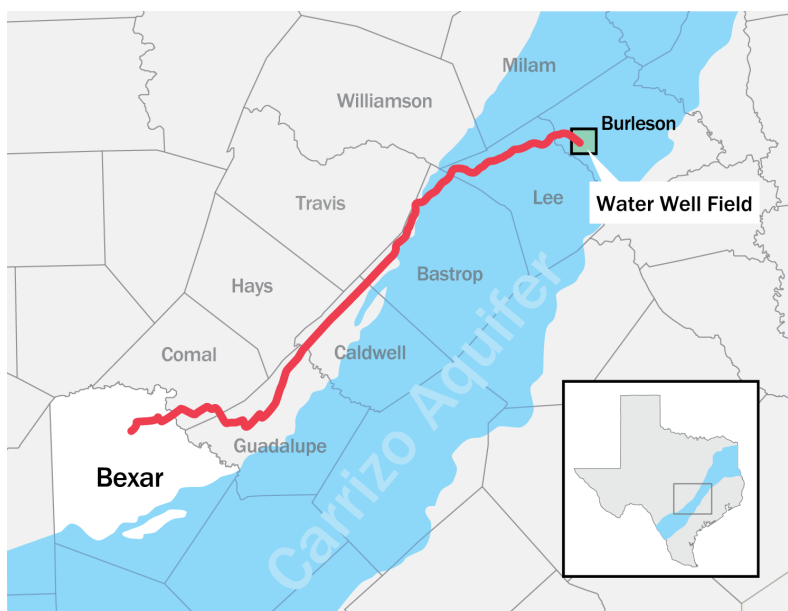
Near Term Projects (2017-2025)

During the Near Term, SAWS will continue the two-pronged approach that it has implemented over the last few decades: supply diversification with the purchase of Vista Ridge water, and water conservation efforts to include reducing total usage to 112 GPCD and residential usage to 72 GPCD by 2025.

Diversified Water Supply

SAWS has a contract with Vista Ridge LLC to purchase up to 50,000 acre-feet per year of Carrizo/Simsboro Aquifer groundwater. Vista Ridge LLC will build and operate wells and a pipeline system to pump the groundwater in Burleson County and deliver it to San Antonio for 30 years. Project construction began during spring 2017.

Figure 7-1: Texans Helping Texans – The Vista Ridge pipeline will transport high quality drinking water through one of the highest growth areas in the nation.



SAWS will pay a fixed unit price for water delivered, plus all operating and maintenance and utility costs. Ownership of the wells and pipeline system will transfer to SAWS at the end of the term, after which a separate agreement with the owner of the groundwater leases, Blue Water Vista Ridge, will give SAWS the ability to continue production for an additional 30 year term and deliver the water at a much lower price. Combined, the two agreements provide for a 60-year contracted supply of water. The project is expected to be completed early 2020, adding to SAWS' diversified water supply portfolio.

SAWS' arrangement with Vista Ridge LLC is a first-of-its-kind water supply public-private partnership (P3) in Texas, which merges the strengths of a public utility and private

Figure 7-2: Construction underway on the Vista Ridge pipeline in Caldwell County, April 2017.



industry. The agreement transfers risk of project development, financing, and water source availability to Vista Ridge LLC. The project represents a major step forward in water diversification and will meet San Antonio's water needs for decades.

Vista Ridge was approved by the SAWS Board of Trustees in September 2014. This was followed by a unanimous City Council

vote in support of Vista Ridge in October 2014, as well as a unanimous City Council vote in November 2015 supporting of rate adjustments to fund Vista Ridge. On November 2, 2016, Vista Ridge LLC reached Financial Close by entering into an agreement with a group of international banks to finance design and construction of the project. SAWS previously exercised an available option which enabled SAWS to lock in the fixed portion of the cost of the water. This action saved SAWS customers approximately \$529 million over the 30 year term of the project compared to the potential maximum price established in the contract.

The Vista Ridge pipeline route parallels the I-35 corridor, one of the highest growth regions in the country. Communities throughout the region have increasing water needs to sustain both growing populations and flourishing economies. SAWS may wholesale up to 15,000 acre-feet per year from the Vista Ridge pipeline or its existing water supply

projects, developing regional partnerships, providing communities a diversified water supply, and potentially reducing costs to SAWS ratepayers. Before any wholesale agreements are executed, SAWS will engage in associated policy and rate discussions with the SAWS Board of Trustees and City Council.

In addition to Vista Ridge LLC's construction of the pipeline system to convey water to the delivery point in northern San Antonio, SAWS must build the infrastructure needed to integrate the water within its system. This integration infrastructure will be elaborated upon in Section 12.

World Class Water Conservation

SAWS will continue to focus on conservation, by implementing education, incentives, and reasonable regulations to continue reducing demand. During this period, SAWS aims to reduce total planned per capita consumption in an average year from 124 GPCD in 2017 to 112 GPCD in 2025 (+/- 8-11 GPCD). SAWS total per capita consumption in 2016 was 117 GPCD, due in large part to above average rainfall. Despite rapid population growth in this time period, SAWS progressive GPCD goals will help moderate the growth in total annual demand, for an increase of approximately 7,000 acre-feet per year during that period.

Figure 7-3: In 2017, SAWS distributed 6,000 rain barrels in a single day – the largest distribution event of its kind in U.S. history.



Over the last 20 years, CoSA has developed and continuously improved what has been described by the Alliance for Water Efficiency as the most comprehensive water conservation and drought management ordinance in the country. Seen as a model conservation ordinance across the region and country, language taken directly from the CoSA ordinance is often found in other communities' ordinances. SAWS is tasked with implementing this comprehensive ordinance that includes both drought demand management generally focused on outdoor peak demand reductions, as well as

reasonable, year-round rules that focus on best management practices resulting in better water management. This 20-year effort of continuous improvement of meaningful, reasonable regulations has been punctuated by three major updates. All ordinance updates considered by City Council for approval are vetted by the community through public processes including but not limited to: stakeholder workshops, community outreach, and surveys.

SAWS provides numerous programs that assist all customers, residential and commercial, in implementing permanent structural changes in the landscape that reduce or eliminate any negative impacts from drought regulations. SAWS offers incentive programs that address year-round regulations focused on promoting best management practices found in the CoSA ordinance.

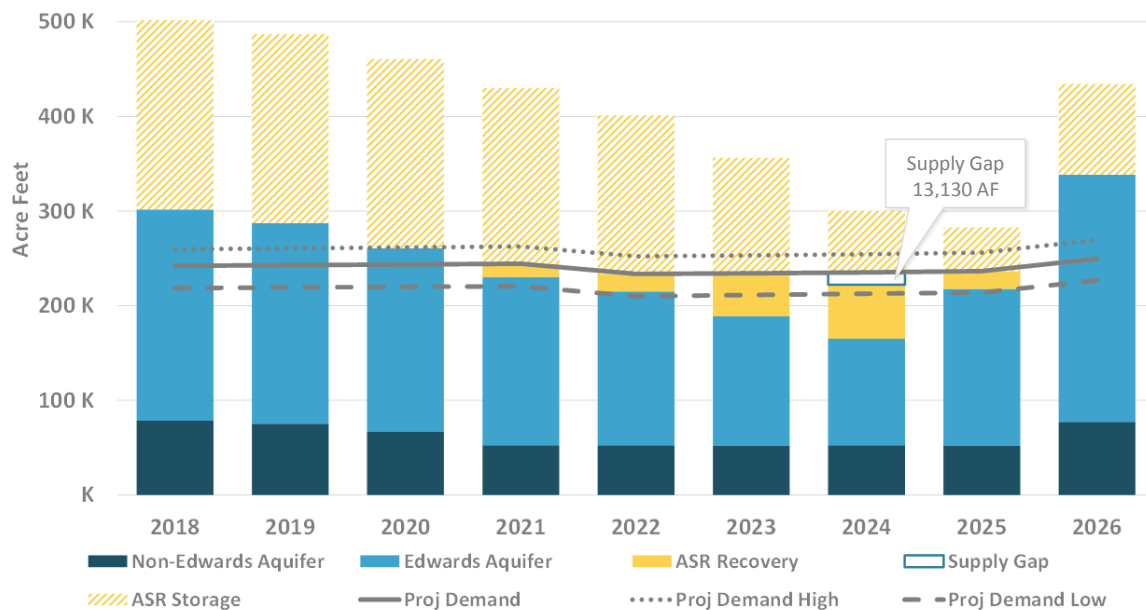
SAWS will continue to expand its input process for any future updates to the CoSA ordinance, and continue to expand its extensive suite of incentive and education programs over the Near Term, as well as the Mid Term and Long Term time frames.

8

Evaluation of Near Term Supply and Demand

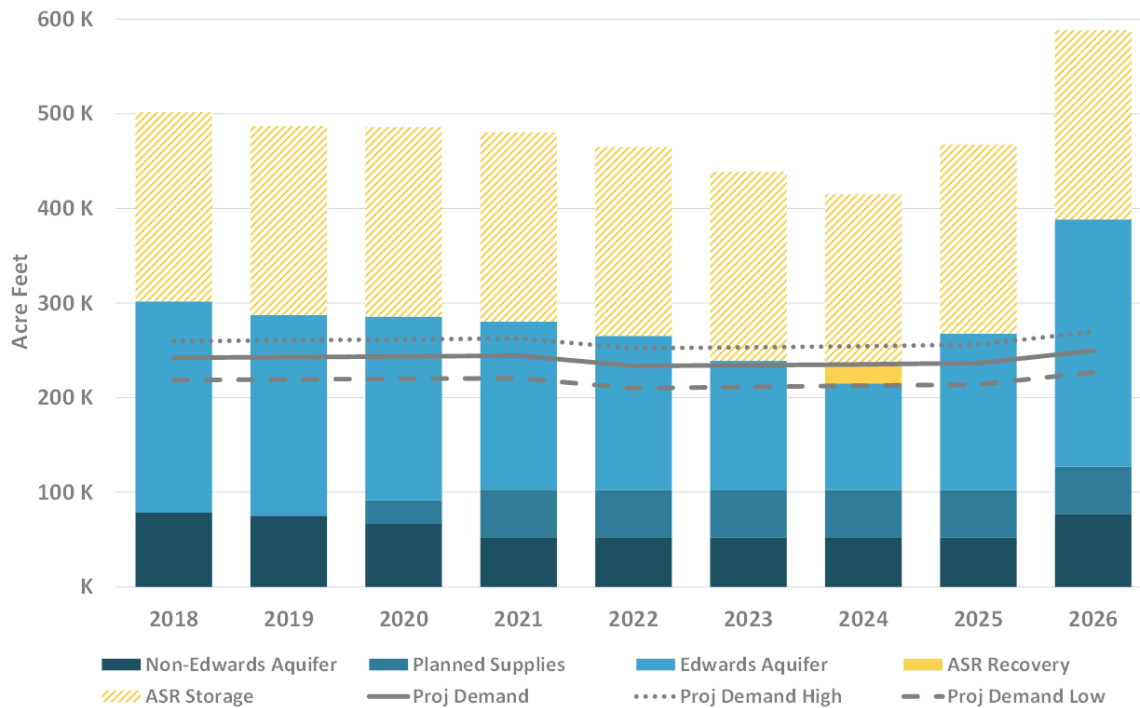
Even with the progressive per capita goals described in Section 5 and the robust, diversified water supply portfolio that SAWS has managed to acquire over the last two decades, without further development of supplies, SAWS **could** experience Permitted Supply Gaps in the 2020s, assuming a recurrence of the hybrid Drought of Record.

Figure 8-1: SAWS Near Term supply and demand outlook shows a supply gap of 13,130 acre-feet could occur in 2024 without further supply development, such as Vista Ridge. Scenario below represents a Drought of Record.



The combination of progressive per capita consumption goals and the acquisition of the Vista Ridge water supply project will give San Antonio water security in the Near Term, and for the decades that follow in the Mid Term (see Section 11).

Figure 8-2: SAWS Near Term supply and demand outlook shows no supply gap with further supply development, such as Vista Ridge. Scenario below represents a Drought of Record.



Understanding the Supply and Demand Graphs

For ease of understanding, the 2017 Water Management Plan has been broken down into bracketed time periods described as Near Term, Mid Term, and Long Term.

There are various elements to the supply and demand graph presented in the Executive Summary, and in later sections. The three lines in the graphs illustrate three different demand scenarios: high demand, average demand, and low demand. High demand is characterized by well above average temperatures, and/or well below average rainfall. Average demand is characterized by average temperatures, and/or average rainfall. Low demand is characterized by below average temperatures, and/or above average rainfall. Outdoor watering restrictions will also reduce discretionary usage, to some degree. While the 2012 Water Management Plan incorporated reductions in demand due to conservation as a supply bar, this 2017 Water Management Plan reduces the demand lines. This was done in response to recommendations that showing conservation as a reduction in the demand lines would aid in understanding the graphs.

SAWS' Edwards Aquifer supply is shown as a teal bar, and non-Edwards supply (dark blue) and planned supplies (light blue) are combined for simplicity of display into single bars. Unlike other water supplies in this Plan, Aquifer Storage and Recovery (ASR) is not an annual supply that renews with the passing of the calendar. Rather, it is a supply reserve whose yield is based on artificial recharge as opposed to natural cycles or regulatory management. Cumulative water stored in ASR is shown as hatched yellow bars, whereas annual water recovered from ASR is shown as solid yellow bars. A more detailed description of each supply is provided in Section 3.

In the graphs, when the line (demand) exceeds the totality of the bars (supply), a Permitted Supply Gap is shown. Since most water resources are regulated and administered through an annual permit, it is typically the case that a shortfall of firm yield is regulatory in nature rather than a physical absence of water during extreme drought or any inadequacy in the infrastructure necessary to access that supply. Therefore, the term Permitted Supply Gap should not be construed as an allowable or hydrological deficit of supplies – rather, it is a term chosen to specifically reflect the primarily regulatory nature of firm yield in South Central Texas at this time.

Planned Projects for the Mid Term (2026-2040)

During the Mid Term Term, SAWS will continue the two-pronged approach that it has implemented over the last few decades: supply diversification such as expanding its treatment capacity, and water conservation to include reducing total usage to 96 GPCD and residential usage to 63 GPCD by 2040.

Diversified Water Supply

SAWS does not anticipate a new water supply project in the Mid Term. During this period, SAWS will seek to maintain its inventory of Edwards Aquifer groundwater withdrawal rights at 281,000 acre-feet per year. SAWS also plans to address water treatment and integration issues. Water integration challenges between 2026 and 2040 will be identified in Section 12. As to water treatment, the ability to treat Carrizo Aquifer groundwater at the H₂Oaks facility is currently limited to 30 million gallons per day (MGD). During the latter portion of the Mid Term planning

Figure 9-1: Raw water undergoes aeration, clarification and sand filtration at the SAWS H₂Oaks Center treatment plant.



horizon, SAWS anticipates relying more heavily on the ability to recover ASR water in order to delay the construction of costly water supply projects. As larger quantities of water are recovered, more treatment capacity may be required. In order to accommodate the additional treatment, SAWS will likely need to add an additional 30 MGD of treatment capacity. Fortunately, SAWS anticipated this eventual need in the original design of the H₂Oaks facility, and has gained valuable hands-on knowledge of the treatment requirements of the Carrizo Aquifer in southern Bexar County, which will make for optimal design, construction, and operation.

World Class Water Conservation

SAWS has implemented a prudent combination of sustainable water supply projects and reasonable water usage for decades, and the strategy in the Mid Term is no different.

Figure 9-2: In 2015, 2016 and 2017, SAWS customers replaced more than 2 million square feet of turf grass with drought-tolerant landscaping via the highly popular WaterSaver Coupon programs.



During this period, SAWS will strive to continue leading the nation in water conservation, aiming to reduce its total planned per capita consumption in an average year from 112 GPCD in 2025 to 96 GPCD in 2040 (+/- 8-11 GPCD). These per capita reductions will help to largely offset increases in demand stemming from population growth with its total annual demand during that time frame increasing by only 20,000 acre-feet.

This approach will delay the need to build additional water supply projects for decades (see Section 11).

10

Planned Projects for the Long Term (2041-2070)

During the end of its planning horizon, SAWS will continue the two-pronged approach that it has implemented over the last few decades: supply diversification such as brining online additional phases of brackish desalination and Carrizo Aquifer production, and water conservation to include reducing total usage to 88 GPCD and residential usage to 55 GPCD by 2070.

Diversified Water Supply

Design of new infrastructure will begin in the 2040s, with construction and operation shortly thereafter. Recent modeling has shown that the maximum yield of brackish groundwater from Bexar County is estimated at 22 MGD. Building the project with an ultimate yield of 30 MGD will therefore likely require SAWS to drill production wells outside of Bexar County. Without changes in current groundwater regulations, and public buy-in from surrounding counties, development of brackish groundwater outside of Bexar County could pose permitting challenges that may impact the project at that time. At this point, however, the 30 MGD ultimate yield of this project is included in the current DFCs for GMA 13.

Also located in southern Bexar County, the Expanded Carrizo project will improve with the operational knowledge gained from the Local Carrizo project, and take advantage of the additional 30 MGD of treatment capacity. The project will develop an additional 21,000 acre-feet per year of Carrizo Aquifer from properties in Bexar County proximal to the H₂Oaks facility. Some advantages of this project are: It can be designed and

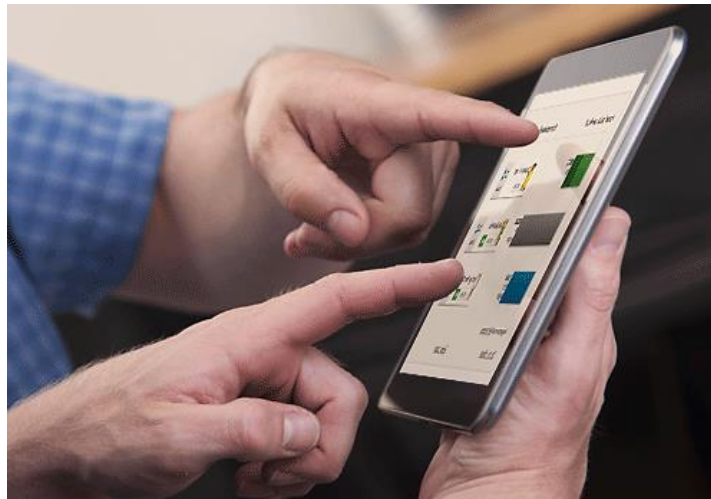
constructed quickly relative to other supplies, the project easily ties into existing infrastructure, and the project's yield is included in the current DFC for GMA 13.

The implementation of future phases of the brackish groundwater desalination and the Expanded Carrizo projects are highly flexible due to SAWS ownership and control. If any unforeseen circumstances arise during the Near or Mid Terms in regards to SAWS water supply projects or to demand, SAWS has the ability to adjust the timing of these projects to fill those voids quickly.

World Class Water Conservation

SAWS will implement programs that are intended to reduce total planned per capita consumption in an average year from 96 GPCD in 2040 to 88 GPCD in 2070. Combined with the change in population growth rate to half-migration starting in 2040 outlined in Section 4, this means that total annual demand will only increase by approximately 40,000 acre-feet between 2041 and 2070.

Figure 10-1: Technology, such as mobile apps that allow customers to track their own water use, will be instrumental in reducing total consumption to 88 GPCD by 2070.

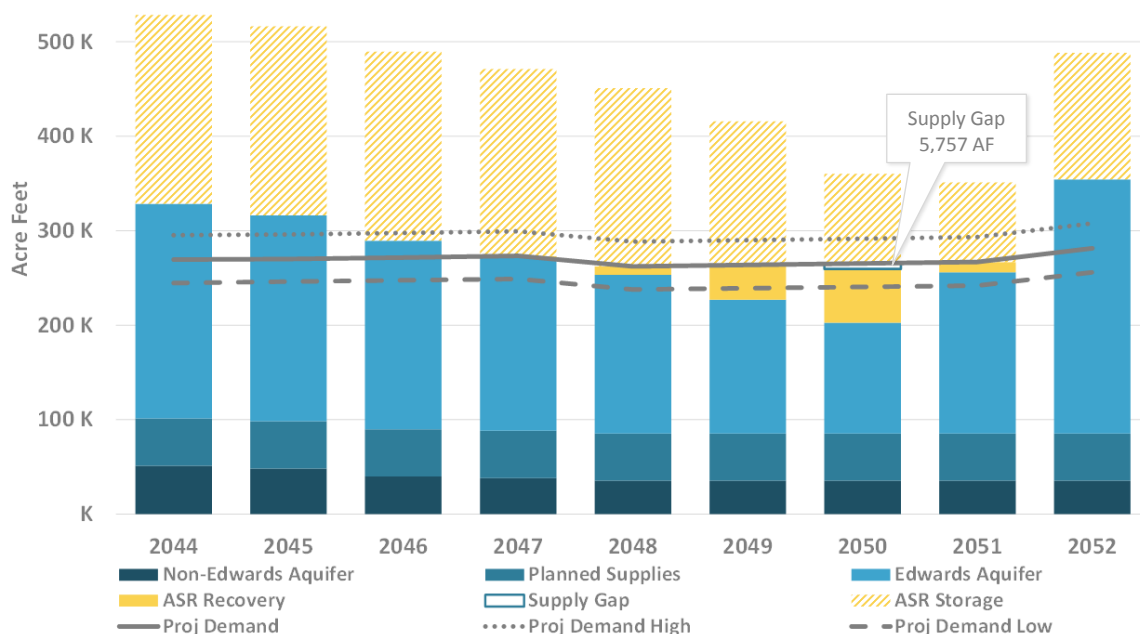


11

Evaluation of Mid Term (2026-2040) and Long Term (2041-2070) Supply and Demand

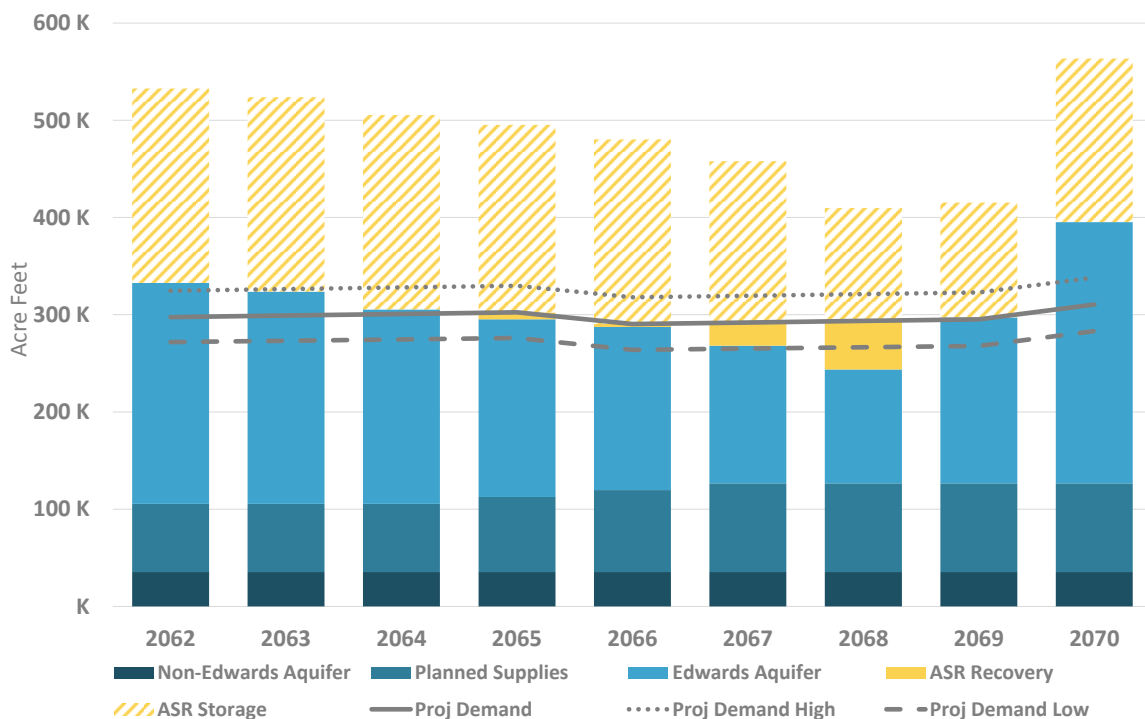
The combination of progressive per capita consumption goals and timely additions to SAWS' water supply portfolio is expected to give San Antonio water security for decades. Without expansion of either brackish groundwater desalination or Local Carrizo Aquifer production, the first Permitted Supply Gap after the acquisition of the Vista Ridge water supply project is not anticipated until 2050.

Figure 11-1: After 30 years of water security from Vista Ridge supply, SAWS Long Term supply and demand outlook shows a supply gap of 5,757 acre-feet could occur in 2050 without further supply development, such as desalination or Expanded Carrizo. Scenario below represents a Drought of Record.



Starting in the 2040s, SAWS will likely begin design and construction of the additional two phases of its Brackish Groundwater Desalination program for startup to coincide with projected Permitted Supply Gaps. However, this could alternatively be switched by two phases of the Expanded Carrizo project or any combination of sources. This provides SAWS with flexibility. With full build-out of both brackish groundwater desalination and Expanded Carrizo Aquifer production, SAWS will have water security for the entire planning period.

*Figure 11-2: SAWS Long Term supply and demand outlook shows **no** supply gap with further supply development, with desalination and Expanded Carrizo fully built. Scenario below represents a Drought of Record.*



12

Integration of Multiple Water Supplies

The SAWS water distribution system was originally built to distribute Edwards Aquifer groundwater. Most of the primary pump stations function largely as independent systems that are not strongly interconnected by significant pipelines. In order to expand utilization of these facilities to accommodate new supplies, SAWS must construct additional large diameter pipelines to effectively interconnect the stations and to connect them to new sources of water.

Eastern Pipeline

The Eastern Pipeline was built with the dual purpose of storing and recovering water to and from the ASR facility (now called H₂Oaks Center). The pipeline has sufficient capacity to also accommodate delivery of treated water from the initial phases of brackish groundwater desalination and Local Carrizo Aquifer production. This large-diameter pipeline is approximately 36 miles long and links the H₂Oaks Center to the Artesia, Seale, and Randolph Pump Stations along the eastern edge of the SAWS service area.

Western Pipeline

The Western Pipeline was designed to increase the ability and flexibility to integrate water from the H₂Oaks Center by delivering that water to western Bexar County. The first phase of the pipeline includes 28 miles of large capacity water transmission pipeline and new pump stations at the H₂Oaks facility and the Old Pearsall Pump Station. Phase

one became operational in 2016 and will enable SAWS to integrate H₂Oaks water to south Bexar County.

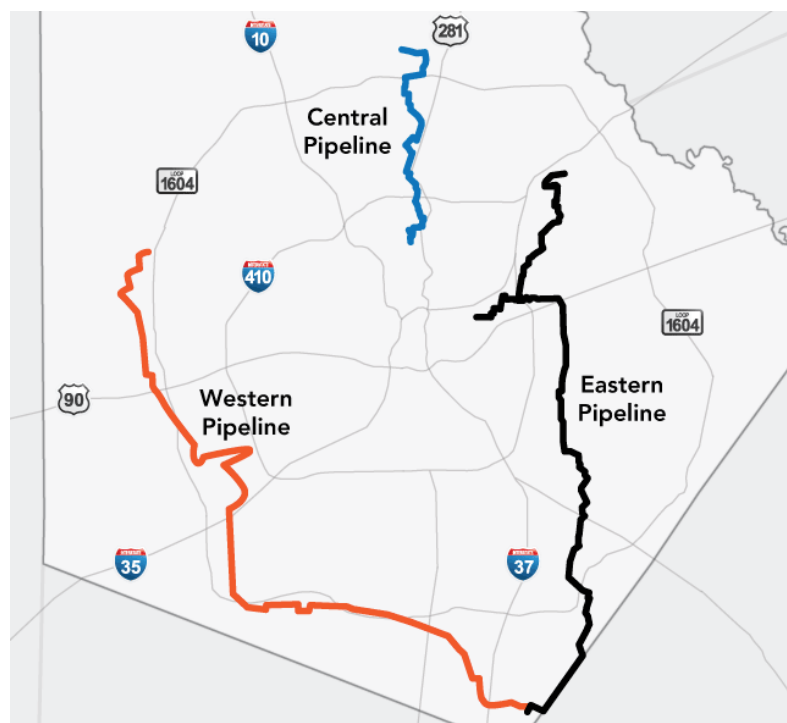
The second phase of the pipeline includes 17 miles of large diameter pipeline and additional pumping capacity at the H₂Oaks and Old Pearsall Pump Stations. This project is planned to be operational by 2020. With the addition of the Anderson Pump Station facility as a water integration point, the rated capacity of both phases of the pipeline will be 75 MGD.

Central Water Integration Pipeline

The Vista Ridge project will introduce approximately 45 MGD of water to the SAWS system through a single entry point. The biggest integration challenge SAWS faces in the early years of this project will be using this constant rate water supply during times of low customer demand. This is typically the cooler winter months when demand is at a minimum.

During cold and/or wet periods during the early years of the project, the Vista Ridge water will make up approximately one-third of the total water demand of the system. This water must be conveyed to locations in the distribution system where it can be effectively

Figure 12-1: By 2020, SAWS will complete construction of a sophisticated transmission system that will give operators a great deal of flexibility in water distribution.



consumed. This will require construction of new integration infrastructure. Integration improvements include a combination of re-purposing existing infrastructure, and construction of new pipelines, control valves, tanks and pumps. Design and construction encompasses a segment from the terminus point of the Vista Ridge delivery line north of Loop 1604, delivering to both the existing Knights Cross facility and south to the existing Basin Pump Station.

The completion of the Central Water Integration Pipeline comes with a number of benefits to customers. The former BexarMet service areas of north central San Antonio will gain water service reliability and reduced water turbidity. Water distribution operators will have greater flexibility to feed multiple pressure zones across San Antonio and to provide water as far south as Calaveras Lake. The integration of Vista Ridge water allows SAWS to eliminate an outdated former BexarMet facility in need of major renovations, saving customers over \$9 million. Integration of Vista Ridge water will provide SAWS with both its largest non-Edwards Aquifer source of water and increased water distribution reliability.

13

Climatic Conditions

SAWS supplies are relatively resilient to changing climatic conditions, due in part to an already diverse water portfolio. Many water utilities across the country are analyzing how reductions in snowpack and rising sea levels might impact them. SAWS is not directly affected by those phenomena.

The majority of municipal water supplies delivered in the U.S. are from surface water, and those utilities are having to mitigate against increasing evaporation. Less than 10

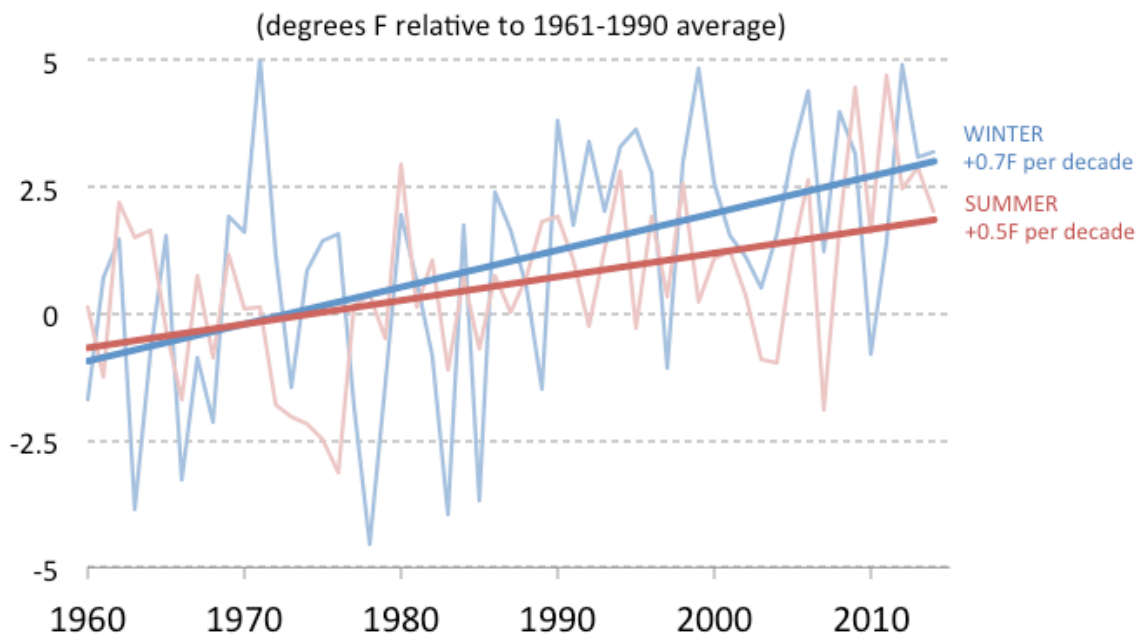
Analysis suggests that San Antonio will experience higher temperatures and more extreme precipitation in the future.

percent of SAWS' supply portfolio comes from surface water. In fact, SAWS built the largest groundwater-based Aquifer Storage & Recovery system in the country over 10 years ago, which has a storage capacity almost the size of Medina Lake, but without the risk of evaporative loss.

Finally, the Edwards Aquifer is an ideal natural system to harvest projected additional flooding events. The Edwards Aquifer is one of the most prolifically recharging karst aquifers in the world. Recharge is provided by precipitation over eight major drainage basins. The median recharge since 1934 is estimated at 557,000 acre-feet per year, with a low of 44,000 acre-feet in 1956 and a

high of 2,486,000 acre-feet in 1992. The Edwards Aquifer remains a reliable resource for agriculture, water supply, and the environment for south central Texas, now and into the future.

Figure 13-1: Seasonal Average Temperatures (Source: City of San Antonio Sustainability Plan)



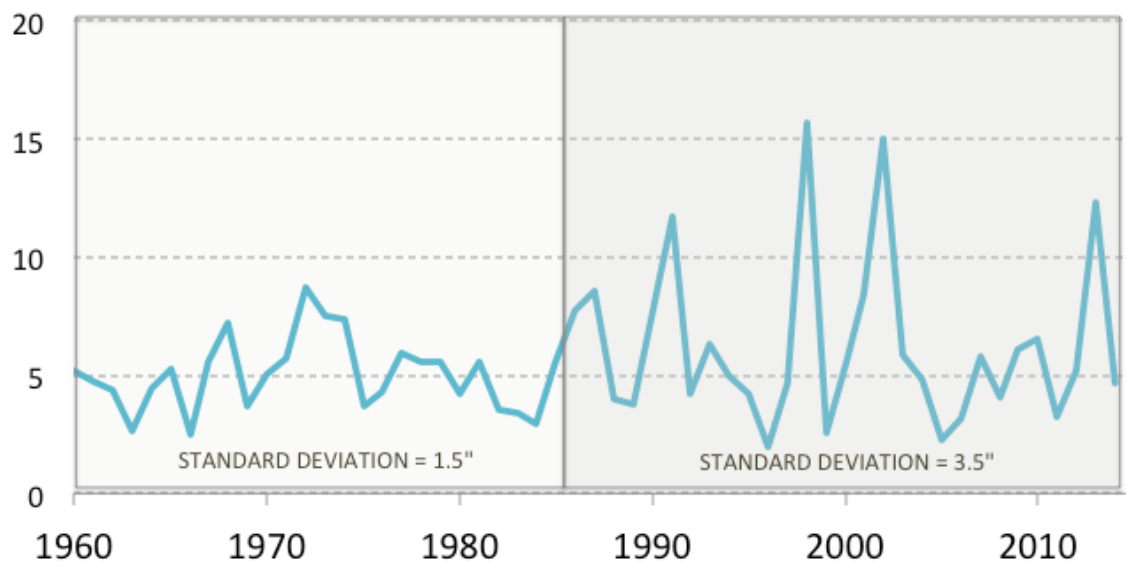
SAWS planning accounts for predicted changes in climate in several ways. Rather than use the standard 1950s Drought of Record scenario for planning, SAWS uses a hybrid Drought of Record scenario that incorporates the more extreme reductions experienced during the 2011-2014 drought. SAWS has developed models that allow this scenario to be applied and tested during many different time periods and under different supply planning assumptions to assess needs under many worst-case scenarios. SAWS has direct experience with climate change research due to its involvement in the LCRA-SAWS Water Project and the EAHCP. In addition, SAWS has analyzed water planning implications of research that was done for CoSA and the City of Austin by Dr. Katherine Hayhoe, Ph.D., a leading climate science expert.

While not climatologically the same, Austin and San Antonio have very similar climate patterns. Dr. Hayhoe found that projected changes for Austin include increases in annual and seasonal average temperatures, more frequent high temperature extremes, and more frequent extreme precipitation. Higher temperatures and flashier rain patterns may make customer demand patterns more challenging to predict. An important strategy to mitigate these challenges has been implementation of

conservation programs that transition San Antonio landscapes to attractive, resilient plant material.

Regarding more nationwide/global climatic conditions, Dr. Hayhoe co-authored the June 2017 *U.S. Global Change Research Program Climate Science Special Report (CSSR)*. The findings from that report agree with other previous research, with some new information. Authors of that report state with very high confidence that longer duration hydrological droughts will become increasingly probable. As mentioned previously, this plan uses a more severe drought by merging the intensity of the 2011-2014 drought with the duration of the 1950s drought. Also mentioned previously, this hybrid Drought of Record is a layer of conservatism that is in addition to the layer of conservatism that SAWS has been using for its last two Water Management Plans: projecting supply and demand during a 108-month drought, versus the 77-month drought used in the State Water Plan.

Figure 13-2: Wettest 5-Day Rainfall in Inches (Source: City of San Antonio Sustainability Plan)



SAWS' water supply portfolio might be relatively mitigated in instances of extreme weather patterns, but every water utility will face operational challenges associated with changes in climatic conditions. Pipe corrosion, tree root ingress, sanitary sewer overflows, pipe bursts, degraded disinfection byproducts due to higher water temperature, pump and motor inefficiencies due to higher air temperature, and higher irrigation demand are all potential ramifications against which all water utilities will need to be vigilant. During the development of CoSA's Sustainability Plan, SAWS participated in a Climate Vulnerability Assessment, a summit of dozens of regional

agencies that might be affected by climatic conditions. The findings of that body can be found as Appendix B to the Sustainability Plan.

Several initiatives have been undertaken to lessen SAWS' impact on the environment.

"I don't think there's a better example than San Antonio. It's remarkable what you've done here...It's going to be the kind of project we tout across the U.S."

These initiatives are exemplified by SAWS' Dos Rios Water Recycling Center which recycles water, biosolids and methane, and houses one of the largest solar fields in the state via a public-private partnership. Upon visiting Dos Rios, former EPA Administrator Gina McCarthy stated, "I don't think there's a better example than San Antonio. It's remarkable what you've done here...It's going to be the kind of project

we tout across the U.S." SAWS also has implemented load reduction programs that lower emissions, by shifting energy load to non-peak hours.

SAWS is uniquely well positioned to manage the challenges predicted by changing conditions and by extreme weather variations, due to its resiliency via diversification, relative immunity to increased evaporation, distance from the coast, and lack of reliance to snowpack. Geographically, San Antonio is just south enough from Tornado Alley, just northwest enough from the destruction caused by hurricanes and sea level rise, and just east enough from arid west Texas. SAWS continues to join water utilities across the nation that are analyzing how variable and extreme weather patterns might impact supplies, demand and infrastructure, and this Plan outlines a water management program that mitigates these conditions, and are also good business practices for SAWS.

14

Risk Management

The 2017 Water Management Plan identifies the path toward SAWS' water security. Implementing the plan provides a balanced planning approach between conservation and a diversified water portfolio. However, no matter how well a plan is developed, uncertainty remains. The underlying assumptions used to develop the WMP are conservative in nature and rely on the side of meeting demand through a hybrid drought of record rather than risk the potential of not having enough water to meet demand. The WMP is flexible enough and updated often enough to adjust and mitigate for those changes. Risks and uncertainties take many forms such as the examples provided in the following: under/over predicting demand (inaccurate population projections and/or GPCD targets), variability of water supply yield, changes in regulations impacting access to water supply, storage capacity of ASR, severity and duration of the next drought, and fluctuations in water quality. The list of risks and uncertainties identified (while not exhaustive) provide the greatest impact to the success of the WMP. The WMP is generally updated on a five year basis unless conditions warrant change sooner. A significant change to one or more assumptions due to a described risk would warrant a revision of the WMP prior to the five year cycle. The table below describes strategies that could be included, should significant change occur, in an update or amendment to this WMP if needed.

Risk	Mitigation Strategies
Over estimating demand	Supplies are planned to meet certain demand projections. If demand falls short of expectations, SAWS will effectively manage the utilization of current supplies as well as reevaluate the delivery date of planned water supplies such as brackish groundwater desalination and expanding the Local Carrizo project.
Under estimating demand	<p>The WMP provides for flexibility in adjusting for demands exceeding projections. Additional conservation initiatives will be initiated to offset the higher than projected GPCD.</p> <p>If demand warrants, SAWS will bring online the expanded Local Carrizo project and additional phases of brackish groundwater desalination sooner than identified in this document. In addition, the option of implementing a project included in the further consideration section would be evaluated.</p>
Variability of water supply yield	Water supply yields are based on the best available information at the time of the WMP publication. Conditions can change based on the physical limitations of the source water or by infrastructure based limitations to produce, treat and/or distribute. SAWS has the ability to gain access to additional water through current agreements to offset loss of supply. Infrastructure limitations will be identified and mitigated by implementing a capital improvement program correcting project limitations.
Changes in regulations impacting access to water supply	<p>All SAWS water supplies are affected by varying degrees of regulatory constraints. SAWS will continue to work collaboratively and partner with those regulating entities towards the goal of developing the best science and policy.</p> <p>If regulations reduce project yields, SAWS will bring online the expanded Local Carrizo project and additional phases of brackish groundwater desalination sooner than identified in this document. In addition, the option of implementing a project included in the further consideration section would be evaluated.</p>

Storage capacity of the ASR

SAWS commissioned the University of Texas at San Antonio to calculate the potential maximum storage capacity of the ASR program. Researchers identified a maximum storage capacity of 200,000 acre-feet. Current ASR storage is 143,000 acre-feet. If additional storage bears evidence of being hydrogeologically constrained, SAWS will re-evaluate the impact of this reduced storage capacity to the supply and demand model. The ability to store above the 200,000 acre-feet is also a possibility that would be of tremendous benefit in mitigating longer term droughts. Updates to the WMP would be made if change to storage capacity is of enough significance.

Severity and duration of drought

Changes in climatic conditions could result in less supply than planned and/or greater demand than planned. Should the region experience a drought more severe or longer than SAWS hybrid Drought of Record, mitigation could be achieved by:

- SAWS proactive demand management programs including drought restrictions could serve to reduce demand during an extended or severe drought.
 - SAWS has the ability to bring online the expanded Local Carrizo project and additional phases of brackish groundwater desalination sooner than identified in this document. In addition, the option of implementing a project included in the further consideration section of this plan would be evaluated.
-

15

Projects That Merit Further Consideration

While this Plan identifies the timing and magnitude of water supply projects and water conservation programs up until 2070, SAWS evaluates many different strategies and technologies. In the event of a change in demand projections or supply reliability, other options are also available to SAWS for further consideration. These options are compared against other projects and could be implemented during the planning horizon. Similarly, should the planning assumptions in this document prove to be accurate, the projects identified in this section would provide water security for San Antonio for decades beyond 2070.

Expansion of Brackish Groundwater Desalination

Above and beyond the three phases of brackish desalination identified in Sections 3 and 10, additional brackish groundwater desalination could be undertaken in the future. SAWS would acquire brackish groundwater production rights from interested landowners whose properties overlie aquifers containing brackish groundwater. Wells would be drilled and brackish water would be piped to a desalination plant constructed proximate to San Antonio. The amount of water that would be developed would be based on future needs, and could be constructed in phases as demand develops. SAWS did a preliminary analysis of an expanded desalination project into Wilson County in 2011; however, regulatory and permitting challenges were noted, and the project was found to be a similar per unit cost as Vista Ridge.

Expansion of the Direct Non-Potable Recycled Water System

Presently, more than 130 miles of pipeline deliver high-quality recycled water for use by commercial and industrial customers, golf courses, and parks, as well as the River Walk. As the volume of wastewater treated by SAWS increases with population growth, SAWS may consider further expansion of the recycled water system to offset future potable water needs.

Direct Potable Reuse of Treated Wastewater

The technology and techniques for treating wastewater to potable standards to be reused as drinking water are well established and mature. Texas leads the nation in direct potable reuse, with El Paso (pilot project), Wichita Falls (currently indirect potable) and Colorado River Municipal Water District (Big Spring) currently engaged in potable reuse to some degree. The largest obstacle to direct potable reuse of treated wastewater is public perception. This type of project would require significant public discussion before proceeding.

Desalination at the Gulf of Mexico

One day it may be economically feasible to desalinate seawater, manage the resulting brine in an environmentally responsible way, and pump the treated water inland to San Antonio. SAWS will continue to evaluate the feasibility of seawater dealination. However, the intent now, and for the foreseeable future, is to remain focused on brackish groundwater desalination in close proximity to Bexar County. The present obstacles to using brackish groundwater are primarily regulatory in nature, and SAWS intends to continue cooperating with those stakeholders considering state-wide regulatory reforms that facilitate responsibly making more brackish groundwater available for desalination.

Stormwater Management

Stormwater management can be categorized into recharge enhancements and direct surface applications. Regarding recharge enhancements, the San Antonio community is already taking advantage of the Edwards Aquifer's astounding ability to harvest stormwater naturally. The Edwards Aquifer is one of the most effective aquifers in the country at recharging stormwater. In fact, EAA operates four recharge dams on the Edwards Aquifer Recharge Zone, which have recharged approximately 210,000 acre-feet since their construction in the 1970s/1980s for the benefit of its regional permit holders. Future stormwater management via recharge will require partnerships, scientific studies, and collaboration. The present regulatory environment is not favorable for recharge enhancement initiatives for municipal supply purposes. SAWS views the enhancement of recharge as a public good and continues to support its implementation

as a regional benefit, but will not be pursuing the matter from the municipal water supply perspective at this time. However, there are smaller projects that will continue to be explored, and implemented when benefit can be shown.

Directly using stormwater at the surface for irrigation on a large scale by SAWS would still require significant treatment facilities, as well as multiple grey infrastructure facilities for storing and distributing the water across the service area. Unless treated to the same quality as SAWS existing water sources, which would be very cost intensive, a larger stormwater management system would be required, as well as new end-user plumbing upgrades. Instead, SAWS is pursuing more natural stormwater management solutions, such as distributing rain barrels, and partnering with builders, and community organizations to promote its respective incentives to build rain gardens. From a water supply perspective, stormwater supply is highly variable, and would frequently not be available during the times of highest demands and extended drought conditions. In fact, stormwater management efforts could be significantly challenging when one considers the potential of longer and more intense droughts that will likely occur in the future, meaning water would not be available when its needed. SAWS will continue to monitor industry developments in stormwater management technology and evaluate potential applications.

16

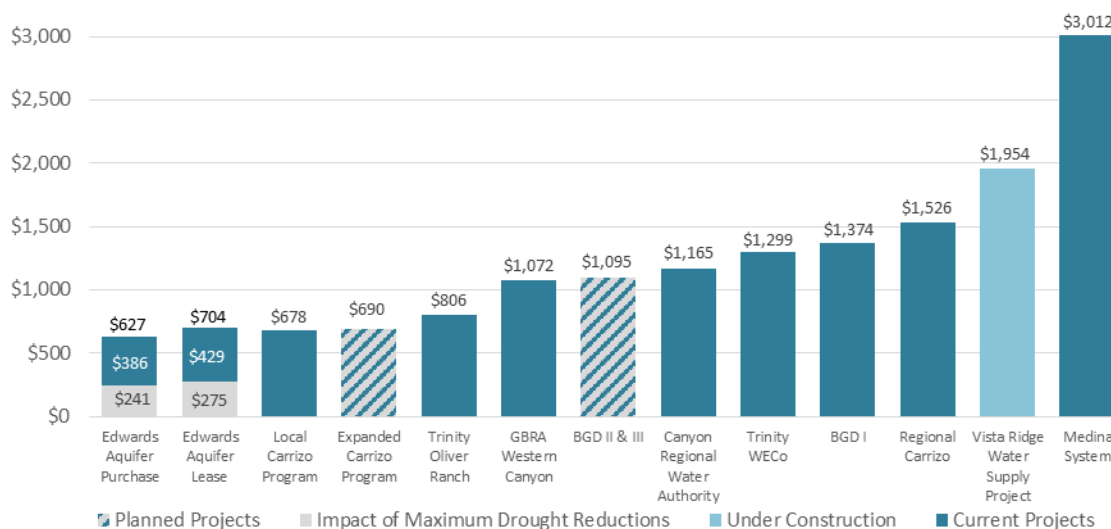
Financial Analysis

To allow for meaningful comparison, the updated costs per acre-foot of the water supply projects and the associated integration projects that have been described in this plan are presented here. Specifically, the costs for projects that have been completed will be presented alongside planned projects. This section also presents the impact on average residential monthly charges through the year 2020.

Water Supply Project Costs per Acre-Foot

The annual costs per acre-foot of current and planned projects in the 2017 Water Management Plan are shown below in Figure 16-1.

Figure 16-1: Annual Cost per Acre-Foot by Project (NOTE: Does not include integration costs.)



Integration Costs

Major transmission pipelines are necessary to transport water from several water supply projects to distribution lines serving SAWS customers. Since these transmission lines may support multiple projects, it is difficult to allocate the costs of integration infrastructure directly to specific projects. Consequently, integration capital costs are not included in Figure 16-1 above. Separate integration costs per acre-foot are shown in the below table in Figure 16-2. Calculation of the integration costs per acre-foot follow the same assumptions used to develop the project costs shown in Figure 16-1 above, to include debt service payments, pump station energy costs and maintenance on the pump stations and pipelines.

Figure 16-2: Integration Costs per Acre-Foot

Integration Project	Cost per AF	Capacity (MGD)
Eastern (Complete)	\$212.17	50
Western Phase I (Complete)	\$226.74	50
Western Phase II (Future)*	\$458.55	25
Central Water Integration (Future)*	\$316.61	45

*O&M cost estimates are not final.

Impact on Water Supply Fee Charges

In November 2015, to ensure that sufficient resources are available to implement the Vista Ridge project, the City Council approved in advance five consecutive years of Water Supply Fee (WSF) rate adjustments (2016 through 2020). The fee adjustments approved for the four years from 2017 through 2020 are maximum allowable adjustments. If the projected costs in these years are less than the anticipated costs, the rate adjustment will be lowered accordingly.

Please see the table in Figure 16-3 below. The maximum anticipated increases to the WSF each year are expressed in terms of its impact on the projected total average residential bill for a customer using 7,092 gallons of water and 5,668 gallons of wastewater. The table below shows the maximum adjustments authorized each year through 2020.

Figure 16-3: Projected Maximum Monthly Bill Impact of WSF Through 2020

Authorized Adjustments			
	% Change	WSF Charge	
2016	1.8%	\$	10.73
2017	1.3%	\$	11.46
2018	3.1%	\$	13.30
2019	4.4%	\$	16.15
2020	9.7%	\$	23.00

Based on Average Residential Bill:
7,092 gal. water & 5,668 gal. sewer

Rate Structure and Affordability

SAWS rates continue to be in a tiered structure to incentivize lower water consumption. This is meant to send a price signal to the higher water usage tiers in hopes of achieving more water conservation through our rate structure. In addition to conservation, SAWS new rate structure also strives to ensure that life essential uses of water are made as affordable as possible. While a rate strategy, this is also a water management, conservation, and affordability strategy that is revisited approximately every five years through a community Rates Advisory Committee.

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Community Input

SAWS' Board of Trustees and Executive Management committed early in the process to expand the outreach to not only inform the public of the process of updating the utility's Water Management Plan, but also to solicit feedback concerning the priorities that form the basis for planning the utility's water future through 2070.

In its continued commitment to transparency, SAWS started previewing information on the upcoming Water Management Plan to the SAWS Citizens Advisory Panel which made recommendations to staff and the SAWS Board of Trustees on key aspects of formulating the 2017 WMP along with presentations to the Community Conservation Committee. SAWS committed to live stream every Board meeting, have updates on the Vista Ridge project at every Board meeting, conduct both public meetings and one-on-ones with key stakeholders, as well as holding Facebook Live community input sessions. Going forward, SAWS is committed to keep the community updated throughout the process.

A public relations campaign was launched to begin soliciting input from previously underrepresented groups. The website WaterCitySA.com featured overview videos of the Water Management Plan and included opportunities for input from those who would normally not attend homeowner/neighborhood association or public meetings.

Water-related information disseminated through the WaterCitySA.com site allowed SAWS to better reach the community. Visitors to the site have reached nearly 10,000. To further reach the community, information was promoted through social media platforms including Twitter, Facebook, and Nextdoor. Communications also reached out to the city's extensive bloggers groups (influencers), who then shared information via their social channels, increasing SAWS' reach.

Continued outreach by SAWS Water Resources and Communications solicited input from homeowner/neighborhood associations as well as leadership groups including:

- San Antonio City Council
- City of San Antonio
- Chambers of commerce
- Environmental groups
- Industry and trade organizations

In a SAWS first, Facebook Live broadcasts were utilized to inform the community of the Water Management Plan's importance as an open discussion of the WMP's key components. There have been over 20,000 viewers who have watched the Facebook broadcasts and were able to ask questions providing input during and after the live broadcast.

As a result of thoughtful input from the community prior to this plan's approval by SAWS Board of Trustees, the 2017 Water Management Plan Task Force added language and data that addresses comments they received. Some of these topics include conservation strategies, stormwater management, sustainable groundwater management and mitigation, risk management, water quality, and transparency.

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Summary

San Antonio Water System's path toward water supply diversity began in the 1990s with the onset of state regulation of San Antonio's only water source, the Edwards Aquifer.

With regulation of the Edwards Aquifer, what was once an unlimited source of water became a permitted supply that alone couldn't sustain the long-term needs of the region. Rapidly increasing population, coupled with the threat of another extended drought, stressed the capacity of available water.

Once perceived as a city with limited water availability, San Antonio leadership has worked for the last 20 years to radically change the water supply situation, thereby sustaining a thriving economy. Development of numerous water supply projects constructed over that time frame, combined with progressive conservation efforts, place San Antonio in an enviable position.

Once perceived as a city with limited water availability, San Antonio leadership has worked for the last 20 years to radically change the water supply situation.

In fact, San Antonio has stepped forward to provide primary or backup water services to the city's water-challenged military bases, ensuring bases can sustain current and future missions and accommodate growth.

Since the 2012 Water Management Plan, SAWS has implemented a number of water supply and conservation initiatives securing San Antonio's water future:

- Over 2 million square feet of water-intensive grass was replaced with low water-use plants or permeable patios through WaterSaver Landscape Coupon programs.
- Regional Carrizo Water Project was brought on line in 2013, providing more than 10,000 acre-feet of water in both 2015 and 2016 from the Carrizo Aquifer in Gonzales County to San Antonio.
- In January 2017, SAWS held the grand opening of the H₂Oaks Desalination Plant and water center, Phase I of which is capable of producing 12 million gallons of drinking water daily from desal operations.
- WaterSaver Irrigation Consultations providing home irrigation and landscape education visits have reduced household usage by 84 million gallons per year.
- The GardenStyleSA.com website and e-newsletter providing timely San Antonio-focused low water use landscape information to reduce outdoor watering.
- SAWS' ASR at H₂Oaks has reached a record storage volume of 143,000 acre-feet, representing over a half-year of SAWS potable demand.
- SAWS has partnered with The University of Texas at Austin based Pecan Street to develop an integrated conservation platform that will expand water conservation opportunities in the future.
- The public-private partnership with Vista Ridge LLC for up to 50,000 acre-feet per year of groundwater from Burleson County by 2020 is recognized globally as a benchmark agreement in water projects.

All this has been achieved by implementing continuous planning, with the Water Management Plan as the road map for San Antonio's water future. SAWS will continue to expand on its previous successes in implementing the 2017 Water Management Plan using a two-pronged approach by reducing demand through its industry-leading conservation programs and investment in reducing its nonrevenue water.

These efforts will ultimately lead to a decrease in the total gallons per capita per day (GPCD) in an average year from 124 GPCD in 2017 to 88 GPCD in 2070, with additional savings during drought from outdoor watering restrictions.

Conservation coupled with the timely development of diversified water supply projects will provide water security for SAWS ratepayers through 2050 with current supplies and water supply projects currently under construction.

Meeting demands beyond 2050 requires continued implementation of key elements in this plan to include: progressive GPCD goals, further diversification of supply, and targeted investment in infrastructure to reduce nonrevenue water loss. Implementing the 2017 Water Management Plan ensures water security for San Antonio through 2070.

Time Frame	Action
Near Term (2017-2025)	Reduce total planned GPCD in an average year from 124 GPCD in 2017 to 112 GPCD in 2025
	Secure up to 50,000 acre-feet per year of Vista Ridge groundwater
	Reduce nonrevenue water to 14 percent by total production volume
Mid Term (2026-2040)	Reduce total planned GPCD in an average year from 112 GPCD in 2026 to 96 GPCD in 2040
	Expand treatment capacity at H ₂ Oaks Center for ASR recovery and Local Carrizo production
Long Term (2041-2070)	Reduce total planned GPCD in an average year from 96 GPCD in 2040 to 88 GPCD in 2070
	Build out Brackish Groundwater Desalination, for a total yield of 33,600 acre-feet per year
	Develop the 21,000 acre-feet per year Expanded Carrizo project

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Acronyms and Abbreviations

AACOG	Alamo Area Council of Governments
AF	acre-foot (325,851 gallons)
ASR	Aquifer Storage & Recovery facility
BGD	Brackish Groundwater Desalination
BMA	Bexar-Medina-Atascosa Water Control & Improvement District #1
BexarMet	Bexar Metropolitan Water District
BSR	Bulverde Sneckner Ranch
CoSA	City of San Antonio
CAP	Citizens Advisory Panel
CCC	Community Conservation Committee
CCN	Certificate of Convenience and Necessity
CPSE	CPS Energy
CRWA	Canyon Regional Water Authority
DFCs	Desired Future Conditions
DOR	Drought of Record
EAA	Edwards Aquifer Authority

EAHCP	Edwards Aquifer Habitat Conservation Plan
EAPP	Edwards Aquifer Protection Program
EARIP	Edwards Aquifer Recovery Implementation Program
GBRA	Guadalupe-Blanco River Authority
GMA	Groundwater Management Area
GPCD	Gallons per Capita per Day
ICI	Industrial, Commercial, Institutional (General Class)
ILI	Infrastructure Leak Index
MAG	Modeled Available Groundwater
MGD	Million Gallons per Day
MPO	Metropolitan Planning Organization
MW	Megawatt
NRW	Nonrevenue Water
RCP	Regional Carrizo Project
SARA	San Antonio River Authority
SAWS	San Antonio Water System
SSLGC	Schertz-Seguin Local Government Corporation
TCEQ	Texas Commission on Environmental Quality
TSDC	Texas State Data Center
TWDB	Texas Water Development Board
USFWS	U.S. Fish and Wildlife Service
WEC	Water Exploration Company
WMP	Water Management Plan

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Appendices

Supply and Demand Model Assumptions

Population Projections

- Utilized COSA adopted full migration growth rates from 2015-2040. The population from 2017 – 2040 is 1,817,387 to 2,596,769.
- Utilized 2014 Texas State Data Center half migration growth rates to extend the SAWS population projections out to 2070. The population for this period (2040-2070) is 2,596,769 to 3,278,889.

2017	2020	2030	2040	2050	2060	2070
1,817,387	1,919,271	2,257,905	2,596,769	2,824,828	3,052,026	3,278,889

Disaggregated Demand Projections

Residential (single family and multi-family)

	2017	2020	2030	2040	2050	2060	2070
Population	1,817,387	1,919,271	2,257,905	2,596,769	2,824,828	3,052,026	3,278,889
Planned GPCD	73	71	69	63	59	57	55
Planned Demand (AF)	158,331	162,622	174,382	182,803	186,578	194,688	202,005

Industrial, Commercial, and Institutional

	2017	2020	2030	2040	2050	2060	2070
Number of Connections	25,849	26,910	30,771	35,187	40,237	46,011	52,614
Monthly Usage (kgal/bill)	48.5	47.1	43.3	40.0	38.1	36.5	35.0
Annual Usage (kgal/bill)	582	566	519	480	458	438	420
Planned Demand (AF)	46,135	46,711	49,031	51,833	56,523	61,820	67,815

Industrial, Commercial, and Institutional - Irrigation

	2017	2020	2030	2040	2050	2060	2070
Number of Connections	8,163	8,498	9,717	11,112	12,706	14,530	16,615
Monthly Usage (kgal/bill)	26.4	23.0	18.4	15.8	15.0	15.0	15.0
Annual Usage (kgal/bill)	316	276	220	190	180	180	180
Planned Demand (AF)	7,928	7,210	6,574	6,472	7,019	8,026	9,178

Nonrevenue Water Program

	2017	2020	2030	2040	2050	2060	2070
Real Loss + Apparent Loss + Authorized Use (AF)	40,457	38,392	37,440	39,250	40,717	43,064	45,418
Nonrevenue as % of Total Production	16.00%	15.06%	14.00%	14.00%	14.00%	14.00%	14.00%

Non-Revenue Water (NRW)

- An initial 17% NRW has been planned for, decreasing to 14% by 2025. Staff will continue to review System processes and outside consultant recommendations to determine what improvements can be implemented that are financially beneficial.

Total Demand Projections without restrictions (*high, average, and low*)

Total GPCD (*high, average, low*)

2017	2020	2030	2040	2050	2060	2070
133	128	115	106	101	98	96
124	119	106	96	92	90	88
113	108	97	89	85	82	80

Total Acre-Feet per Year (*high, average, low*)

2017	2020	2030	2040	2050	2060	2070
270,000	273,000	289,000	305,000	317,000	335,000	352,000
253,000	255,000	267,000	280,000	291,000	308,000	324,000
229,000	231,000	244,000	255,000	266,000	281,000	296,000

- Total demand projections above incorporate the progressive GPCD goals in SAWS 2017 WMP, but not additional Stage 1 and 2 drought restrictions. However, SAWS 2017 WMP does assume demand reductions from its residential customers due to Stage 1 and 2 drought restrictions, throughout the nine-year hybrid Drought of Record.

Supply Assumptions

Edwards

- Allow leased Edwards portfolio to reduce from 36,000 AFY to 25,000 AFY. The maintenance of the 25,000 AFY long-term will be achieved via combination of leasing, buying, dry year option and spot leasing.
- Total Edwards inventory maintained at 281,146 AFY. Short-term 273,146 AFY available to meet demand and 8,000 AFY committed to the HCP through 2027.

Trinity

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
BSR	2020	0	0	0	0	0	0	0	0	0	0	0	0
WECO	2027	17,000	13,100	13,100	0	0	0	0	0	0	0	0	0
Oliver Ranch	2035	2,000	2,000	2,000	2,000	1,000	0	0	0	0	0	0	0
Timberwood	No Expiration	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total		20,000	16,100	16,100	3,000	2,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Regional Carrizo – planned volume of 13,557 in 2017, 2018 to 2070 at 11,057 AFY with no planned SSLGC surplus.

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
Regional Carrizo	Available through planning period	13,557	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057

CRWA – Current volume 6,300 AF with an additional 500 AFY in 2024 for a total of 6,800 AF

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
Lake Dunlap	2038	3,500	3,500	4,000	4,000	4,000	0	0	0	0	0	0	0
Wells Ranch	2047	2,800	2,800	2,800	2,800	2,800	2,800	2,800	0	0	0	0	0
Total		6,300	6,300	6,800	6,800	6,800	2,800	2,800	0	0	0	0	0

BMA

- Contract yield is 19,974 AF with an expiration date of December 31, 2049
- 13,000 AF included in the Supply & Demand model in 1st, 2nd and 9th years of a drought

Western Canyon

- Contract expires on December 31, 2037, but can be extended by SAWS to December 31, 2077

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
Western Canyon	2037	9,000	8,135	7,354	6,647	6,008	0	0	0	0	0	0	0

Current ASR Recovery Assumptions

- Current recovery expected to be 30,100 AFY from ASR up the Eastern Leg
- With the addition of the Water Resource Integration Pipeline, ASR recovery could increase to 57,000 AFY.
- Maximum annual ASR storage 50,000 AFY (45 mgd)
- ASR storage capped at 200,000 AF

Brackish Groundwater Desalination

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
Brackish Desal	Available through planning period	8,000	13,440	13,440	13,440	13,440	13,440	13,440	26,880	33,600	33,600	33,600	33,600

- Peak capacity of phase I of the Brackish Groundwater Plant is 13,440 AFY (12 mgd)
- Phases II & III will provide an additional 13,440 AFY (12 mgd) and 6,720 AFY (6 mgd) respectively. These will be developed and brought online as potential supply gaps are anticipated.

Local Carrizo

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
Local Carrizo	Available through planning period	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900

Expanded Local Carrizo

- Phases I, II & III are all planned at 7,000 AFY (6.25 mgd) and will be developed and incorporated into the System as water is needed to meet potential supply gaps in the future.

Vista Ridge LLC

	Contract Expires	2017	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070
Vista Ridge LLC	Available through planning period	0	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000

Water Supply Contract Terms

Source	Unilateral or Mutual Consent?	Staff Recommendation	Reason
Medina System	N/A	Assume termination in 2049	Extension not an option
WEC	Mutual Consent	Assume termination in 2027	Not unilateral
BSR	Unilateral	Assume termination in 2020	Not firm supply
Western Canyon	Unilateral	Assume termination in 2037	Large lump sum payment required
Lake Dunlap	Mutual Consent	Assume termination in 2038	Not unilateral
Wells Ranch	Mutual Consent	Assume termination in 2047	Not unilateral
Oliver Ranch	Unilateral	Assume extension to 2035	Unilateral
SSLGC	Unilateral	Assume extension to 2070	Unilateral
Vista Ridge	Unilateral	Assume extension to 2070	Unilateral

EAHCP Commitments

SAWS assumes that the EAHCP commitment will continue throughout the planning period. EAHCP commitment requires two triggers before SAWS is required to forbear Edwards Aquifer production. The two triggers are:

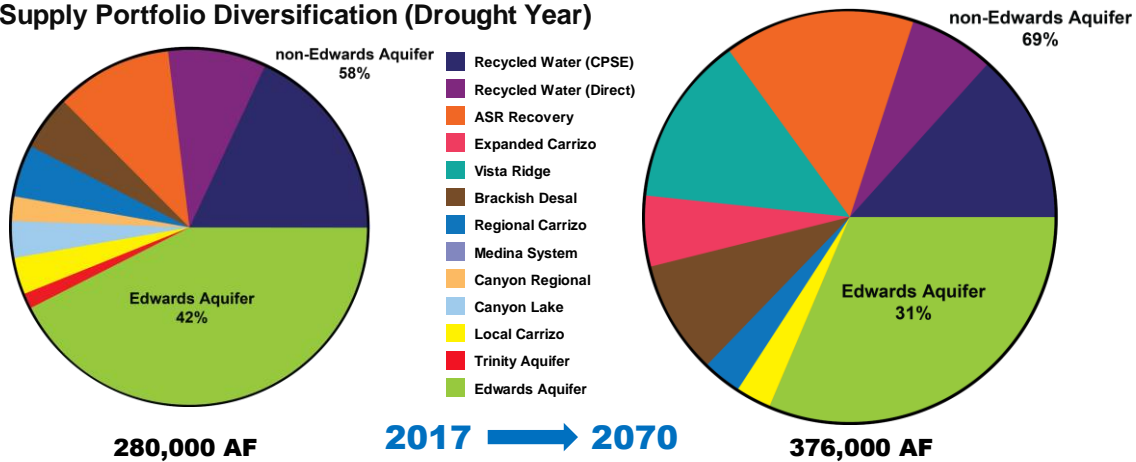
- J-17 falling below 630' MSL before June 30th
- The Rolling 10 year average of the Edwards Aquifer recharge falling below 500,000 AFY

Once triggered SAWS would be required to forbear 110,300 AF of Edwards over a 3 ½ year period if the EAA has provided the water to store. Forbearance has to be initially targeted towards the Northeast quadrant of the SAWS service area.

Future Water Supply Portfolios

SAWS' 2017 WMP plans for a recurrence of the Drought of Record. In this scenario, SAWS' Edwards Aquifer supply is reduced by ~42%, plus the EAHCP forbearance (discussed above). SAWS' water supply portfolio in 2017 and 2070 under drought conditions is illustrated below.

Supply Portfolio Diversification (Drought Year)



In average years, SAWS water supply portfolio expands, and the Edwards Aquifer comprises a larger percentage. SAWS' water supply portfolio in 2017 and 2070 in average conditions is illustrated below.

Supply Portfolio Diversification (Average Year)

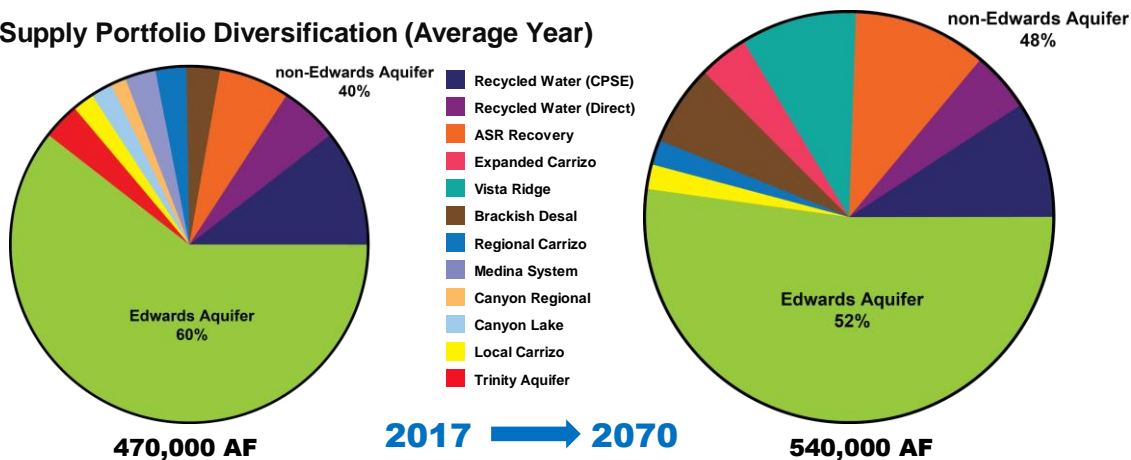


Figure 1-3: SAWS aims to achieve a total GPCD of 88 by 2070. If SAWS were to remain at 124 GPCD through 2070, SAWS demand would be an additional 132,000 AFY, as identified in the light gray bars below.

Figure 5-6: SAWS population projections, total GPCD projections, and total demand projections.

Total Water Demand = GPCD x Population. If SAWS were to remain at 124 GPCD through 2070, SAWS demand would be an additional 132,000 AFY, as identified in the light gray bars below.

	2017	2020	2030	2040	2050	2060	2070
Population	1,817,387	1,919,271	2,257,905	2,596,769	2,824,828	3,052,026	3,278,889
Planned GPCD	124	119	106	96	92	90	88
Planned Demand (1000s of AF)	253	255	267	280	291	308	324
Additional Demand @ 124 GPCD (1000s of AF)	0	12	47	81	102	117	132

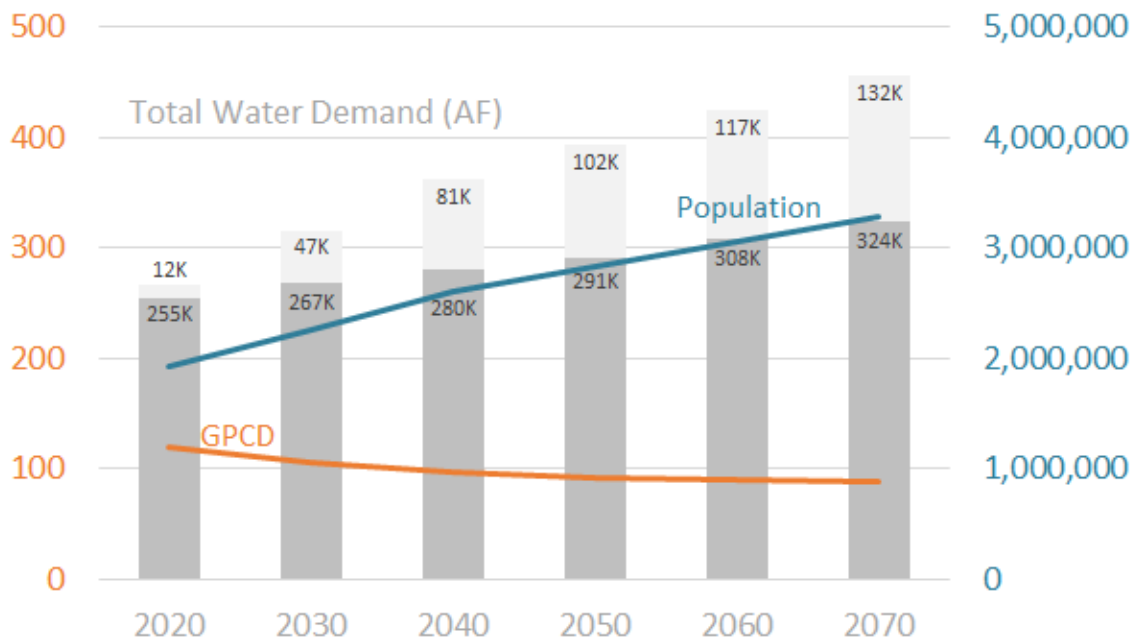


Figure 1-6: SAWS ensures water for generations by setting progressive demand goals with stage 1 and 2 landscape watering restrictions, and then evaluating the need to develop future planned supplies. Scenario below represents a Drought of Record.

Figure 11-2: SAWS Long Term supply and demand outlook shows no supply gap with further supply development, with desalination and Expanded Carrizo fully built. Scenario below represents a Drought of Record.

	2062	2063	2064	2065	2066	2067	2068	2069	2070
Projected Demand High	324,717	326,418	328,120	329,820	317,897	319,547	321,197	322,849	338,319
Projected Demand	297,543	299,176	300,808	302,440	290,449	292,031	293,614	295,198	310,600
Projected Demand Low	270,363	271,793	273,222	274,650	262,454	263,831	265,207	266,533	281,684
ASR Storage	200,000	200,000	200,000	200,000	200,000	176,093	126,195	128,239	178,239
ASR Recovery	0	0	0	0	0	23,907	49,898	0	0
Supply Gap	0	0	0	0	0	0	0	0	0
Edwards Aquifer Supply	227,166	218,141	199,839	182,745	167,992	141,567	117,158	170,685	268,776
Brackish Desalination Ph II	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440
Brackish Desalination Ph III	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720
Vista Ridge	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Expanded Carrizo Ph I	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Expanded Carrizo Ph II	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Expanded Carrizo Ph III	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Planned Supplies	91,160	91,160	91,160	91,160	91,160	91,160	91,160	91,160	91,160
Trinity Project	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Local Carrizo	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
Western Canyon	0	0	0	0	0	0	0	0	0
Medina Surface Plant	0	0	0	0	0	0	0	0	0
CRWA	0	0	0	0	0	0	0	0	0
Regional Carrizo	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057
Brackish Desalination Ph I	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440
Non-Edwards Supplies	35,397	35,397	35,397	35,397	35,397	35,397	35,397	35,397	35,397

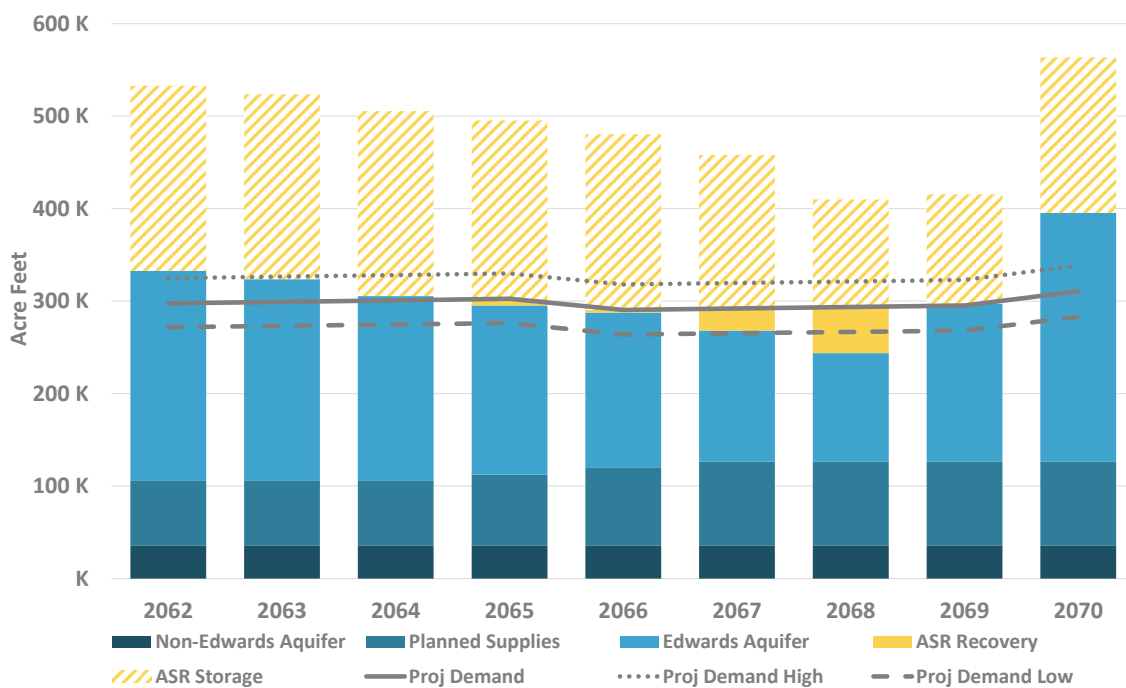


Figure 4-1: SAWS Water Management Plan population projections

	2010	2020	2030	2040	2050	2060	2070
2005 WMP	1,282,967	1,444,042	1,577,597	1,691,280	1,791,681		
2009 WMP	1,330,000	1,429,000	1,536,800	1,664,400	1,792,000	1,919,600	
2012 WMP*	1,585,271	1,835,136	2,051,768	2,249,685	2,426,607	2,599,818	2,799,889
2017 WMP*	1,578,850	1,919,271	2,257,905	2,596,769	2,824,828	3,052,026	3,278,889

* Includes population in areas formerly served by Bexar Metropolitan Water District.

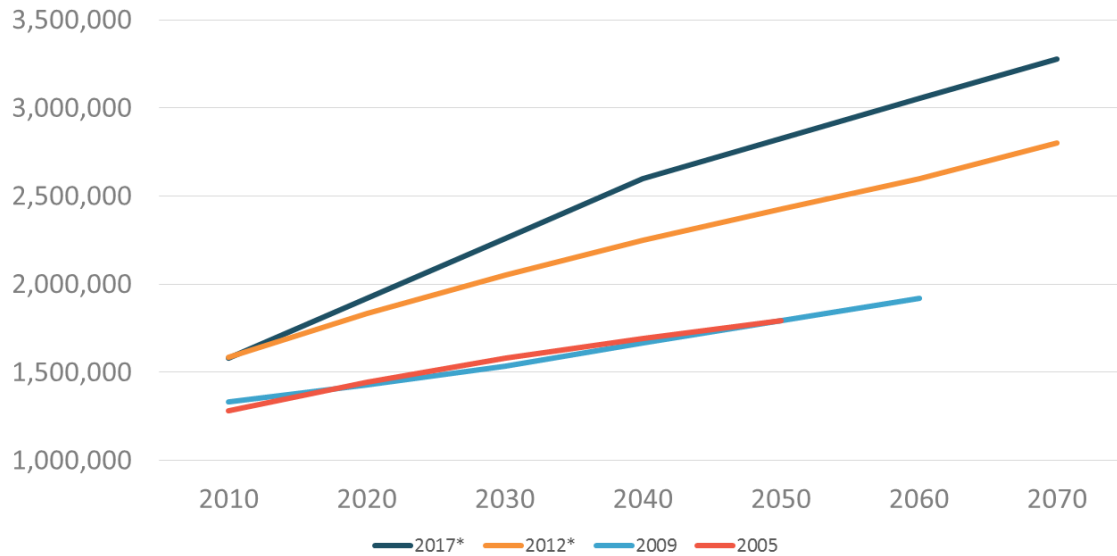


Figure 5-2: Long-Term Conservation Projections for Residential Customers

	2017	2020	2030	2040	2050	2060	2070
Projected Demand High (GPCD)	87	85	77	70	66	64	62
Projected Demand (GPCD)	78	76	69	63	59	57	55
Projected Demand Low (GPCD)	70	68	61	55	51	50	48

	2001	2002	2003	2004	2005	2006	2007	2008
Historic Demand (GPCD)	90	88	85	82	88	95	77	92

	2009	2010	2011	2012	2013	2014	2015	2016
Historic Demand (GPCD)	87	81	91	81	79	75	72	70

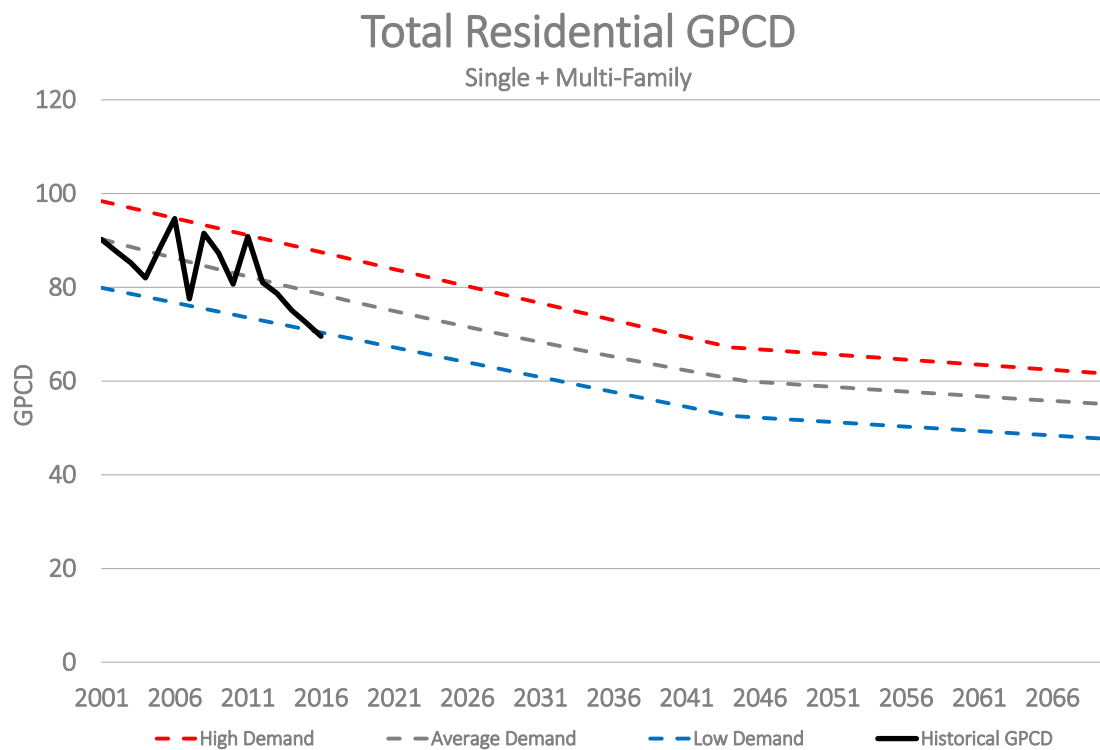


Figure 5-3: Long-Term Conservation Projections for ICI Irrigation Water Use

	2017	2020	2030	2040	2050	2060	2070
Projected Demand High (kgal/bill)	33	30	26	24	23	23	23
Projected Demand (kgal/bill)	26	23	18	16	15	15	15
Projected Demand Low (kgal/bill)	23	20	15	12	11	11	11

	2001	2002	2003	2004	2005	2006	2007	2008
Historic Demand (kgal/bill)	50	39	39	38	46	43	35	51

	2009	2010	2011	2012	2013	2014	2015	2016
Historic Demand (kgal/bill)	38	36	33	29	27	26	26	30

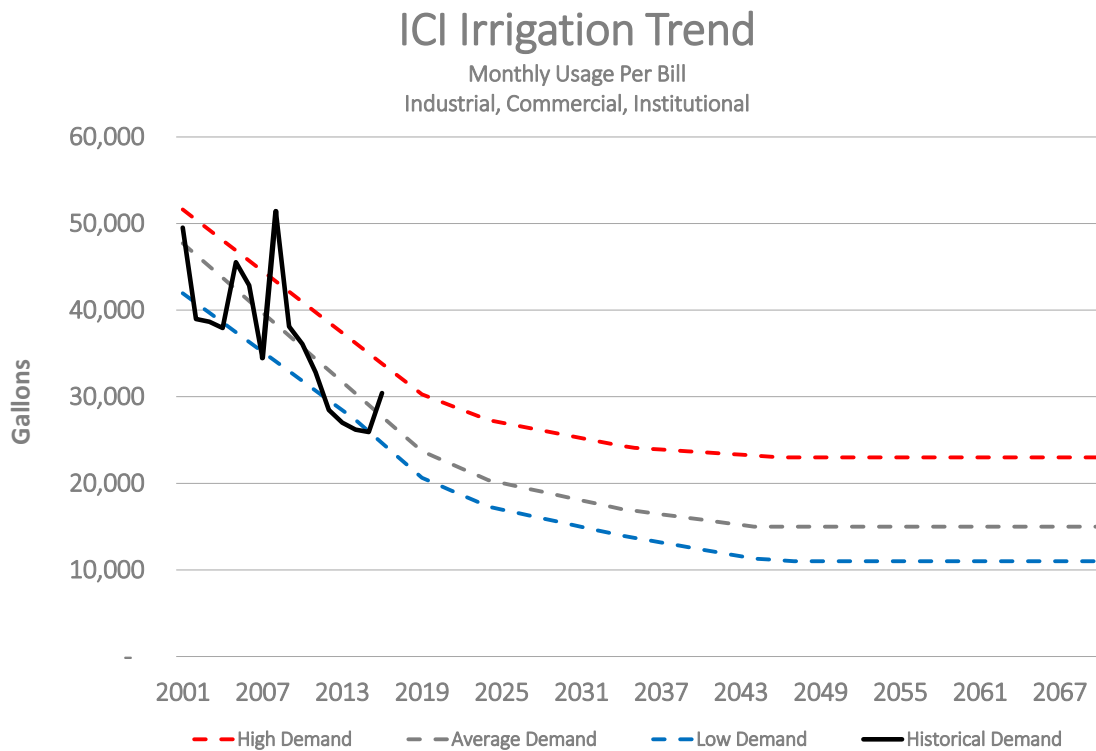


Figure 5-4: Long-Term Conservation Projections for ICI Usage

	2017	2020	2030	2040	2050	2060	2070
Projected Demand High (kgal/bill)	49	46	43	40	38	36	35
Projected Demand (kgal/bill)	48	47	43	40	38	36	35
Projected Demand Low (kgal/bill)	46	43	40	38	36	34	33

	2001	2002	2003	2004	2005	2006	2007	2008
Historic Demand (kgal/bill)	65	59	56	53	55	55	52	55

	2009	2010	2011	2012	2013	2014	2015	2016
Historic Demand (kgal/bill)	55	52	53	52	49	49	51	51

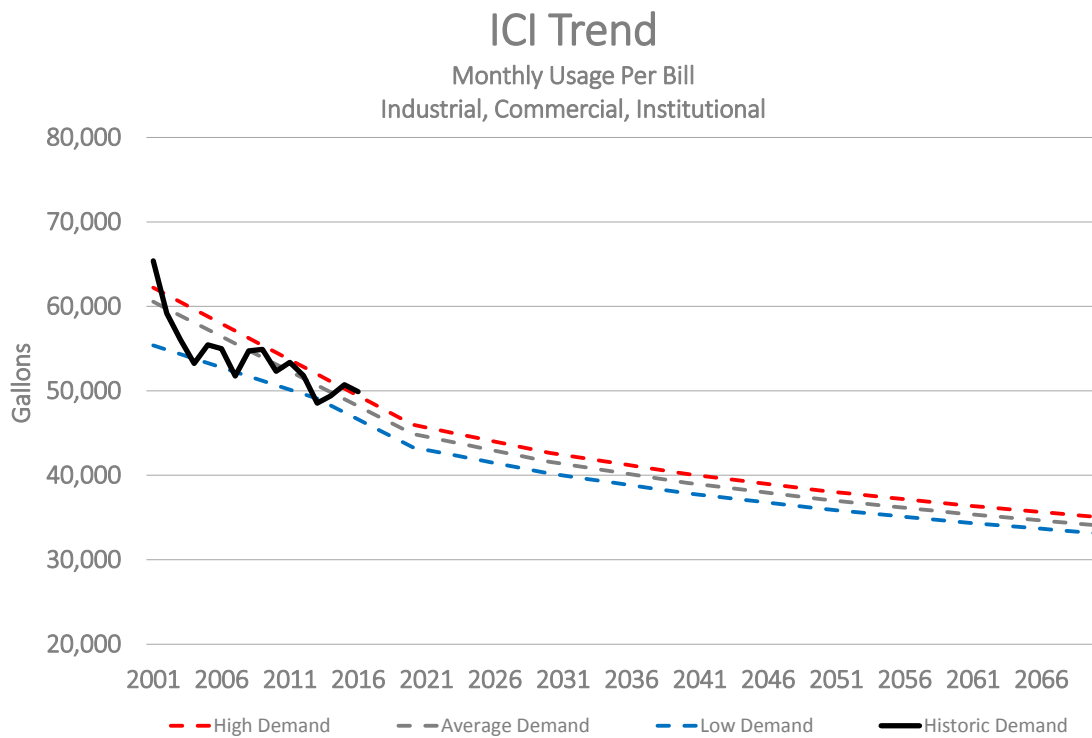


Figure 5-5: Long-Term Total Demand Projections for All Customer Classes

	2017	2020	2030	2040	2050	2060	2070
Planned GPCD (High)	133	128	115	106	101	98	96
Planned GPCD (Average)	124	119	106	96	92	90	88
Planned GPCD (Low)	113	108	97	89	85	82	80

	2001	2002	2003	2004	2005	2006	2007	2008
Historic GPCD	142	128	132	121	138	149	127	150

	2009	2010	2011	2012	2013	2014	2015	2016
Historic GPCD	136	131	143	129	126	124	118	117

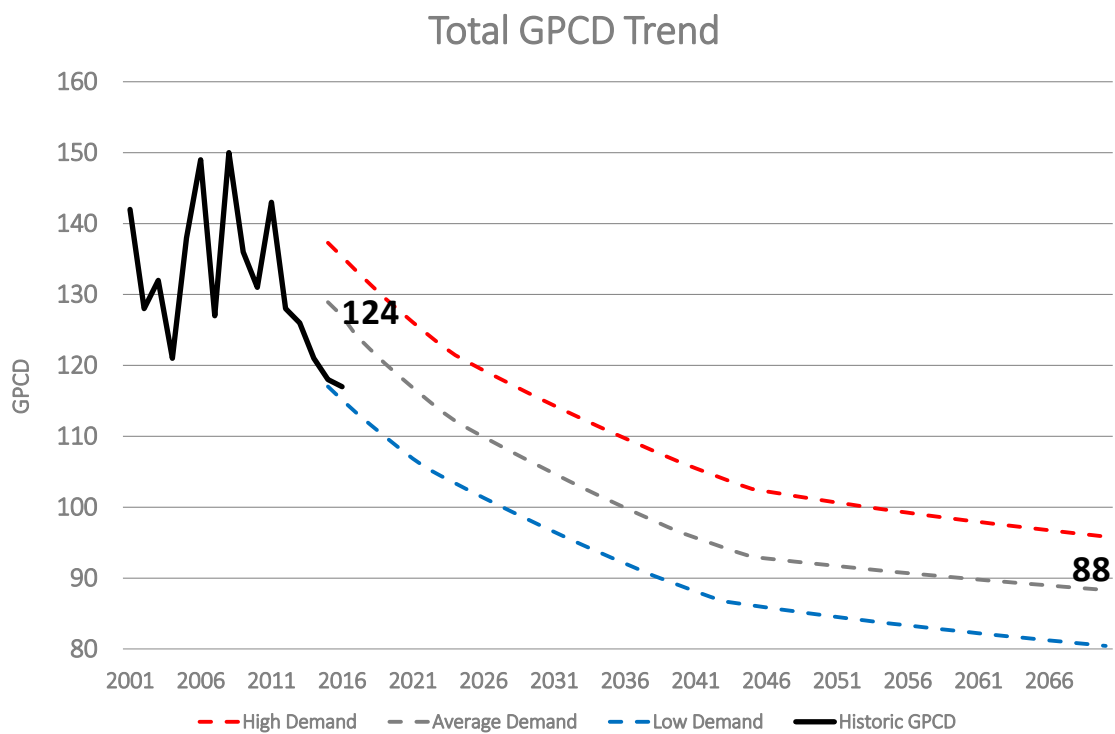


Figure 8-1: SAWS Near Term supply and demand outlook shows a supply gap of 13,130 acre-feet could occur in 2024 without further supply development, such as Vista Ridge. Scenario below represents a Drought of Record.

	2018	2019	2020	2021	2022	2023	2024	2025	2026
Projected Demand High	259,699	260,580	261,638	262,651	252,263	253,159	254,347	256,139	269,608
Projected Demand	242,360	242,914	243,673	244,388	233,703	234,301	235,168	236,595	249,699
Projected Demand Low	218,705	219,365	219,986	220,561	210,035	211,382	212,736	214,001	226,865
ASR Storage	200,000	200,000	200,000	185,902	167,480	122,016	65,016	46,117	96,117
ASR Recovery	0	0	0	14,098	18,423	45,463	57,000	18,899	0
Supply Gap	0	0	0	0	0	0	13,130	0	0
Edwards Aquifer Supply	223,223	211,934	194,152	177,545	162,773	136,579	112,507	165,404	261,128
Brackish Desalination Ph II	0	0	0	0	0	0	0	0	0
Brackish Desalination Ph III	0	0	0	0	0	0	0	0	0
Vista Ridge	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph I	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph II	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph III	0	0	0	0	0	0	0	0	0
Planned Supplies	0	0	0	0	0	0	0	0	0
Trinity Project	16,100	16,100	16,100	4,000	4,000	4,000	4,000	4,000	16,100
Local Carrizo	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
Western Canyon	8,762	8,524	8,286	8,048	7,810	7,561	7,333	7,095	6,857
Medina Surface Plant	13,000	10,000	1,500	0	0	0	0	0	13,000
CRWA	6,300	6,300	6,300	6,300	6,300	6,300	6,800	6,800	6,800
Regional Carrizo	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057
Brackish Desalination Ph I	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440
Non-Edwards Supplies	78,559	75,321	66,583	52,745	52,507	52,258	52,530	52,292	77,154

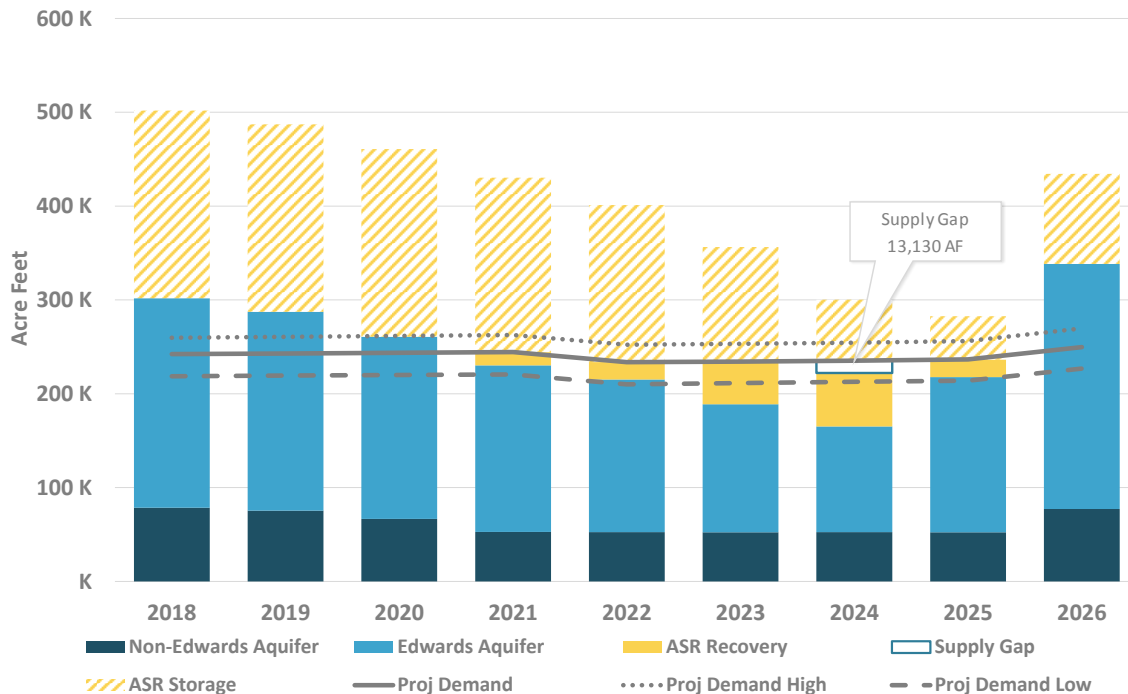


Figure 8-2: SAWS Near Term supply and demand outlook shows no supply gap with further supply development, such as Vista Ridge. Scenario below represents a Drought of Record.

	2018	2019	2020	2021	2022	2023	2024	2025	2026
Projected Demand High	259,699	260,580	261,638	262,651	252,263	253,159	254,347	256,139	269,608
Projected Demand	242,360	242,914	243,673	244,388	233,703	234,301	235,168	236,595	249,699
Projected Demand Low	218,705	219,365	219,986	220,561	210,035	211,382	212,736	214,001	226,865
ASR Storage	200,000	200,000	200,000	200,000	200,000	200,000	179,870	200,000	200,000
ASR Recovery	0	0	0	0	0	0	20,130	0	0
Supply Gap	0	0	0	0	0	0	0	0	0
Edwards Aquifer Supply	223,223	211,934	194,152	177,545	162,773	136,579	112,507	165,404	261,128
Brackish Desalination Ph II	0	0	0	0	0	0	0	0	0
Brackish Desalination Ph III	0	0	0	0	0	0	0	0	0
Vista Ridge	0	0	25,000	50,000	50,000	50,000	50,000	50,000	50,000
Expanded Carrizo Ph I	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph II	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph III	0	0	0	0	0	0	0	0	0
Planned Supplies	0	0	25,000	50,000	50,000	50,000	50,000	50,000	50,000
Trinity Project	16,100	16,100	16,100	4,000	4,000	4,000	4,000	4,000	16,100
Local Carrizo	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
Western Canyon	8,762	8,524	8,286	8,048	7,810	7,561	7,333	7,095	6,857
Medina Surface Plant	13,000	10,000	1,500	0	0	0	0	0	13,000
CRWA	6,300	6,300	6,300	6,300	6,300	6,300	6,800	6,800	6,800
Regional Carrizo	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057
Brackish Desalination Ph I	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440
Non-Edwards Supplies	78,559	75,321	66,583	52,745	52,507	52,258	52,530	52,292	77,154

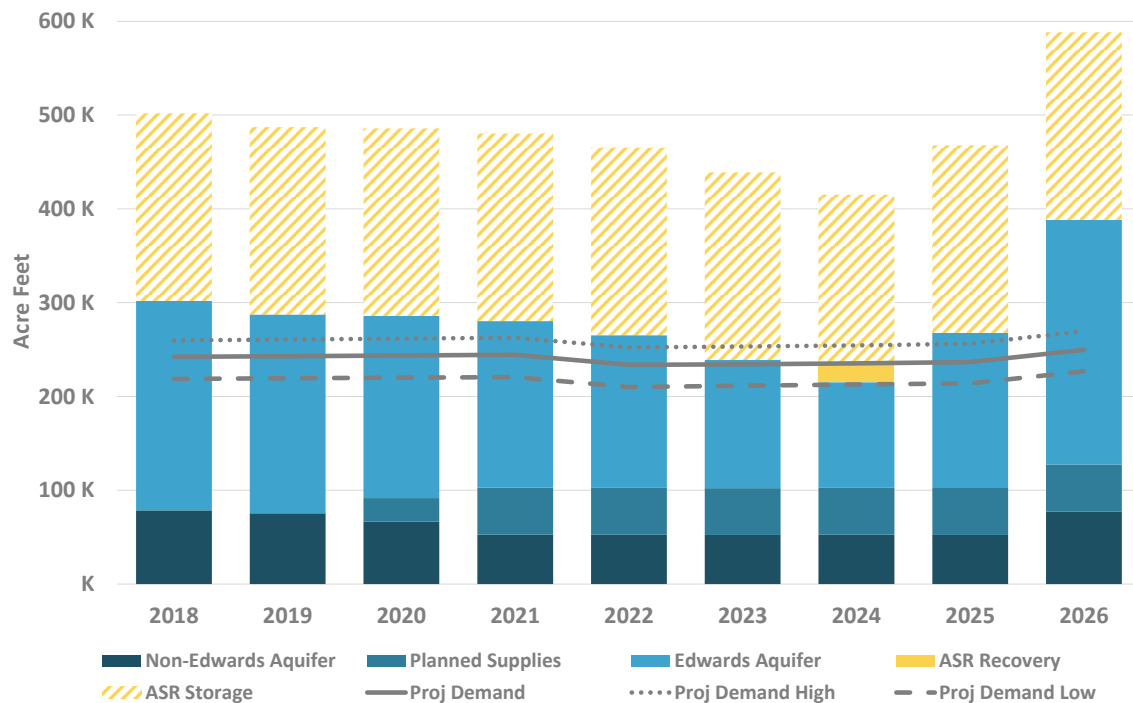


Figure 11-1: After 30 years of water security from Vista Ridge supply, SAWS Long Term supply and demand outlook shows a supply gap of 5,757 acre-feet could occur in 2050 without further supply development, such as desalination or Expanded Carrizo. Scenario below represents a Drought of Record.

	2044	2045	2046	2047	2048	2049	2050	2051	2052
Projected Demand High	295,226	295,967	297,666	299,357	288,396	290,003	291,624	293,279	307,774
Projected Demand	269,528	270,034	271,655	273,269	262,232	263,766	265,313	266,889	281,311
Projected Demand Low	244,555	246,093	247,524	248,949	237,722	239,067	240,421	241,801	256,029
ASR Storage	200,000	200,000	200,000	197,673	188,829	152,027	95,027	84,219	134,219
ASR Recovery	0	0	0	2,327	8,843	36,803	57,000	10,808	0
Supply Gap	0	0	0	0	0	0	5,757	0	0
Edwards Aquifer Supply	227,166	218,141	199,839	182,745	167,992	141,567	117,158	170,685	268,776
Brackish Desalination Ph II	0	0	0	0	0	0	0	0	0
Brackish Desalination Ph III	0	0	0	0	0	0	0	0	0
Vista Ridge	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Expanded Carrizo Ph I	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph II	0	0	0	0	0	0	0	0	0
Expanded Carrizo Ph III	0	0	0	0	0	0	0	0	0
Planned Supplies	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Trinity Project	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Local Carrizo	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900	9,900
Western Canyon	0	0	0	0	0	0	0	0	0
Medina Surface Plant	13,000	10,000	1,500	0	0	0	0	0	0
CRWA	2,800	2,800	2,800	2,800	0	0	0	0	0
Regional Carrizo	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057	11,057
Brackish Desalination Ph I	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440	13,440
Non-Edwards Supplies	51,197	48,197	39,697	38,197	35,397	35,397	35,397	35,397	35,397

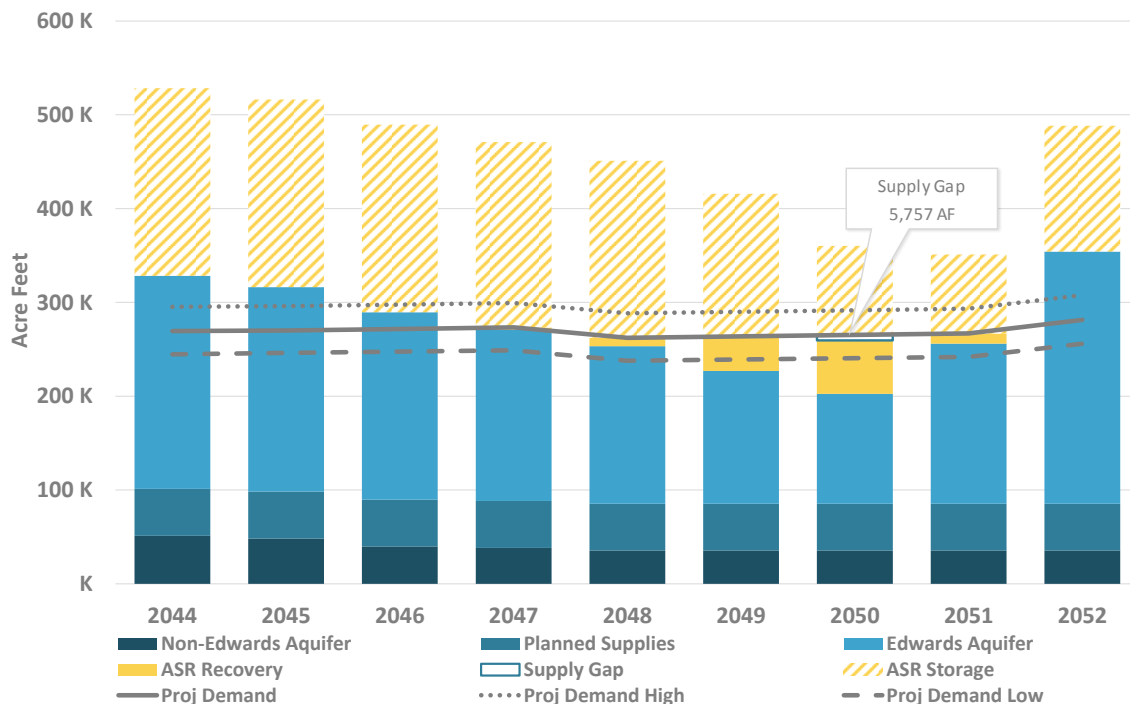
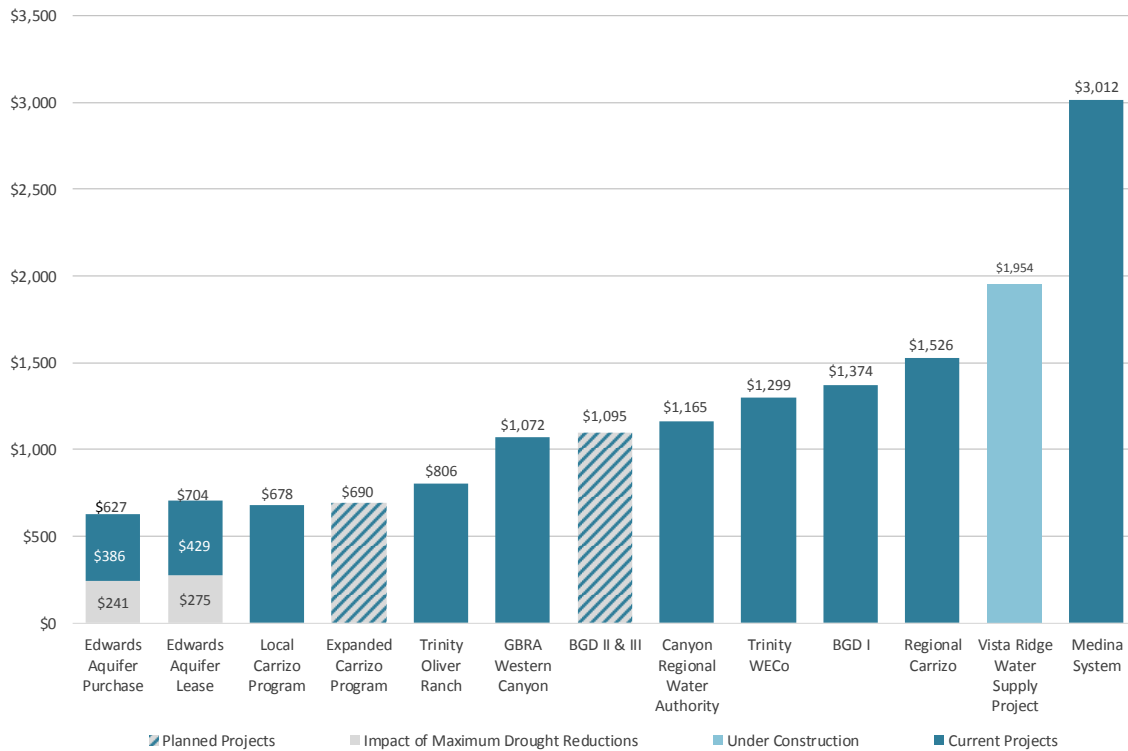


Figure 16-1: Annual Cost per Acre-Foot by Project

Project	Yield (AFY)	Total Capital	Annual O&M	Annual Debt Service	Without Integration (\$/1000 gal)	Without Integration (\$/AF)	Integration Cost (\$/AF)	Total Cost (\$/AF)
Edwards Aquifer Purchase (Best)	284,277	549,094,374	74,084,853	35,719,377	\$ 1.19	\$ 386	-	\$ 386
Edwards Aquifer Purchase (Worst)	159,195	549,094,374	64,138,289	35,719,377	1.93	627	-	627
Edwards Aquifer Lease (Best)	284,277	549,094,374	86,283,936	35,719,377	1.32	429	-	429
Edwards Aquifer Lease (Worst)	159,195	549,094,374	76,337,371	35,719,377	2.16	704	-	704
Regional Carrizo	11,557	127,075,429	9,363,929	8,266,439	4.68	1,526	-	1,526
Local Carrizo *	9,900	15,225,003	721,458	990,408	2.08	678	212.17	890
Expanded Carrizo*	21,000	44,316,451	1,000,000	2,883,000	2.12	690	304.01	994
GBRA Western Canyon	8,980	15,668,083	8,602,527	1,019,231	3.29	1,072	-	1,072
Trinity Oliver Ranch	2,000	10,032,492	960,132	652,628	2.47	806	-	806
Trinity WECO	16,467	17,908,870	20,220,691	1,164,998	3.99	1,299	-	1,299
Desal Phase I	13,440	196,449,708	5,684,384	12,779,335	4.22	1,374	304.01	1,678
Desal Phase II	13,440	160,872,944	5,119,298	10,465,016	3.56	1,160	304.01	1,464
Desal Phase III	6,720	61,128,352	2,508,361	3,976,487	2.96	965	304.01	1,269
Desal Total	33,600	418,451,005	13,312,043	27,220,838	3.70	1,206	304.01	1,510
Medina System	2,000	19,702,001	4,742,259	1,281,643	9.24	3,012	-	3,012
Canyon Regional Water Authority	6,300	-	7,341,262	-	3.58	1,165	-	1,165
Vista Ridge	50,000	-	97,700,000	-	6.00	1,954	316.61	2,271

*This includes ASR Program costs



MEMORANDUM



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TO: File

CC: Karen Guz, Darren Thompson, Adam Conner, Rene Gonzalez, Donovan Burton

FROM: Spencer Schnier, Jeremy Rice, and Tom Gooch

SUBJECT: Assessment of Water Savings from Year-Round Once Per Week Watering Restrictions

DATE: May 25, 2017

PROJECT: GUT17159

Executive Summary

The objective of this study is to estimate the potential water savings as a result of the San Antonio Water System (SAWS) adopting a year-round once per week watering schedule. The purpose of this memorandum is to describe the method and results of the study. The analysis did not consider the effectiveness of Stage 1 watering restrictions due to a lack of available data (11% of the period of record). Based on analysis of drought response strategies implemented between 2006 and 2016, we reached the following conclusions:

- The potential water savings from implementing Stage 2 watering restrictions (once per week watering) during non-drought conditions are **approximately 1.25%** on an annualized basis.
- Estimated water savings were greater during the summer months, when higher outdoor water use would be expected.
- No water savings were shown for 2016 conditions if Stage 2 had been applied. Whether this suppressed demand is transient or part of a long-term trend is unknown at this time.
- There would be no additional water savings from being in Stage 2 restrictions year-round if SAWS would already be in Stage 2. SAWS was in Stage 2 restrictions 39% of the period of record (Table 2). Additional savings from year-round restrictions would probably be very limited if SAWS would already be in Stage 1, which also limits watering to once per week.

Table 1 summarizes the results for the model of SAWS water demand used in our analysis, giving the R^2 coefficients for the calibration and validation periods and the water savings

estimated using the model. (R^2 is a measure of goodness of fit, with an R^2 of 1.0 indicating a perfect fit.) The R^2 coefficients are reported for monthly estimates. The model is discussed in greater detail below.

Table 1. Summary of Results

Model	Calibration R^2	Validation R^2	Applied to	Estimated Annualized Water Savings
Stage 2 Predicted Use	0.97	0.94	Stage 0 Observed Use	1.25%

Introduction

Wholesale water providers in Texas have evaluated the effectiveness of their water conservation measures in the past. In 2013, the Tarrant Regional Water District (TRWD) estimated that their four primary customers experienced water savings of 5% to 11% of total water use with twice per week watering¹. In a 2014 study, the Lower Colorado River Authority (LCRA) estimated savings between 12 percent and 20 percent annually due to once per week watering in Austin². A 2015 study for North Texas Municipal Water District (NTMWD) estimated an overall annual reduction of around 10% annually from once per week watering, but identified no savings from twice per week watering³. In 2016, SAWS undertook a study to determine the impact of once per week watering on their demand⁴. They concluded that 36.6 ac-ft/day on average was saved while restrictions were in place, and that savings varied seasonally. These four studies of water providers in Texas are not directly comparable because they analyzed different periods of record, used different methodologies, have distinct service areas, varying degrees of existing watering restrictions, and customer bases. SAWS has a long history of successful water conservation, and as a result their demand is lower and less elastic than other providers.

The history of recent drought response measures in the SAWS service area is summarized in Table 2. For the purposes of this study, we used SAWS water use data from January 1, 2006 through December 31, 2016. The times when SAWS customers were subject to watering

¹ Alan Plummer Associates, Inc. (2013). Tarrant Regional Water District Strategic Water Conservation Plan. Appendix I: Water Savings from TRWD Stage 1 Drought Response Measures

² Anderson, R., and Oliver, L. (2014). Municipal Water Use Tracking of the City of Austin. Presentation to the Partnership Technical Meeting at Lower Colorado River Authority (LCRA) on 10/22/2014.

³ Schnier, S., and Gooch, T. (2015). Assessing the Effectiveness of NTMWD Drought Response Measures. Prepared for North Texas Municipal Water District (NTMWD). Technical Memorandum dated 8/19/2015.

⁴ Thompson, D. (2016). Impact of Once Per Week Watering on Demand & Supply. Presentation to San Antonio Water System on June 2, 2016.

restrictions during this 11 year period were provided by SAWS. SAWS has four stages of increasingly severe watering restrictions, however only the first two stages occurred during the period of record. The key features of Stages 1 and 2 pertinent to this study are that Stage 1 allows once per week watering before 11:00 a.m. and after 7:00 p.m. on designated watering days, while Stage 2 restricts that window to 7:00-11:00 a.m. and 7:00-11:00 p.m. Prior to 2013, the hours for Stage 2 were from 3:00-8:00 a.m. and 8:00-10:00 p.m. Historically, Stage 1 was implemented for periods lasting only a few weeks before and after more prolonged implementations of Stage 2. For this reason, this analysis did not evaluate the effectiveness of Stage 1 watering restrictions directly.

Table 2. History of Watering Restrictions in SAWS Service Area

Drought Stage	Description	Dates	Days	Percent of Record
0	No Watering Restrictions	1/1/2006 - 7/18/2006 1/24/2007 - 4/9/2009 11/10/2009 - 4/11/2011 3/7/2012 - 4/11/2012 6/16/2015 - 7/30/2015 12/3/2015 - 12/31/2016	2,000	50%
1	Once Per Week Watering (before 11am & after 7pm)	7/19/2006 - 1/23/2007 4/10/2009 - 6/14/2009 10/12/2009 - 11/9/2009 4/12/2011 - 5/31/2011 1/1/2012 - 3/6/2012 4/12/2012 - 4/29/2012 7/31/2015 - 8/14/2015	433	11%
2	Once Per Week Watering (7-11am & 7-11pm)	6/15/2009 - 10/11/2009 6/1/2011 - 12/31/2011 4/30/2012 - 6/15/2015 8/15/2015 - 12/2/2015	1,585	39%

Method

The objective of this study is to estimate the potential water savings as a result of SAWS adopting a year-round once per week watering schedule. In other words, how much water would SAWS save by implementing once per week watering restrictions during times outside of drought conditions when they would otherwise not have implemented them? To answer this question, FNI developed a multiple linear regression (MLR) equation to predict per capita raw water pumping for SAWS during periods with Stage 2 watering restrictions (Stage 2 Model). Both Stage 1 and Stage 2 have once per week watering restrictions, but we developed a model to simulate Stage 2 water use due to data availability. To estimate the savings that would result from limiting watering to once per week during non-drought conditions (Stage 0), the Stage 2 model is used to predict what water use with a once per week limit would have been in non-drought periods. The water use predicted by the Stage 2 Model is then

subtracted from the observed use during periods without watering restrictions (Stage 0) to estimate the savings from implementing once per week restrictions in non-drought periods.

The Stage 2 Model was calibrated and validated exclusively on periods in Stage 2 watering restrictions (i.e., periods with once per week watering restrictions in place). The idea was to develop a model capable of predicting water use during periods when there are watering restrictions in place (i.e. Stage 2). The calibration period for the Stage 2 Model includes the following date ranges: 6/15/2009 - 10/11/2009, 6/1/2011 - 12/31/2011, 4/30/2012 - 12/31/2012, 1/1/2014 - 6/15/2015, 8/15/2015 - 12/2/2015. The validation period was a complete year from 1/1/2013 to 12/31/2013.

The water savings from year-round watering restrictions are estimated in three steps:

1. Develop a model to predict water use when Stage 2 watering restrictions are in place
2. Use the model to estimate what water use would have been if watering restrictions were in place
3. Estimate water savings from watering restrictions by comparing the predictions of the model to actual water use during periods without watering restrictions in place

In multivariate linear regression (MLR), two or more explanatory variables (x_1, x_2, \dots, x_n) are used to estimate the response variable using the form:

$$y = b + m_1x_1 + m_2x_2 + \dots + m_nx_n$$

In this study, the response variable y is the daily per capita raw water pumping for water treatment (gal/person/day), and n is the number of explanatory variables. The population-served numbers used to convert actual pumping to per capita pumping are given in Table A-1 in the Appendix. The model coefficients are estimated using the ordinary least squares (OLS) method. Step-wise regression is used to select the variables to be included in the model. (In step-wise regression, the explanatory variables that do the most to explain the variations in pumping are adopted.) The variance inflation factor (VIF) is used to check for multicollinearities between the variables in the model. This is done to avoid using multiple explanatory variables that are so closely related that they are effectively the same. A detailed description of each step in the regression process, including the variable chosen to enter the model at each step, is provided in the Appendix.

The Stage 2 Model was built using the variables in Table 3, which are available on a daily timescale and have a period of record from 1/1/2006 to 12/31/2016. The full list of model variables considered, from which the five in Table 3 were selected as most useful, is given in Figure A-1 in the Appendix. The dependent variable, Per Capita Pumping, is calculated by dividing the daily total pumping from SAWS by a yearly estimate of the population served from 2006 to 2016 (Table A-1).

Table 3. Independent (X) Variables for Demand Modeling, In Order of Importance

ID	Variable	Units	Range of Calibration Data
X1	Total Days Over 90 F in Last 10 Days	days	0 - 10
X2	Days Since Last Rainfall (May-Nov) cap=20	days	0 - 20
X3	Reference Evapotranspiration (ET ₀)	inches	0.01 - 0.54
X4	Rate First x-gallons	dollars	0.0906 - 0.1006
X5	Total Precipitation in Last 50 Days	inches	0.17 - 15.35

Of the 72 variables listed in Figure A-1, the variable that was most strongly correlated with daily per capita pumping during the calibration period was Total Days over 90°F in Last 10 Days. For this reason, it was the first variable to enter the model during the stepwise regression procedure. For this variable, we considered ranges from 5 to 50 days (in increments of 5 days) over which to sum the number of days over 90 degrees. Of those, ten days was found to be the best window.

Days Since Last Rainfall measures the total number of days since the last precipitation event greater than 0.2 inches. The value of 0.2 inches was provided by SAWS as the threshold for “useful” rainfall. The value of this variable was capped at 20 days and was set equal to 0 from January 1 to April 30 and from December 1 to December 31 every year. It is set to zero during these months because a greater number of days without rainfall from December through April will not create a significant increase in demand for water because this is the low demand season (i.e., decreased outdoor watering). We considered multiple window sizes including unrestricted (i.e., Jan-Dec), May-Nov, May-Oct, May-Sep, and Jun-Sep. We also considered multiple maximum values including uncapped, and 10 through 50 days in increments of 5 days. Of these, May-Nov with a maximum of 20 days was found to be the strongest predictor during the regression.

Daily Reference Crop Evapotranspiration (ET₀), in inches, was provided by SAWS through their membership in the Texas A&M Texas ET Network. This variable was selected by the stepwise regression procedure to be the third variable to enter the model.

The first tier of the SAWS Schedule 8 Residential Class Rates for meters within the City limits (Rate First x-gallons) was the fourth variable to enter the model during the stepwise regression procedure. Values for this variable vary on an annual basis and are included in Table A-2. The value of “x” in the variable name was 7,481 gallons from 2006 to 2009 and 5,985 gallons from 2010 to 2015. In 2016, the SAWS rate structure changed in a way that is not directly comparable with pre-2016 data. The Service Availability Charge increased 42% (the average increase from previous years was 1.8%). Also, the number of tiers increased from four to eight. (The seasonal component of the rate structure for higher tiers was also eliminated). These two changes caused the cost for the first 5,985 gallons to decrease for the first time in the period of record. For these reasons, 2015 rates were repeated for 2016 for both rate variables (i.e., first tier and highest tier rate variables).

Total Precipitation in Last 50 Days was the last independent variable to be included in the model. We considered ranges from 1 to 50 days over which to sum precipitation. During the stepwise regression, summing over the last 50 days was the strongest predictor of pumping behavior.

Results

The final model derived from the stepwise regression procedure is shown in Equation 1. A detailed explanation of how this equation was arrived at is provided in the Appendix.

$$\begin{aligned} \text{Daily Per Capita Pumping} = & \\ & 2.17 * (\text{Days over } 90^{\circ}\text{F in Last 10 Days}) + \\ & 0.91 * (\text{Days Since Last Rainfall (May-Nov) cap}=20) + \\ & 73.17 * (\text{ET (in)}) + \\ & -1114.42 * (\text{Rate First x-gallons}) + \\ & -0.93 * (\text{Total Precip in Last 50 days}) + \\ & 211.68 \end{aligned} \quad (\text{Eq 1})$$

Figure 1 shows how well the predicted monthly Per Capita Pumping matches the actual pumping for periods in Stage 2 watering restrictions. The monthly pumping is the sum of the daily values for the month. The blue line is the actual (observed) Per Capita Pumping. The orange line shows the modeled (predicted) values for the calibration period used to develop the model, and the yellow line shows the modeled values for the verification period used to test the model. Table 4 shows the coefficients of determination (R^2) for the calibration and verification periods based on daily and monthly comparisons. The figure and the table show good agreement of modeled and actual values, indicating that the model predicts actual Per Capita Pumping well.

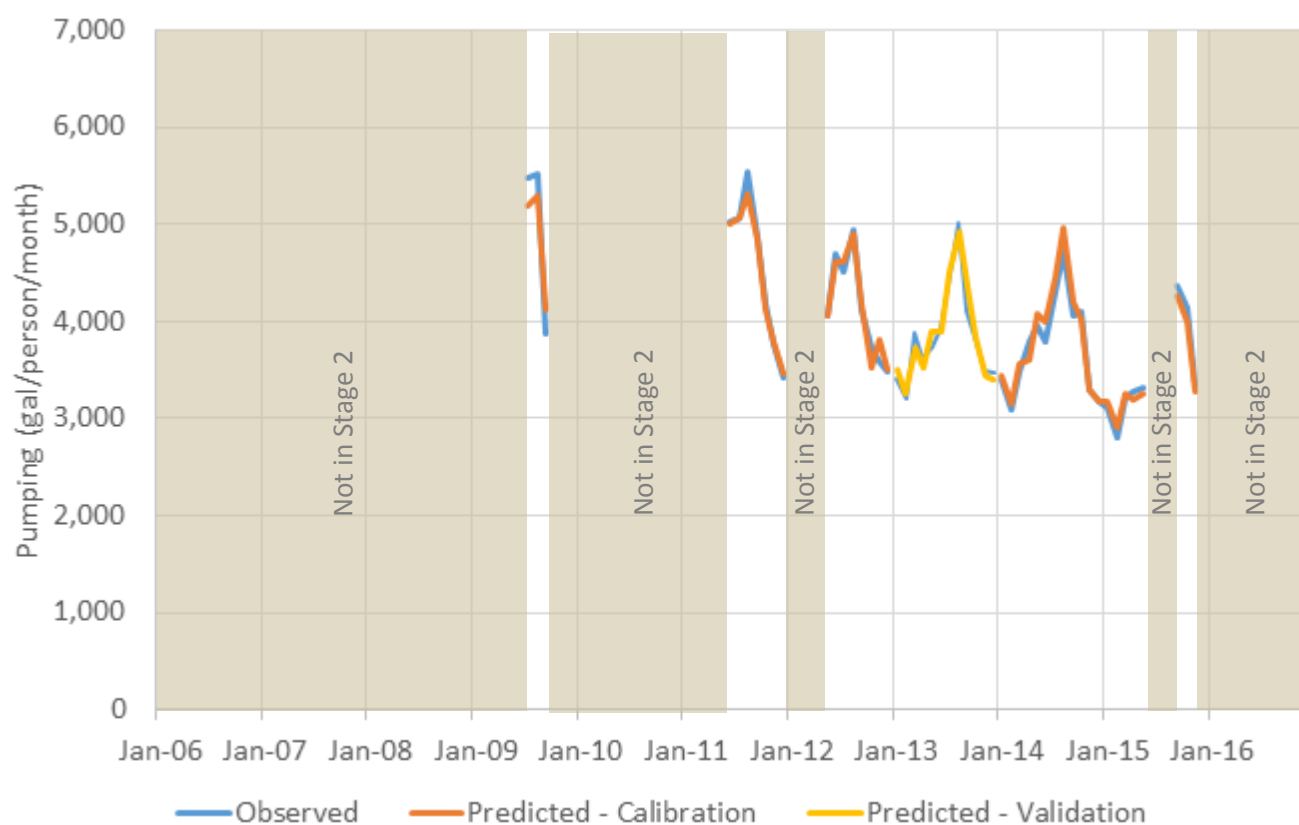


Figure 1. Calibration, Validation, and Observed Daily Per Capita Pumping Aggregated to Monthly Per Capita Pumping for Periods With Stage 2 Watering Restrictions

Table 4. Coefficients of Determination for Calibration and Validation Datasets at Daily and Monthly Scales

	Daily	Monthly
Calibration	0.82	0.97
Validation	0.70	0.94

Figure 2 shows a scatter plot of observed and modeled monthly Per Capita Pumping values.

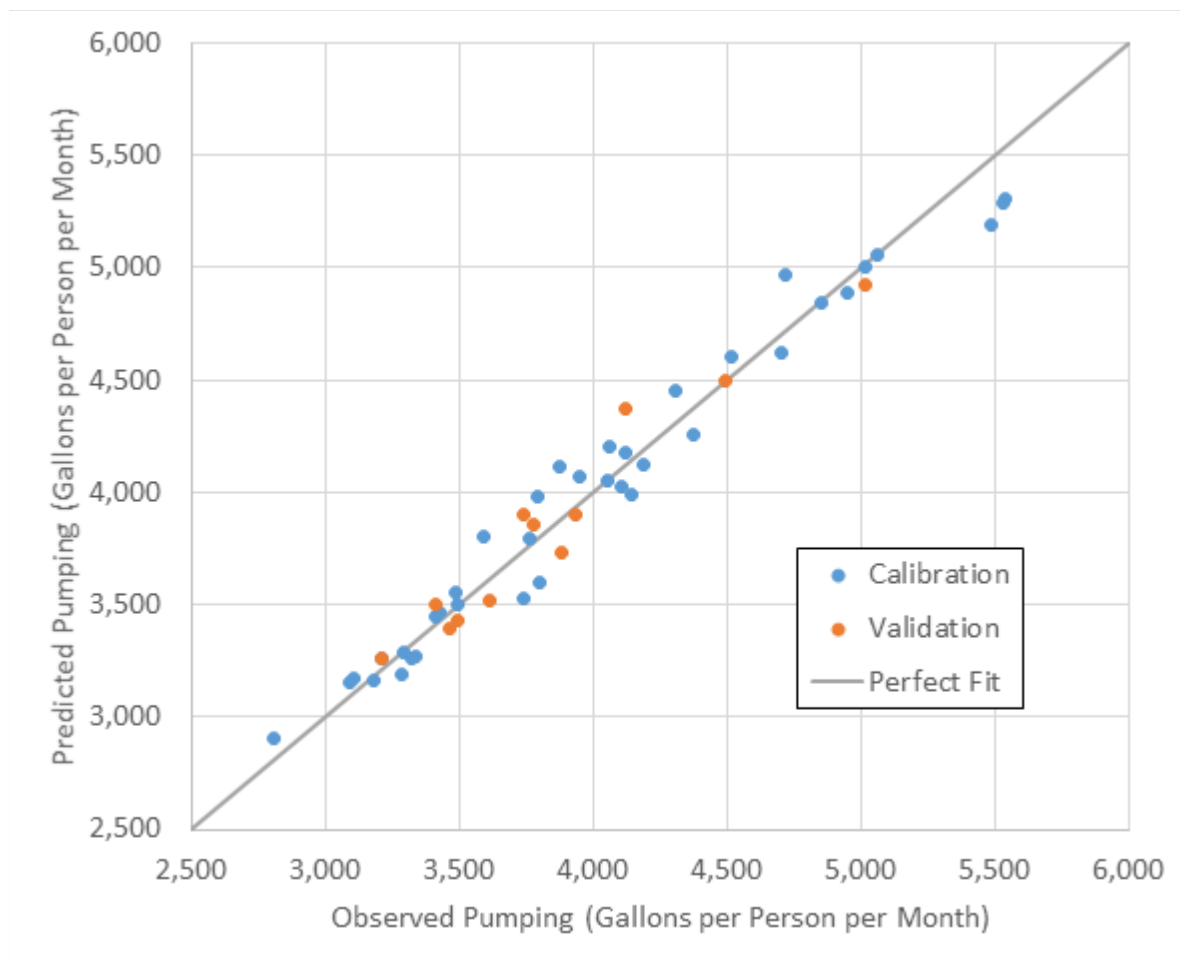


Figure 2. Scatterplot of Predicted Versus Observed Per Capita Pumping

Estimated Savings from Implementing Stage 2 Restrictions During Non-Drought Periods

Figure 3 and Table 5 show the comparison of actual Per Capita Pumping without watering restrictions in place (i.e. Stage 0) to modeled pumping if Stage 2 restrictions were in place. The orange line in Figure 3 shows estimated monthly Per Capita Pumping from the model (i.e. what pumping would be if watering restrictions were in place), and the blue line shows actual values during times without watering restrictions in place. Where the blue line is above the orange line, there may be a water savings from the Stage 2 watering restrictions. According to the model, the total estimated water savings from implementing Stage 2 restrictions during non-drought periods are around 1.25% on an annualized basis, with greater savings during summer months, and no measurable savings (and perhaps increased pumping) from November to February (Table 5).

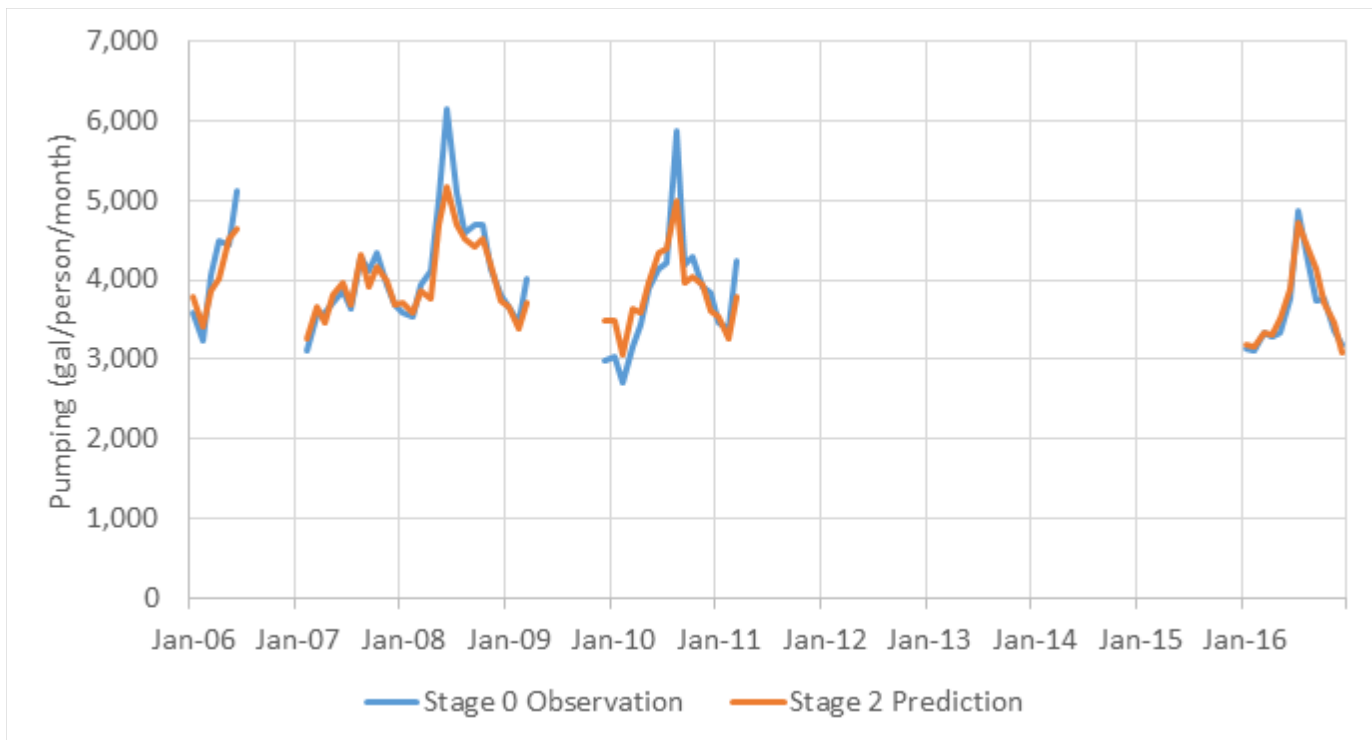


Figure 3. Comparison of Observed Per Capita Pumping and Modeled Pumping if Stage 2 Watering Restrictions (Once Per Week Watering) Were in Place.

Table 5. Estimated Monthly Water Savings from Implementing Stage 2 Watering Restrictions (Once Per Week Watering) During Non-Drought Periods

Month	Instances	Average Observed	Average Predicted	Difference	Percent Difference
1	6	3,410	3,559	-149	-4.36%
2	7	3,217	3,303	-85	-2.65%
3	7	3,761	3,691	70	1.86%
4	5	3,784	3,622	162	4.29%
5	5	4,080	4,102	-21	-0.53%
6	5	4,603	4,396	207	4.49%
7	4	4,453	4,377	77	1.72%
8	4	4,738	4,549	189	3.98%
9	4	4,179	4,111	68	1.63%
10	4	4,272	4,111	161	3.77%
11	4	3,837	3,891	-54	-1.42%
12	5	3,496	3,522	-25	-0.72%
Total	60	47,831	47,233	599	1.25%

The 1.25% savings reported in Table 5 is the water savings SAWS could expect by implementing Stage 2 drought restrictions during non-drought years for a complete year, on average. The amount of water saved will vary by month, as shown in Table 5, but it will also vary by year, as shown in Figure 4 below. Based on a reading of Figure 4, the 1.25% savings per year is conceptually more similar to 5% savings one year and 0% savings the next four years, for an average savings of 1% per year.

It is noteworthy that no water savings were projected for 2016 conditions, as can be seen in Figure 3 and Figure 4. (Actual 2016 water rates for the first 5,895 gallons were lower than the 2015 rates substituted for 2016 in this study; the model would have predicted even less water savings had actual 2016 rates been used instead). This indicates that during 2016, SAWS customers behaved as if they were in Stage 2 drought restrictions in terms of water use even though they were not, so no additional water savings from implementing Stage 2 watering restrictions would have been realized. This suppressed demand could be due to residual effects from being in a multi-year period of watering restrictions, or the result of lower water savings potential due to wet weather. Whether the suppressed demand is transient or the result of a permanent behavior change is not clear at this time.

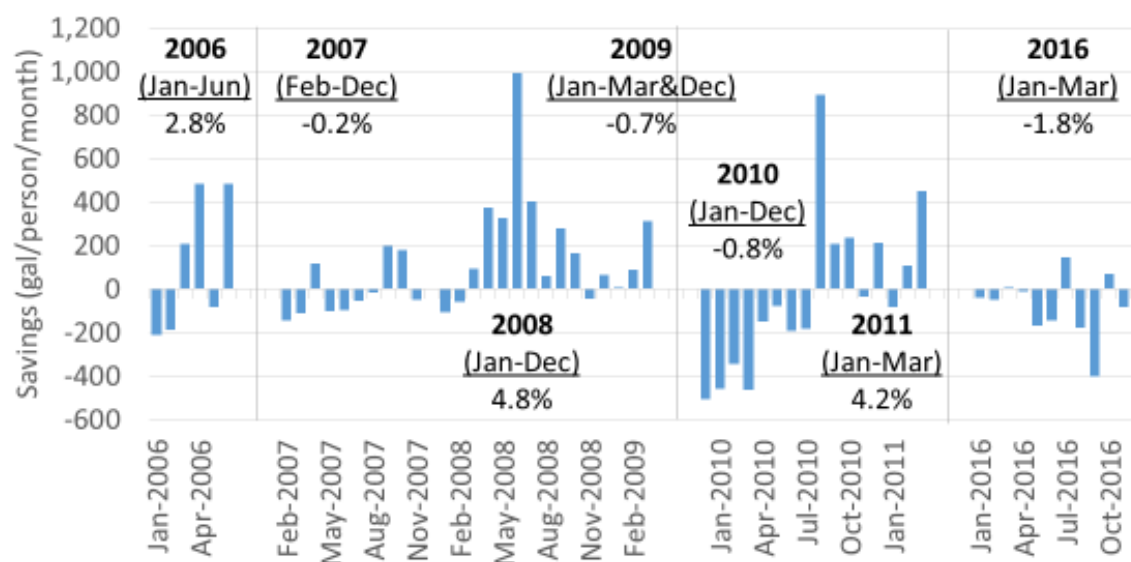


Figure 4. Estimated Water Savings by Year, Where Water Savings is Calculated as Observed Water Use Without Drought Restrictions (Stage 0) Minus Predictions of Stage 2 Model.

Conclusions

The model of water pumping was successfully validated. Estimated water savings were calculated as observed use without drought restrictions minus what water use was projected to be if watering restrictions were in place. Based on analysis of water use and drought response

strategies implemented between 2006 and 2016, we reached the following conclusions:

- The water savings from implementing Stage 2 watering restrictions (once per week watering) during non-drought periods was around 1.25% on an annualized basis.
- Water savings were greater during the summer months (i.e. April through October) when higher outdoor water use occurs, and near-zero other months of the year (Figure 5).
- No water savings were shown for 2016 conditions, but whether this is a residual effect related to recent emergence from years of drought restrictions, or part of a long-term trend remains to be seen.
- By definition, there are no additional water savings from implementing Stage 2 watering restrictions if SAWS would already be in Stage 2 anyway. In other words, implementing restrictions year-round will only produce additional water savings during non-drought periods. For this reason, implementing once per week watering restrictions year-round will have no impact on meeting needs during drought conditions. (It bears mentioning that during non-drought periods, there is more rain and thus less demand for pumping, so the potential water savings from watering restrictions is less than during drought periods). The schedule of water supply projects is not likely to be affected because the need for these projects is typically based on a hypothetical repeat of the drought of record. In its planning, SAWS assumes that watering restrictions would already be in place during a repeat of the drought of record.

Figure 5 shows graphically the same information as Table 5, but superimposed is an “idealized water savings pattern”. This is what we would expect the water savings pattern to look like in a perfect world after the noise and artifacts of the multilinear regression model have been smoothed out.

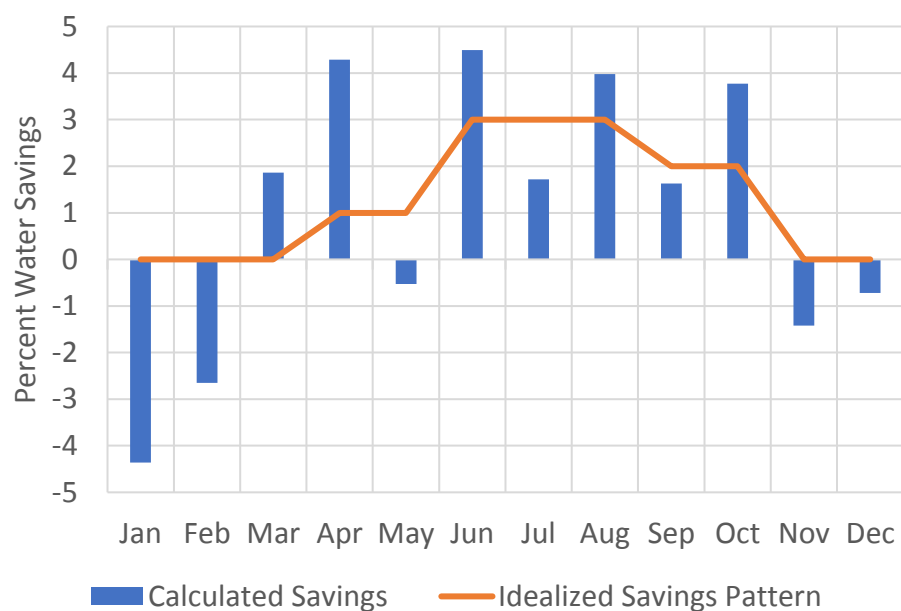


Figure 5. Estimated Water Savings by Month from Implementing Stage 2 Watering Restrictions During Non-Drought Periods.

Appendix

Table A-1 shows the estimated population served by SAWS and BexarMet combined from 2006 through 2016. These data were provided to Freese and Nichols by SAWS, and are used to convert raw water pumping data to Per Capita Pumping.

Table A-1. Estimated Population Served by SAWS & BexarMet Pumping

Year	Population Served
2006	1,490,837
2007	1,521,529
2008	1,549,287
2009	1,574,640
2010	1,601,729
2011	1,628,611
2012	1,659,593
2013	1,671,625
2014	1,712,446
2015	1,742,390
2016	1,783,426

Table A-2. First tier of the SAWS Schedule 8 Residential Class Rates for Meters within the City Limits, as used in the model.

Year	Rate per 100 gallons (\$)
2006	0.0878
2007	0.0878
2008	0.0878
2009	0.0906
2010	0.0917
2011	0.0917
2012	0.0948
2013	0.0948
2014	0.0971
2015	0.1006
2016	0.1006*

* Rate from 2016 is repeated from 2015 because actual SAWS rate structure in 2016 is not directly comparable.

Explanation of Variable Selection

FNI was tasked with developing a model to predict daily per capita pumping (y-variable) as a function of a set of independent variables (x-variables). Figure A-1 shows all 72 of the potential explanatory variables (x-variables) considered in this analysis.

Figure A-1. List of All Potential Explanatory Variables Considered in this Analysis

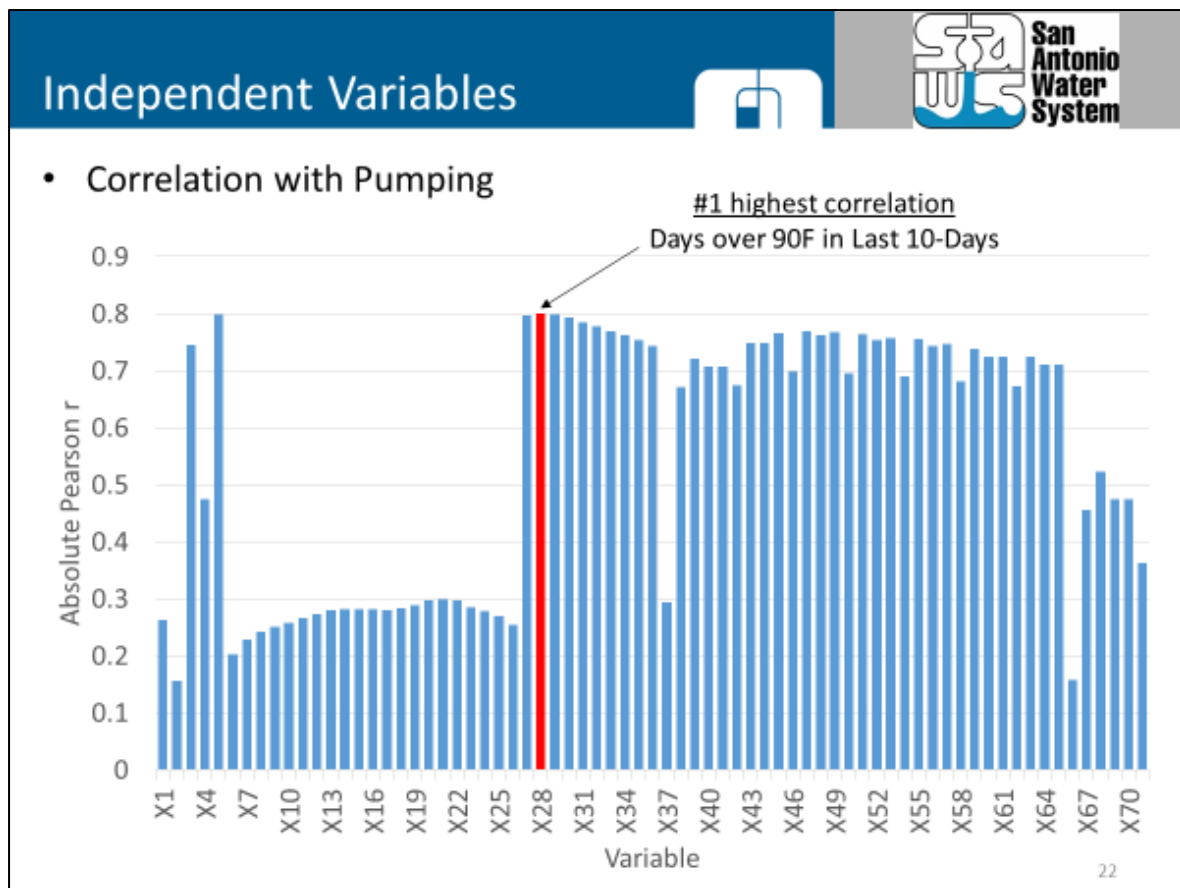
Independent Variables		
Variable	Variable (continued)	Variable (continued)
X1 - J-17 Levels (ft)	X25 - Total Precip in last 45 days	X49 - Days Since Last Rainfall (Jun-Sep) cap=20
X2 - Rainfall (in)	X26 - Total Precip in last 50 days	X50 - Days Since Last Rainfall (May-Nov) cap=25
X3 - Max Temp (deg F)	X27 - Total Days over 90F in Last 5 Days	X51 - Days Since Last Rainfall (May-Oct) cap=25
X4 - Months Since Dec 2000	X28 - Total Days over 90F in Last 10 Days	X52 - Days Since Last Rainfall (May-Sep) cap=25
X5 - Avg Pumping per Day of Year	X29 - Total Days over 90F in Last 15 Days	X53 - Days Since Last Rainfall (Jun-Sep) cap=25
X6 - Total Precip in last 2 days	X30 - Total Days over 90F in Last 20 Days	X54 - Days Since Last Rainfall (May-Nov) cap=30
X7 - Total Precip in last 3 days	X31 - Total Days over 90F in Last 25 Days	X55 - Days Since Last Rainfall (May-Oct) cap=30
X8 - Total Precip in last 4 days	X32 - Total Days over 90F in Last 30 Days	X56 - Days Since Last Rainfall (May-Sep) cap=30
X9 - Total Precip in last 5 days	X33 - Total Days over 90F in Last 35 Days	X57 - Days Since Last Rainfall (Jun-Sep) cap=30
X10 - Total Precip in last 6 days	X34 - Total Days over 90F in Last 40 Days	X58 - Days Since Last Rainfall (May-Nov) cap=40
X11 - Total Precip in last 7 days	X35 - Total Days over 90F in Last 45 Days	X59 - Days Since Last Rainfall (May-Oct) cap=40
X12 - Total Precip in last 8 days	X36 - Total Days over 90F in Last 50 Days	X60 - Days Since Last Rainfall (May-Sep) cap=40
X13 - Total Precip in last 9 days	X37 - Days Since Last Rainfall	X61 - Days Since Last Rainfall (Jun-Sep) cap=40
X14 - Total Precip in last 10 days	X38 - Days Since Last Rainfall (May-Nov) uncapped	X62 - Days Since Last Rainfall (May-Nov) cap=50
X15 - Total Precip in last 11 days	X39 - Days Since Last Rainfall (May-Oct) uncapped	X63 - Days Since Last Rainfall (May-Oct) cap=50
X16 - Total Precip in last 12 days	X40 - Days Since Last Rainfall (May-Sep) uncapped	X64 - Days Since Last Rainfall (May-Sep) cap=50
X17 - Total Precip in last 13 days	X41 - Days Since Last Rainfall (Jun-Sep) uncapped	X65 - Days Since Last Rainfall (Jun-Sep) cap=50
X18 - Total Precip in last 14 days	X42 - Days Since Last Rainfall (May-Nov) cap=10	X66 - Useful Rain
X19 - Total Precip in last 15 days	X43 - Days Since Last Rainfall (May-Oct) cap=10	X67 - Rate First x-gallons
X20 - Total Precip in last 20 days	X44 - Days Since Last Rainfall (May-Sep) cap=10	X68 - Rate over 17,205 gallons
X21 - Total Precip in last 25 days	X45 - Days Since Last Rainfall (Jun-Sep) cap=10	X69 - Days of Drought
X22 - Total Precip in last 30 days	X46 - Days Since Last Rainfall (May-Nov) cap=20	X70 - Months of Drought
X23 - Total Precip in last 35 days	X47 - Days Since Last Rainfall (May-Oct) cap=20	X71 - Years of Drought
X24 - Total Precip in last 40 days	X48 - Days Since Last Rainfall (May-Sep) cap=20	X72 - ET (in)

FNI used the stepwise regression method to build a multi-linear regression (MLR) model. Stepwise regression is carried out in a series of successive steps. In each step, the potential explanatory variable that maximizes adjusted- R^2 is the variable chosen to enter the model at that step. The standard coefficient of determination (R^2) is a measure of goodness-of-fit that equals 1.0 when there is a perfect fit between the prediction and observation. Adjusted- R^2 adjusts the standard coefficient of determination (R^2) based on the number of independent variables in the model, which allows us to compare models with different numbers of independent variables.

In the first step, the model has no x-variables and then a single x-variable is added that maximizes the adjusted- R^2 . The result of the first step is a classic linear model of the form $y = m * x + b$, where y is daily per capita pumping, m is the slope of the line, and b is the y-intercept. In the first step, x is the variable

most strongly correlated with y , because that x -variable will maximize the adjusted- R^2 . Figure A-2 indicates that the variable most strongly correlated with pumping is 'Days over 90 degrees Fahrenheit in the last 10 days'.

Figure A-2. Absolute Pearson Correlations between Independent Variables and Daily Per Capita Pumping for Stage 2 Data



After the first step, the model is in the form $y = m \cdot x + b$ (Equation 1). Interestingly, because the variable 'Days over 90F in Last 10 Days' is zero or near-zero for non-summer months (November through April), the intercept of 111.45 gallons per capita per day is analogous to base-level winter water use. The adjusted- R^2 for Equation A-1 is 0.66 (Figure A-3).

$$\text{Daily Per Capita Pumping} = 4.84 \cdot (\text{Days over 90F in Last 10 Days}) + 111.45 \quad (\text{Eq. A-1})$$

In Step 2, the model is in the form $y = m_1 \cdot x_1 + m_2 \cdot x_2 + b$. Using the variable selected in Step 1, x_1 is the variable 'Days over 90F in the Last 10 Days.' During Step 2, FNI calculated an adjusted- R^2 for 71 different two-variable equations, one equation for each remaining variable in Figure A-1. FNI selected the

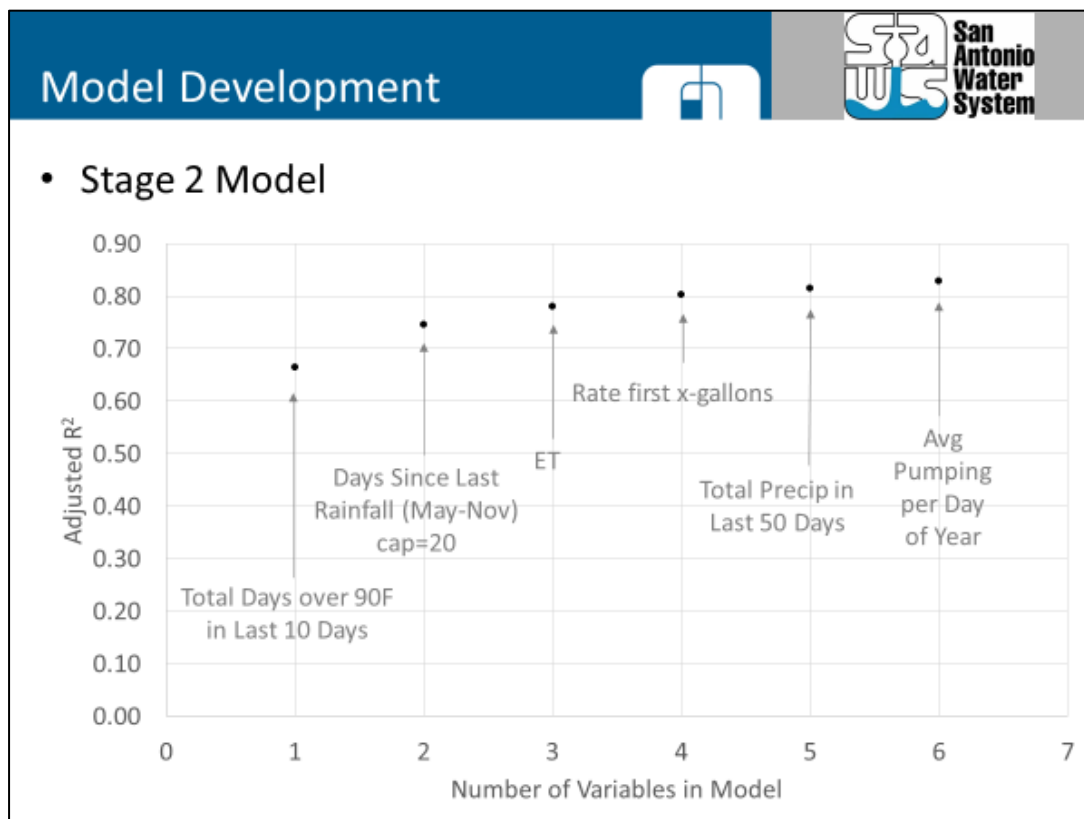
equation with the highest adjusted- R^2 . It is important to bear in mind that the best second variable (i.e. the variable that maximizes adjusted- R^2) is not necessarily the second most correlated variable with pumping because the second most correlated variable could itself be highly correlated with the first variable, which would violate the assumption of independent x-variables. If two x-variables enter the model that are highly correlated with each other, the MLR procedure cannot reliably determine the coefficients (m_1 and m_2) because it cannot reliably distinguish between the two variables, which will lower the adjusted- R^2 . In this way, the stepwise regression procedure is automatically seeking out the combination of independent variables that maximizes adjusted- R^2 . After Step 2, the model is in the form $y = m_1*x_1 + m_2*x_2 + b$ (Equation A-2). The adjusted- R^2 for Equation 2, which is the highest of all 71 models tested, is 0.75 (Figure A-3).

Daily Per Capita Pumping =

$$3.67*(\text{Days over } 90F \text{ in Last 10 Days}) + 1.11*(\text{Days Since Last Rainfall (May-Nov) cap=20}) + 107.55$$

(Eq. A-2)

Figure A-3. Adjusted- R^2 as a Function of the Number of Variables in the Model



In Step 3, the model is in the form $y = m_1*x_1 + m_2*x_2 + m_3*x_3 + b$. The selected x_1 variable from Step 1 is 'Days over 90F in the Last 10 Days' and the selected x_2 variable from Step 2 is 'Days Since Last Rainfall

(May-Nov) cap=20.’ During Step 3, FNI calculated an adjusted-R² for 70 different three-variable equations, one equation for each remaining variable in Figure A-1. FNI selected the equation with the highest adjusted-R². Again, the third variable to enter the model is not necessarily the third most highly correlated with pumping. The model is searching for independent variables that, when combined, are a strong predictor of pumping. After Step 3, the model is in the form $y = m1*x1 + m2*x2 + m3*x3 + b$ (Equation A-3). The adjusted-R² for Equation A-3 is 0.78 (Figure A-3), which was the highest of the 70 models tested.

Daily Per Capita Pumping =

$$2.55*(\text{Days over 90F in Last 10 Days}) + \\ 0.95*(\text{Days Since Last Rainfall (May-Nov) cap=20}) + \\ 79.74*(\text{ET (in)}) + \\ 97.71 \quad (\text{Eq. A-3})$$

In Step 4, FNI built a model of the form $y = m1*x1 + m2*x2 + m3*x3 + m4*x4 + b$. Using the variables from the first three steps, x1 is the variable ‘Days over 90F in the Last 10 Days,’ x2 is the variable ‘Days Since Last Rainfall (May-Nov) cap=20,’ and x3 is the variable ‘ET (in).’ During Step 4, FNI calculated an adjusted-R² for 69 different four-variable equations, one equation for each remaining variable in Figure A-1. FNI selected the equation with the highest adjusted-R². After Step 4, FNI produced Equation A-4, which has an adjusted-R² of 0.80 (Figure A-3), the highest of the 69 models tested. As seen in Figure A-3, the incremental benefit of adding another variable (i.e. the incremental increase in adjusted-R²) is decreasing as we add more variables, which indicates that we are not gaining much in terms of model performance by adding more variables. Interestingly, the first three variables all vary on a seasonal basis. The first three variables also have positive coefficients, which means higher values for those variables increase water use. The newly-added fourth variable varies on a yearly basis, but is constant within a single year, and has a negative coefficient. The addition of the rate variable helps to simulate a decreasing trend in water use with time as the rate variable increases year by year.

Daily Per Capita Pumping =

$$2.40*(\text{Days over 90F in Last 10 Days}) + \\ 0.89*(\text{Days Since Last Rainfall (May-Nov) cap=20}) + \\ 70.37*(\text{ET (in)}) + \\ -1254.44*(\text{Rate First x-gallons}) + \\ 220.99 \quad (\text{Eq. A-4})$$

In Step 5, FNI built a model of the form $y = m1*x1 + m2*x2 + m3*x3 + m4*x4 + m5*x5 + b$. Using the selected variables from the previous four steps, x1 is the variable ‘Days over 90F in the Last 10 Days,’ x2 is the variable ‘Days Since Last Rainfall (May-Nov) cap=20,’ x3 is the variable ‘ET (in),’ and x4 is the variable ‘Rate First x-gallons.’ During Step 5, FNI calculated an adjusted-R² for 68 different five-variable equations, one equation for each remaining variable in Figure A-1. We select the equation with the

highest adjusted-R². After Step 5, we produce Equation A-5, which has an adjusted-R² of 0.81 (Figure A-3), the highest of the 68 models tested.

$$\begin{aligned}
 \text{Daily Per Capita Pumping} = & \\
 & 2.17 * (\text{Days over 90F in Last 10 Days}) + \\
 & 0.91 * (\text{Days Since Last Rainfall (May-Nov) cap=20}) + \\
 & 73.17 * (\text{ET (in)}) + \\
 & -1114.42 * (\text{Rate First x-gallons}) + \\
 & -0.93 * (\text{Total Precip in Last 50 days}) + \\
 & 211.68
 \end{aligned}
 \tag{Eq. A-5}$$

In Step 6, FNI built a model of the form $y = m1 * x1 + m2 * x2 + m3 * x3 + m4 * x4 + m5 * x5 + m6 * x6 + b$. Using the variables selected from the previous five steps, $x1$ is the variable 'Days over 90F in the Last 10 Days,' $x2$ is the variable 'Days Since Last Rainfall (May-Nov) cap=20,' $x3$ is the variable 'ET (in),' $x4$ is the variable 'Rate First x-gallons,' and $x5$ is the variable 'Total Precip in Last 50 days.' During Step 6, FNI calculated an adjusted-R² for 67 different six-variable equations, one equation for each remaining variable in Figure A-1. FNI selected the equation with the highest adjusted-R². After Step 6, Equation 6 was produced, which has an adjusted-R² of 0.83 (Figure A-3), the highest of the 67 models tested.

$$\begin{aligned}
 \text{Daily Per Capita Pumping} = & \\
 & 1.00 * (\text{Days over 90F in Last 10 Days}) + \\
 & .75 * (\text{Days Since Last Rainfall (May-Nov) cap=20}) + \\
 & 66.92 * (\text{ET (in)}) + \\
 & -1305.13 * (\text{Rate First x-gallons}) + \\
 & -1.26 * (\text{Total Precip in Last 50 days}) + \\
 & 0.31 * (\text{Avg Pumping per Day of Year}) + \\
 & 197.29
 \end{aligned}
 \tag{Eq. A-6}$$

As seen in Equation 6, the sixth variable added would be 'Average Pumping per Day of Year.' Since that variable is a function of the previous five variables and is not independent it was not included in the model. We are also no longer gaining significant increases in adjusted-R² by adding more variables. For these reasons, the five-variable model was chosen as the most appropriate equation for our purposes.

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Questions about the contents of this plan?

Email wmp-input@saws.org

