Tucson Water

ONE WATER 2100 PLAN APPENDICES

September 2023

Appendices

Appendix A

ONE WATER 2100 CLIMATE PROJECTIONS

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
CLIMATE CHANGE: IMPACTS TO TUCSON WATER AND THE TUCSON WATER INTEGRATED WATER MASTER PLAN

FINAL | NOVEMBER 2021

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Executive Summary

Tucson has a distinct advantage among U.S. cities regarding its ability to adapt to climate change as climate extremes are, to some degree, part of living in the Sonoran Desert. Whether it is the occasional snowstorm in winter, 110°F plus days in the dry season, or heavy, intense thundershowers during monsoon season, the people of Tucson understand adaptation to changing conditions. The findings of this study quantify the climate of Tucson from a historic perspective, as well as from a perspective of a projected future climate. This quantification has led to the following findings regarding climate change on a regional (Colorado River Basin) and a local (Tucson Water Service Area) basis:

- The current 20-year drought in the Colorado River Basin (CRB) is classified as a "heat drought" that has resulted in flow reduction due to changes in air temperatures rather than annual precipitation (Udall, 2017).
- Historic trends (NCDC, 2020) and climate projections predict a 4 percent reduction in CRB flows per 1°F of annual average temperature increase.
- Precipitation in the CRB is expected to slowly increase over the remainder of this century, but with increasing year-over-year and seasonal variability as well (USBR, 2012, Udall, 2017).
- Annual precipitation in the Tucson Water Service Area (TWSA) is expected to slightly increase over the remainder of this century, but with increasing year-over-year variability and increasing precipitation intensities (Vose et al, 2017, USBR 2020).
- Historic trends and projected climate trends (NCA, 2018, Udall, 2017, Vose et al, 2017) both indicate significant increases in annual average temperatures during the remainder of this century in the southwestern U.S.
- The number of hot days (>100°F) is expected to increase and reach 76 days/year by 2100 in Tucson. The number of 110°F days is expected to be approximately 30 days/year by 2100 in Tucson (USBR, 2018, NCDC, 2020)

These key understandings regarding climate change led to the development of the anticipated impacts to the Tucson Water system, and consequently, should become considerations during the continued development of the One Water 2100 Master Plan. These impacts are as follows:

- Continued reductions in CRB flows are anticipated as a result of climate change, but Federal, State, and Local stakeholders are taking steps to better manage this situation as it evolves through policies like the Drought Contingency Plan (DCP) and the work of the Arizona Reconsultation Committee.
- Water harvesting will remain an efficient, potable water offset in the region, but may be impacted by increasing precipitation intensities.
- Water remediation and reclaimed water are not expected to experience any significant impacts from climate change other than those associated with increased evaporation and evapotranspiration for the end user.

- Due to the fact that the vast majority of Tucson's water supply comes from the Central Arizona Project (CAP), which is consequently stored as groundwater, water quality issues as a result of increased air temperatures due to climate change are not expected to become an issue for the City.
- Due to increasing air temperatures, particularly in regard to the increasing number of extremely hot days, Tucson is expected to feel like present-day Phoenix by the year 2050 (30 day/year with high temperatures of 110°F or higher). These extremely hot days are expected to significantly increase seasonal water usage.

1 Introduction

HDR was tasked with developing an understanding of the potential impacts of climate change as they apply to the One Water 2100 Master Plan that Tucson Water is in the process of developing. Water supplies within the Tucson Water Service Area (TWSA) are made up of groundwater, reclaimed water, remediated water, water harvesting (stormwater capture), and imported renewable water through the Central Arizona Project (CAP), as well as any precipitation that may fall on the region itself throughout a given Water Year (WY).

Climate change is already impacting the physical and social aspects of life in Tucson. According to a recent Climate Central report (Climate Central, 2019) based on data from 1970-2018, average annual temperatures rose 4.48°F in Tucson (NCDC, 2020). While some of this increase is related to the Urban Heat Island effect (UCAR, 2011), much of this increase is attributable to the influence of global climate change (NCA, 2018).

Prior to the initiation of this investigation, a literature review was undertaken to enable a holistic understanding of all the research that has been done in the past and is still ongoing in regard to the impacts of climate change in Tucson and the greater southwestern U.S. This literature resides in Appendix A of this report with citations used in this report existing in the references section as well.

This report is broken down into several components so that a complete understanding of a chronology of historic climate trends and projected climate change impacts on a local and regional scale, as well as a consideration for seasonal components, can be probabilistically quantified. Since the Colorado River Basin (CRB, Figure 1) is responsible for producing flow in the CAP for use in Tucson, the analysis of climate trends and future projections over this region will be provided in tandem with the investigation of local (Figure 2) climate trends and future impacts. These two geographic regions were used to identify specific impacts from changes in air temperature, precipitation, and streamflow that will be summarized and reported in Section 4 of this report.

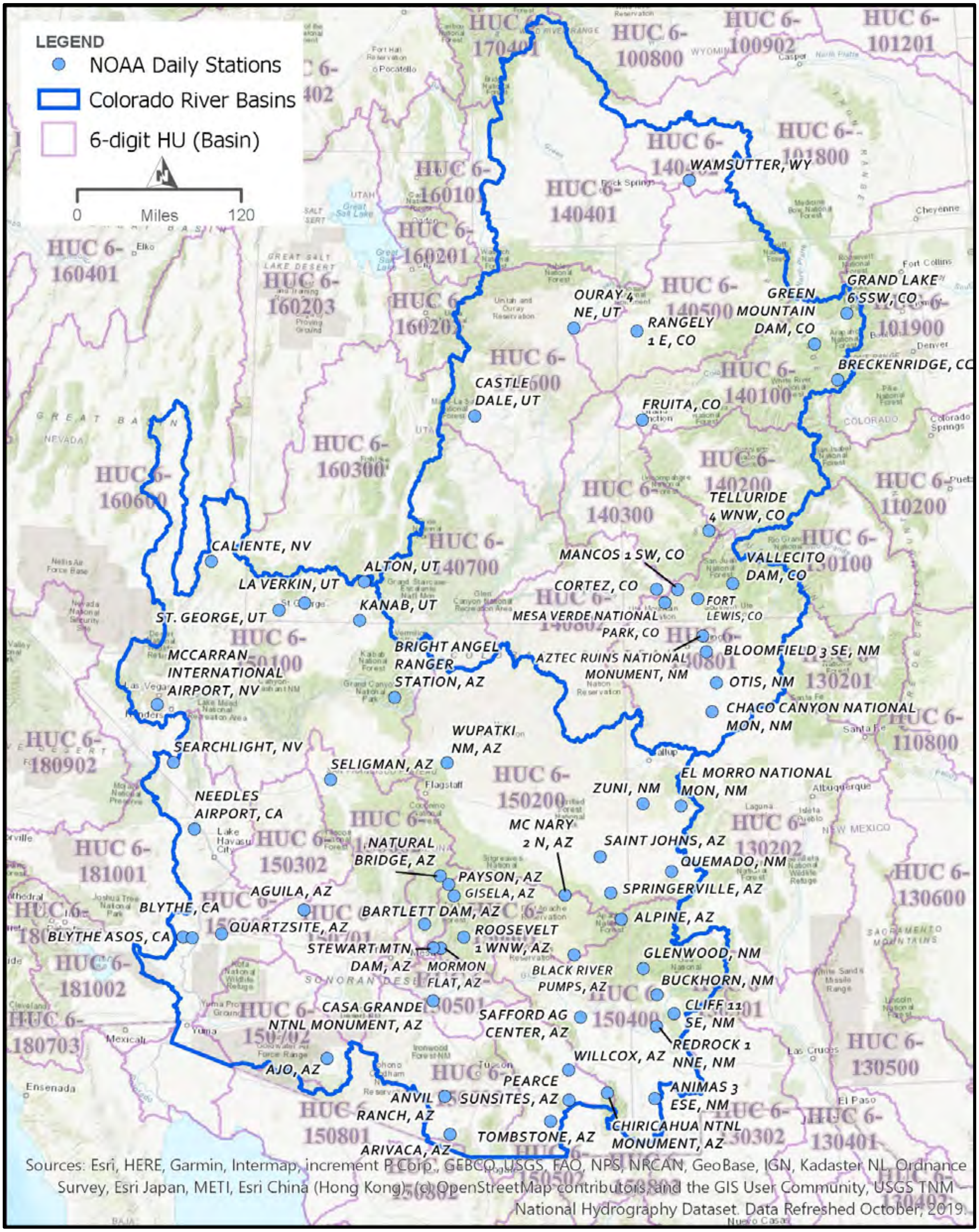


Figure 1. Map of Colorado River Basin within the United States (blue outline) with identified long-term meteorological reporting stations (blue dots).

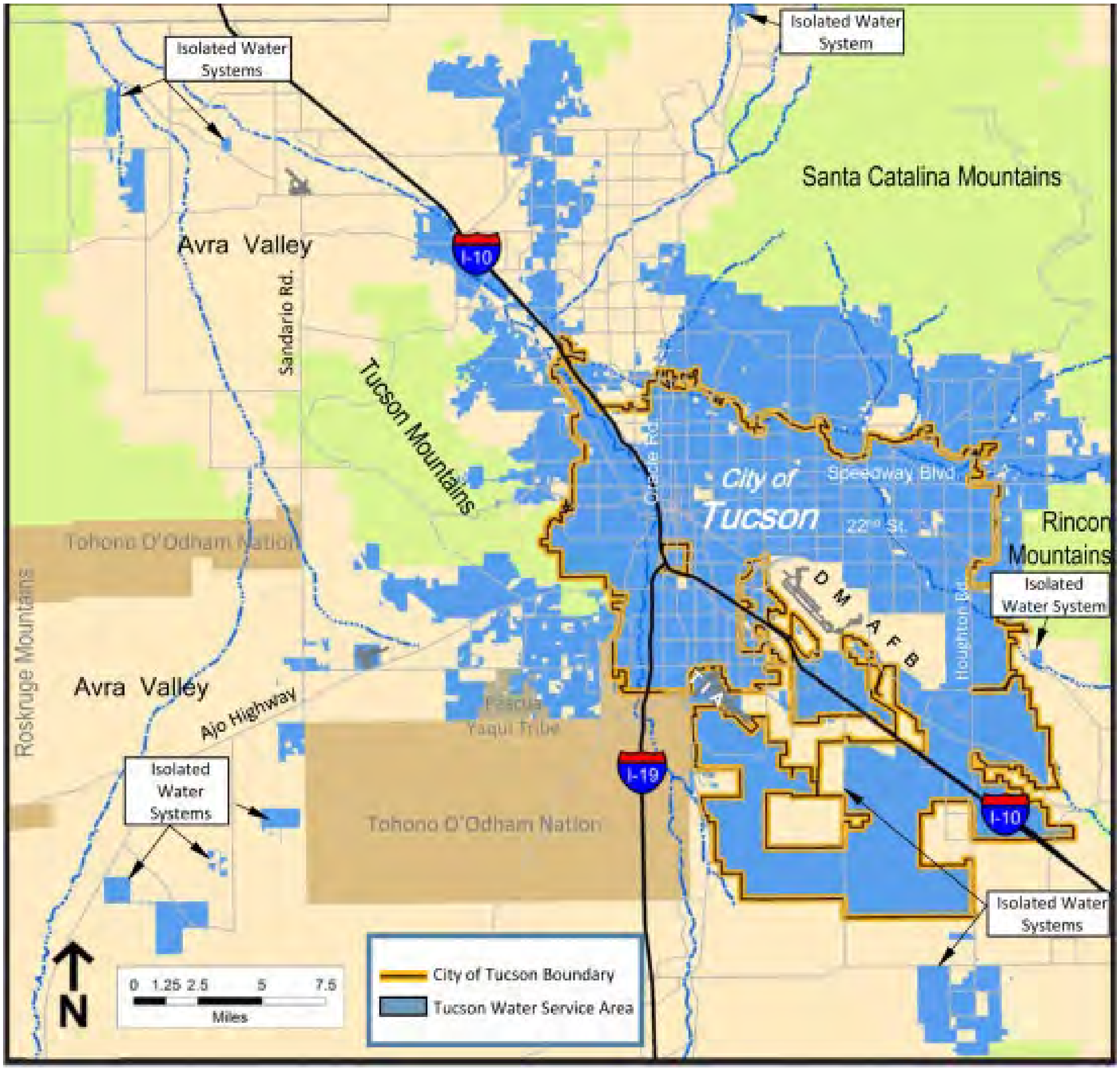


Figure 2. Map of Tucson Water Service Area.

2 Historic Climate Trends

Historic climate trends, particularly climate trends within the last 30 years, are extremely important to understanding the current climate direction, and are a key component of understanding the magnitude of future projected change. These trends, when extrapolated, provide a baseline for anticipated future climate change. Like stock or financial market trends, historic trends help identify overall changes despite short-term variability.

2.1 Colorado River Basin

As can be seen in Figure 1, the CRB covers an enormous area (approximately 250,000 sq. miles) over seven western states and a portion of northwestern Mexico from Yuma southward to the river's terminus in the Sea of Cortez. While this basin is expected to experience continued hydrologic changes due to climate change, long-term hydro-meteorological data help identify both historical and anticipated trends.

2.1.1 Precipitation and Hydrologic Flow

The stations on the map in Figure 1 represent the meteorological reporting stations in the CRB that have a very long period of record (POR) for precipitation data (NCDC, 2020). These are the same stations that were used to provide guidance for the United States Bureau of Reclamation (USBR) 2012 study of climate change impacts on the CRB (USBR, 2012). An analysis of precipitation data from these stations from the POR 1895-2020 reveals (Figure 3) an increasing long-term trend with considerable yearly and decadal variability. This is particularly true during the last 30 years of POR, which, of course, includes the last 20 years of CRB drought.

The precipitation and hydrologic trends discussed in this section provide some perspective for the *projected* trends expected to occur as a result of climate change impacts in the CRB in Section 3.1.1.

The southwestern U.S. has a climate that is conducive to assembly of a paleo-historic reconstruction of stream flows well beyond the range of available observed streamflow data. This is possible through the correlation of the study of tree-ring growth (dendrochronology) to known stream flows within the CRB (Woodhouse, 2007). Figure 4 provides an understanding of the reconstructed and observed Colorado River flow at Lees Ferry, AZ from 762-2019. These data provide a long-term perspective regarding the historic potential for decadal drought periods. The long-term trend in river flows is increasing during this POR; however, during this same POR there have been periods, such as between the years 1200-1350 that saw several multi-decadal drought periods.

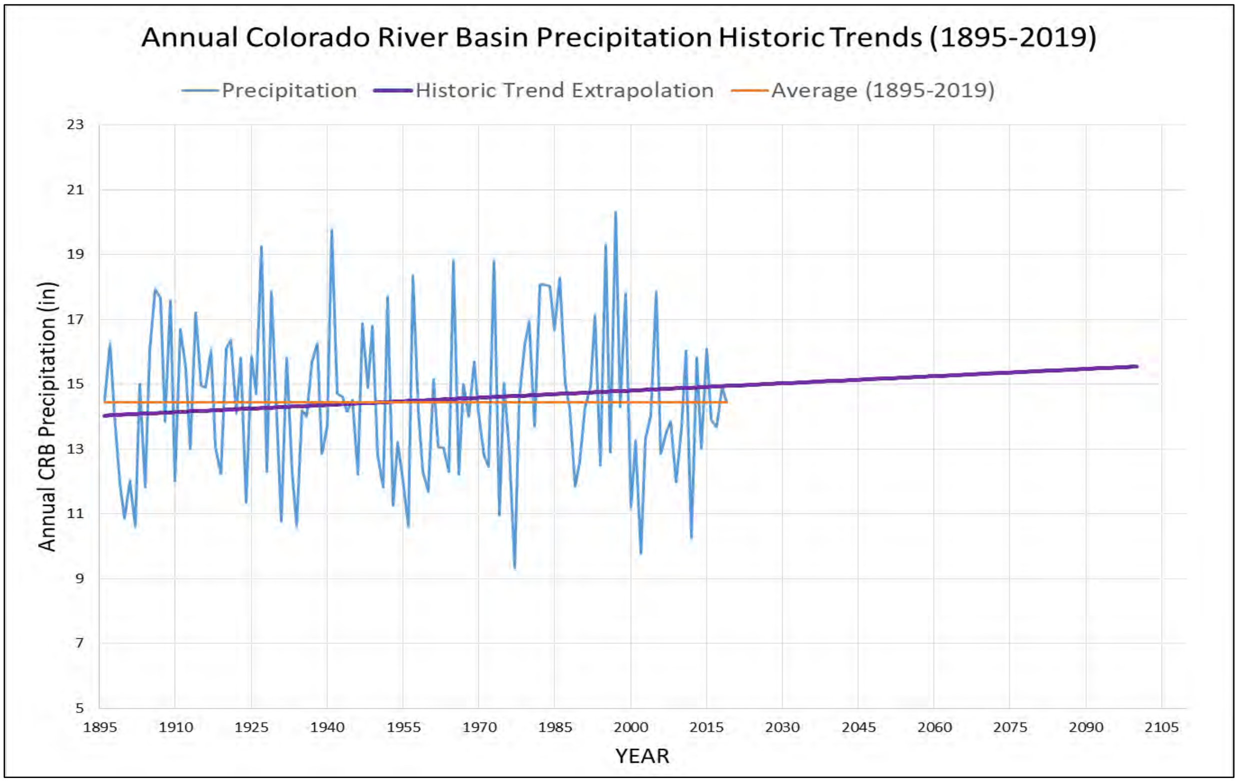


Figure 3. Annual CRB precipitation trend (1895–2020). Trendline in purple. Average in orange. Source data NCDC (2020).

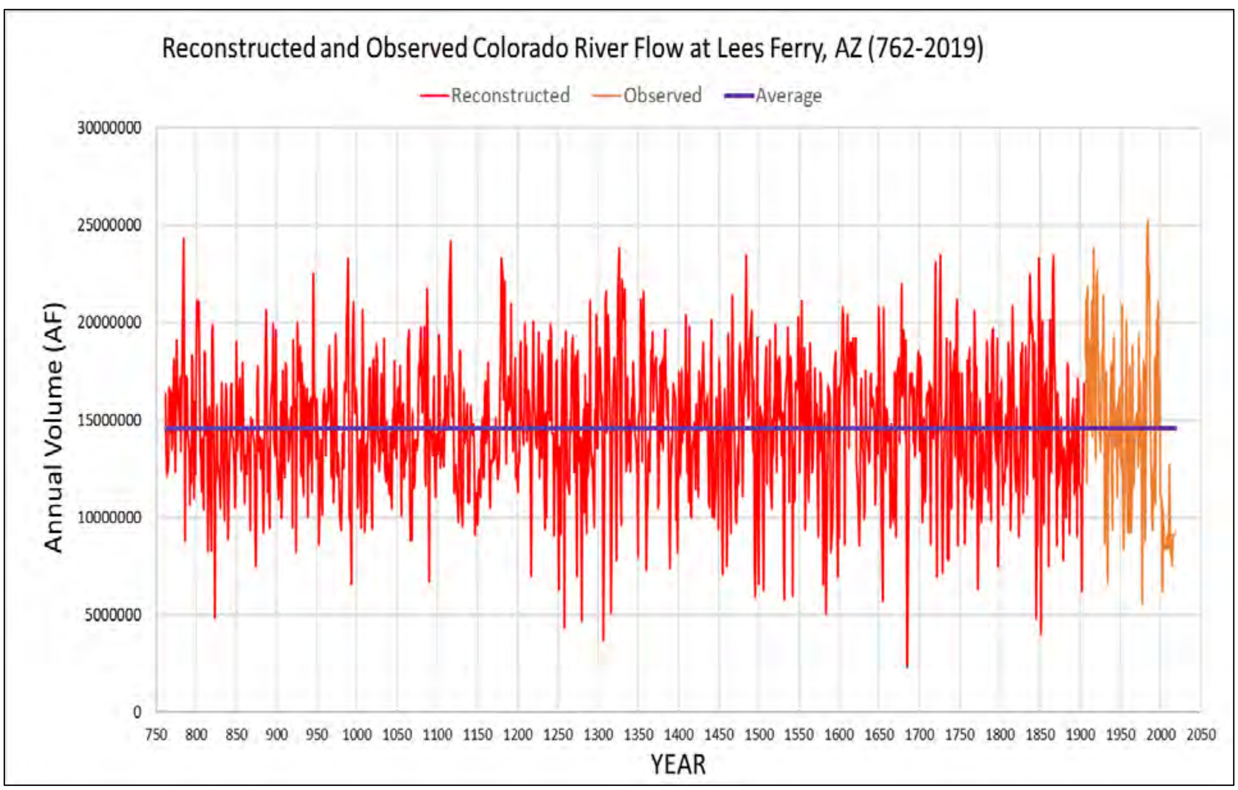


Figure 4. Reconstructed and observed Colorado River Flow (AF/year) at Lees Ferry, AZ (762-2019). Source data Woodhouse (2007) and USGS (2020).

Figure 4 (Woodhouse, 2007 and USGS, 2020) also provides some prospective regarding the magnitude of the drought that the CRB has experienced during the period 2000-2020 in the much larger scheme of the last 1250 years. This drought, which is classified as a "hot drought" (Udall, 2017) is related to temperature in the CRB rather than lack a precipitation as in the drought of 1200-1350. An understanding of a "hot drought" can be gleaned by comparing the graphs in Figure 3 and Figure 5 (Section 2.1.2) with the recent flows identified in Figure 7. Figure 3 shows basin average precipitation at or near the historic average during the period 2000-2019, while basin average air temperatures have shown a significant increase during that same period (Figure 5). Thus, as precipitation has been at or near average, flows in the CRB have dramatically decreased (Section 2.1.2, Figure 7).

2.1.2 Temperature

Air temperatures play a significant role in determining flows on the Colorado. Increasing air temperatures over time have contributed to increases in the levels of evaporation, evapotranspiration, and, ultimately, water demand in the CRB. Figure 5 shows the trend in average annual basin air temperatures within the CRB from 1895-2018. This figure indicates that the long-term trend has been approximately a 2.7°F increase per 100 years during this time period; however, the secondary (orange) trendline in this figure shows that the trend from 1964-2019 (55 years) has shown a 3.23°F increase, which would equate to a rate of increase of 5.87°F per 100 years going forward from 1964.

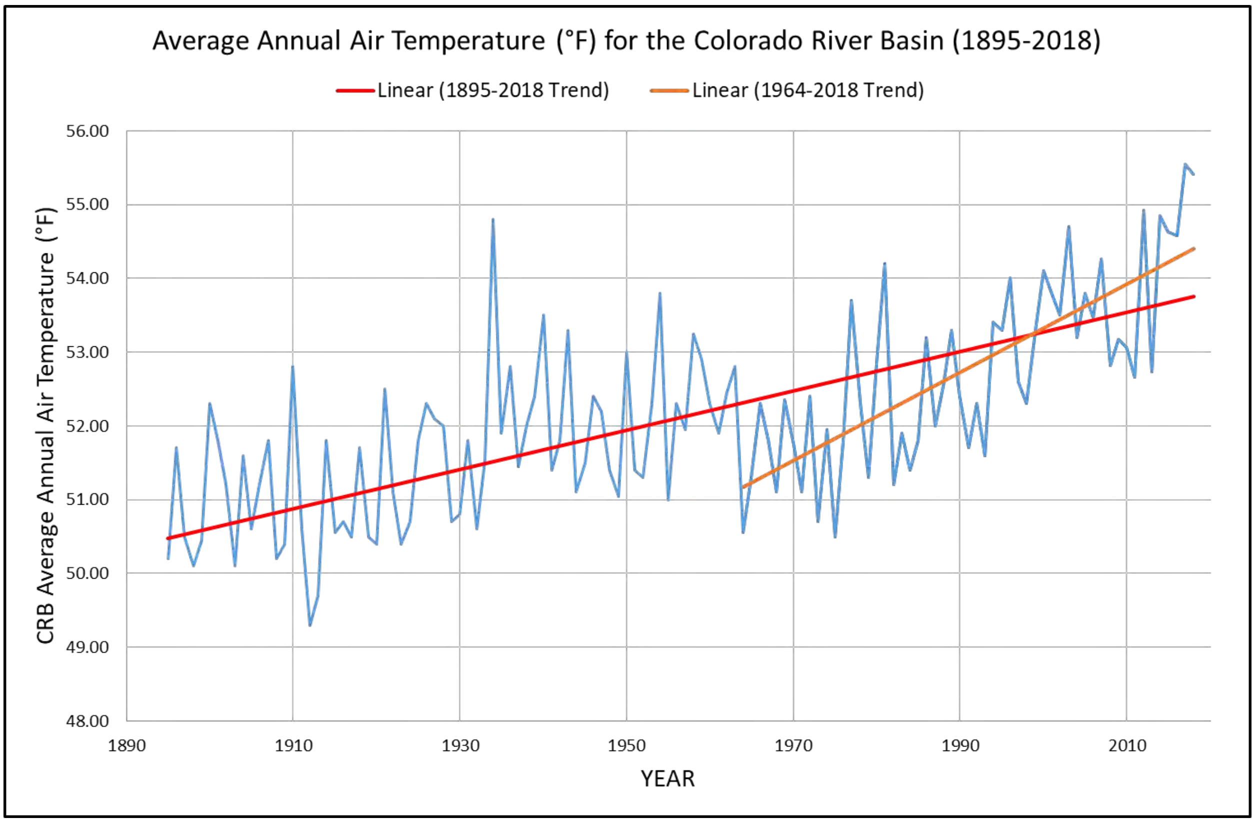


Figure 5. Basin average annual air temperature for the CRB (1895–2018). 1895–2018 trendline in red. 1964–2018 trendline in orange. Source data NCDC (2020).

Figure 6 shows the same graph as in Figure 5 but includes an extrapolation of these data out to year 2100 for both trends identified in Figure 5. As per the research identified in Section 2.1.1 (Udall, 2017), these extrapolations would result in an approximately eight percent (8%) decrease in Colorado River flows from the long-term (1895-2018) trend and a 16% to 18% decrease in Colorado River flows from the near-term (1964-2018) trend by the year 2100. These trends represent important input regarding the understanding of *projected* climate change as it relates to the CRB in Section 3.1.2.

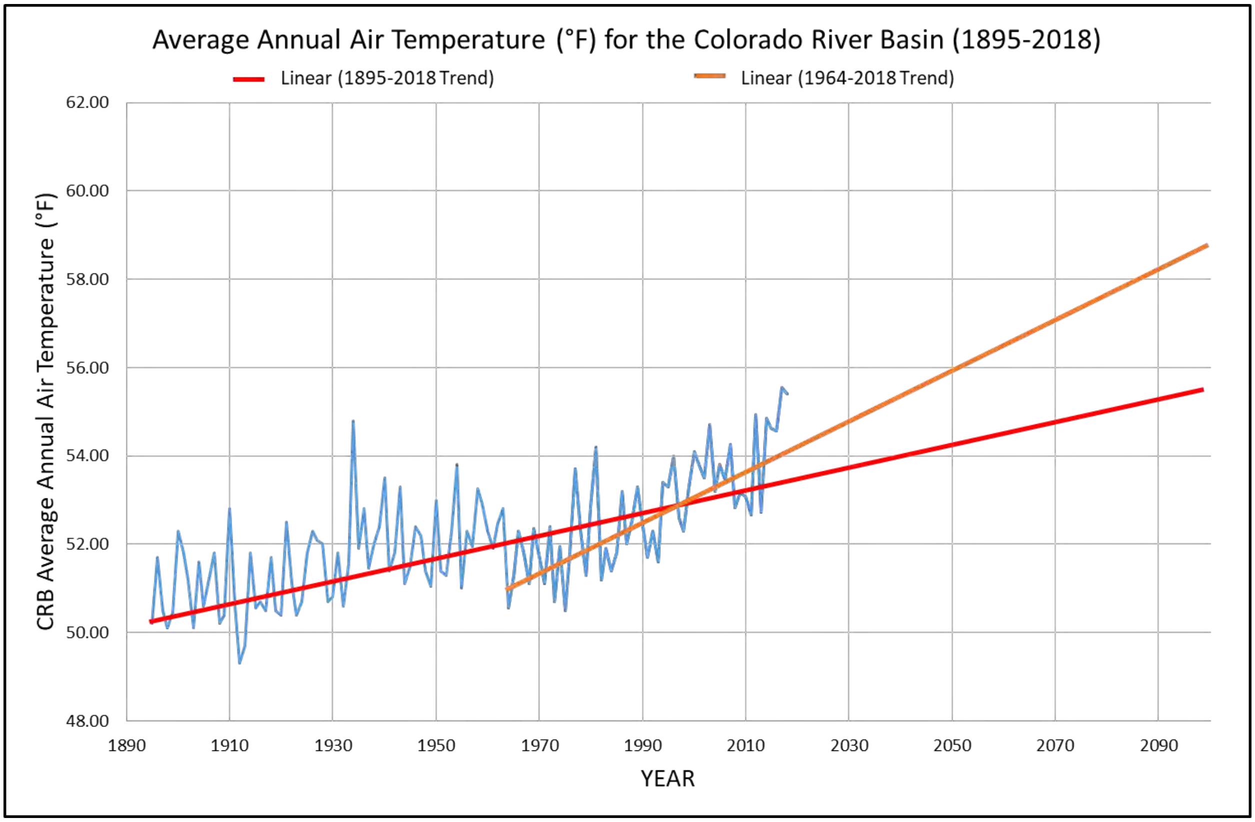
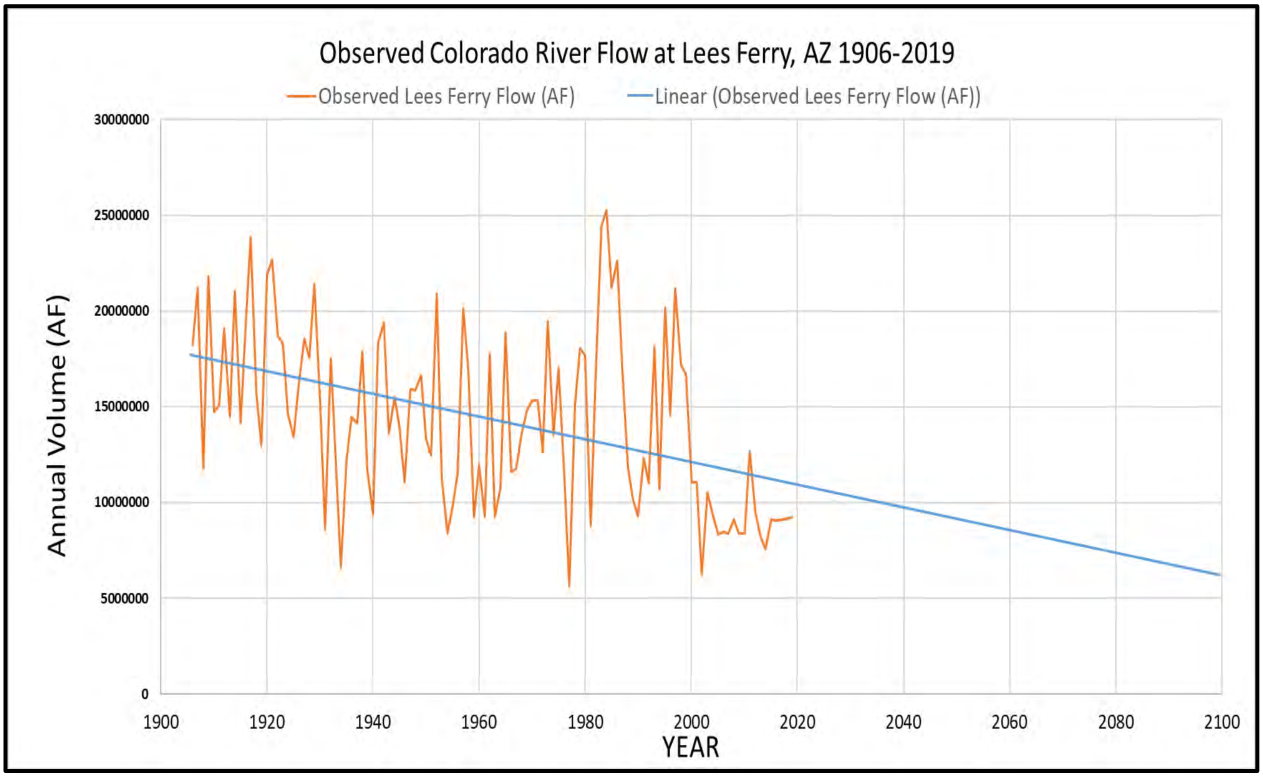


Figure 6. Extrapolations of the long-term (red) and near-term (orange) trends in average annual CRB air temperatures to the year 2100. Source data NCDC (2020).

As reported in a recent article (Udall, 2017) that was the result of climate research by Colorado State University in conjunction with the University of Arizona, flows on the Colorado River decline by about four percent per degree Fahrenheit increase in basin average temperature. As was seen earlier in this section, the temperature trend for the last 120 years has greatly added to the reduction in river flows during that time. The extrapolation of the trendline in Figure 5 indicates that by the year 2100 flows on the Colorado River are expected to produce only half the volume that they produce today.

One issue that has been working against the reported increase in precipitation over time in the CRB is the increased demand for the water resources, particularly in the upper

CRB. While the lower CRB water use was recently shown (Circle of Blue, 2020) to have the lowest level in 33 years in 2019, the upper CRB has been continuously increasing their usage and exercising their water rights over the last 120 years, which includes water for agriculture and a substantial increase in upper CRB water being transferred to the eastern slope of the Rockies through trans-basin diversions. While the upper CRB continues to meet their Colorado River Compact agreement of at least 7.5 million acre-feet (MAF) delivered to the lower CRB, the annual flow trend at Lees Ferry continues downward partially due to upper CRB demands.



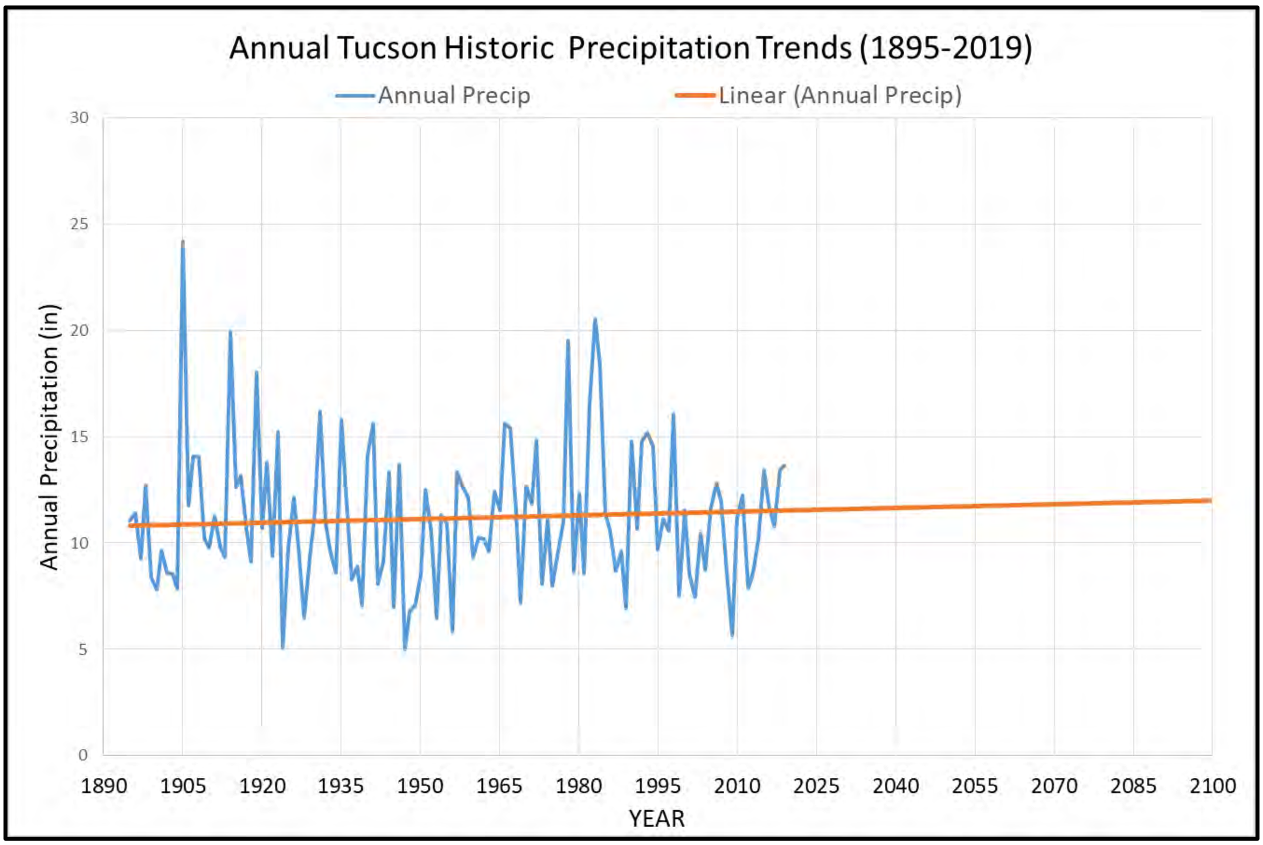
2.2 Lower Santa Cruz River Basin (Tucson Water Service Area)

The TWSA historic climate can be divided into three distinct climate regimes: winter wet season, dry season, and monsoon season. As per the climate information from the very long-term POR from the NWS Weather Forecast Office (WFO) meteorological reporting station in Table 1, the winter wet season is typified by cooler temperatures with occasional 24-48-hour precipitation events (November-March), the dry season by hot, dry weather (April-June), and the monsoon season by hot, humid weather with occasional thundershowers (July-October), respectively.

Table 1. Climate statistics from the WFO meteorological reporting station (1894–2020). Source data National Weather Service (2020).

TUCSON NWS WFO, ARIZONA													
Period of Record Monthly Climate Summary (Period of Record : 9/ 1/1894 to 02/29/2020)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	65.5°	68.5°	74.1°	82.1°	91.6°	100.3°	99.7°	97.4°	94.5°	84.8°	73.5°	64.8°	**83.1°**
Average Min. Temperature (F)	39.8°	42.2°	46.2°	52.0°	60.5°	69.3°	74.4°	73.3°	68.6°	57.3°	46.1°	39.1°	**55.8°**
Average Temperature (F)	52.6°	55.3°	60.1°	67.0°	76.0°	84.8°	87.0°	85.3°	81.6°	71.0°	59.8°	51.9°	**69.4°**
Average Total Precipitation (in.)	0.94"	0.86"	0.73"	0.31"	0.23"	0.20"	2.25"	2.39"	1.29"	0.89"	0.57"	0.93"	**11.59"**

Annual precipitation in Tucson, similar to the CRB, has been slightly increasing over time. Figure 8 shows the significant variability in annual precipitation within the region (standard deviation 3.30 inches), as well as an extrapolation of this trend into the future. The long-term trend shows a slight but steady increase in annual precipitation, which provides the basis for *projected* changes in precipitation in Section 3.2.1.



2.2.2 Precipitation Intensities

One of the basic tenets of climate change science is that as the atmosphere warms its ability to hold more moisture will also increase. This is based on what is called the Clausius-Clapeyron equation, which indicates that the moisture that the atmosphere can hold will increase 3.5 percent per 1°F. This fact becomes very consequential when considering the historic trends in temperature in Section 2.2.3, as well as the projected trends for the region in Section 3.2.2.

A recent study investigating the intensification of the North American Monsoon rainfall in the southwestern U.S. (Demaria, et al., 2019), as part of a United States Dept. of Agriculture and University of Arizona study, has shown that monsoon rains have become more intense. This study, which utilized a high-density rain gauge network (59 gauges) within a 57.5 sq. mile area known as the Walnut Gulch Experimental Watershed, identified that since the 1970's precipitation rates have increased by six to eleven percent. Thus, while storm durations have remained about the same, storm intensities have increased. This historic trend in precipitation intensities has implications regarding the resilience of water infrastructure within the TWSA that will be discussed in Section 4.

2.2.3 Temperature

Air temperatures in the TWSA have been on a steady increase over time. Figure 9 shows the trends in maximum, minimum, and average annual air temperatures in the region from 1895-2018. During this 120+year POR, daytime high air temperatures increased approximately 5.0°F, while nighttime minimum air temperatures increased approximately 10.0°F. While these statistics are on par with changes in much of the southwestern U.S., so are the inflections in these graphs that occur right around 1964. 1964 is the year where the trends show a very noticeable increase in minimum air temperatures. This same inflection point is something that can be partially attributable to increased development in the region (i.e. urban heat island effect) during the 1960's and 1970's, but it is an inflection point that repeats itself during this same time period in data from cities and countries all over the world.

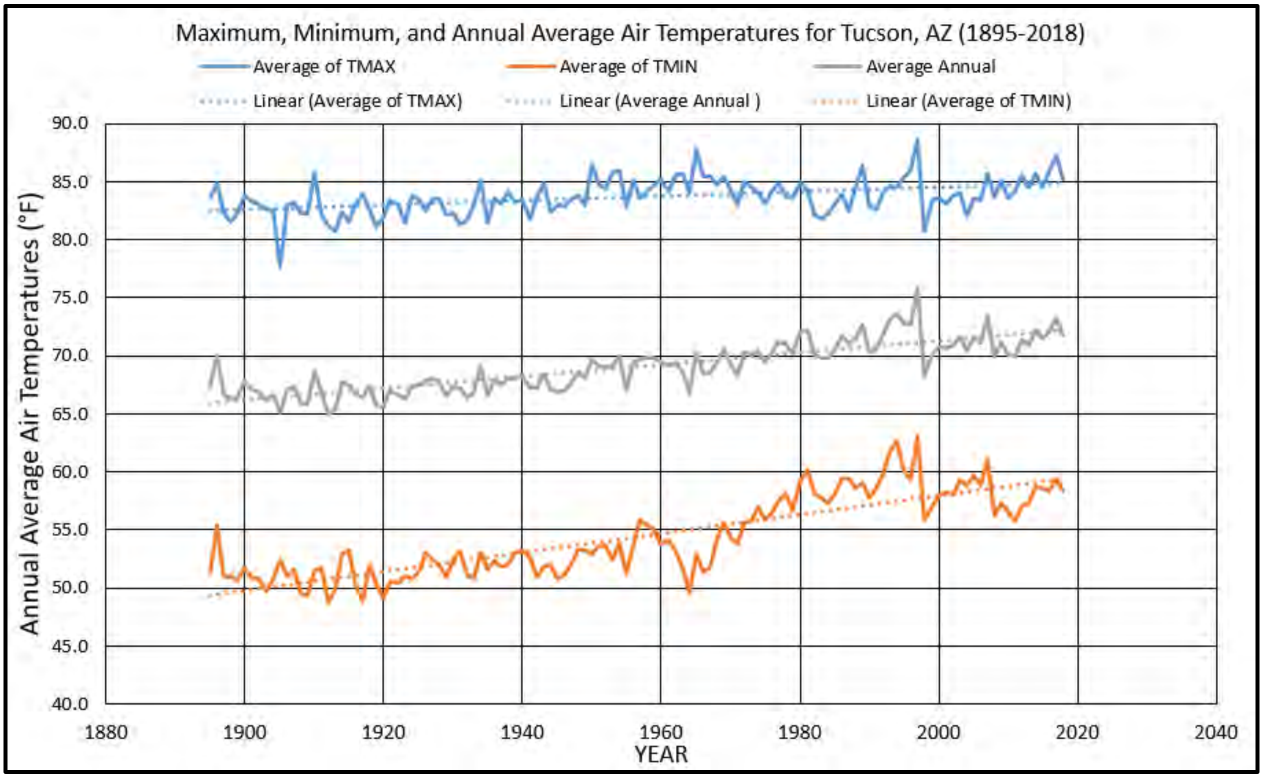
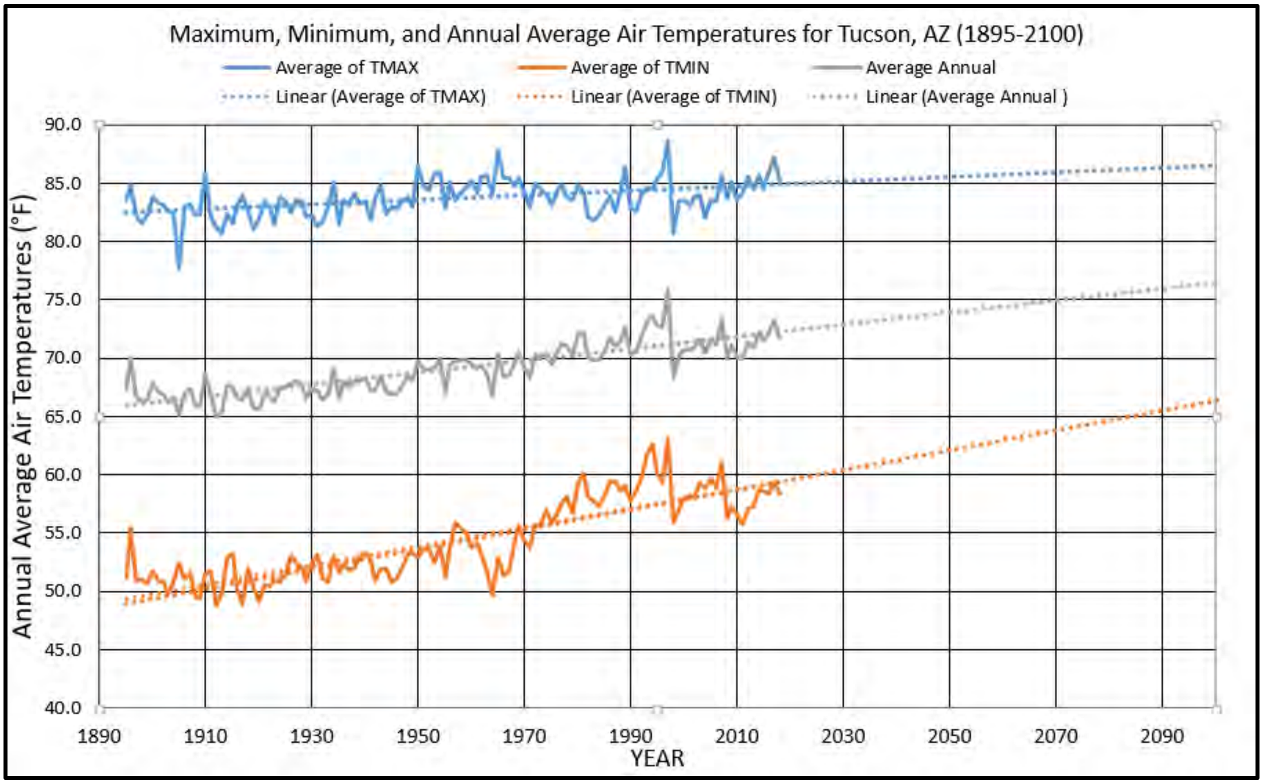


Figure 10 provides an extrapolation of these historic trends in air temperature to the year 2100. These trends indicate an increase in average annual maximum temperatures of approximately 1.5°F by 2100, an increase in average annual air temperatures of approximately 4.1°F, and an increase in average annual minimum air temperatures of approximately 7.8°F. A comparison to the projected changes in annual air temperatures reported in Section 3.2.2 finds these historic trends in good agreement with projections from lower future emissions scenarios (RCP 4.5).



3 Climate Scenarios

As has been shown in Section 2, the historic trends in precipitation, streamflow and air temperature point to the direction that the climate is going within both the CRB and the TWSA. Climate projections are used to provide a physical understanding of what can be expected based on different future climate scenarios that may impact the climate going forward. While there are many different Global Climate Models (GCM), and currently four different climate (emissions) scenarios that have been adapted for use in these models, this study will rely on the output from a variety of recent climate studies that cover both the CRB and the Lower Santa Cruz River Basin, which encompasses the TWSA. These studies primarily utilize the current climate, RCP 4.5 and RCP 8.5 to compare and contrast potential future outcomes.

One of the consequences of using climate projections is that as these projections move into the future, the range of potential outcomes based on a given GCM or RCP will increase over time. This range of potential outcomes will be identified within this section. The findings in this section should compared and contrasted with observed/historic trends in Section 2.

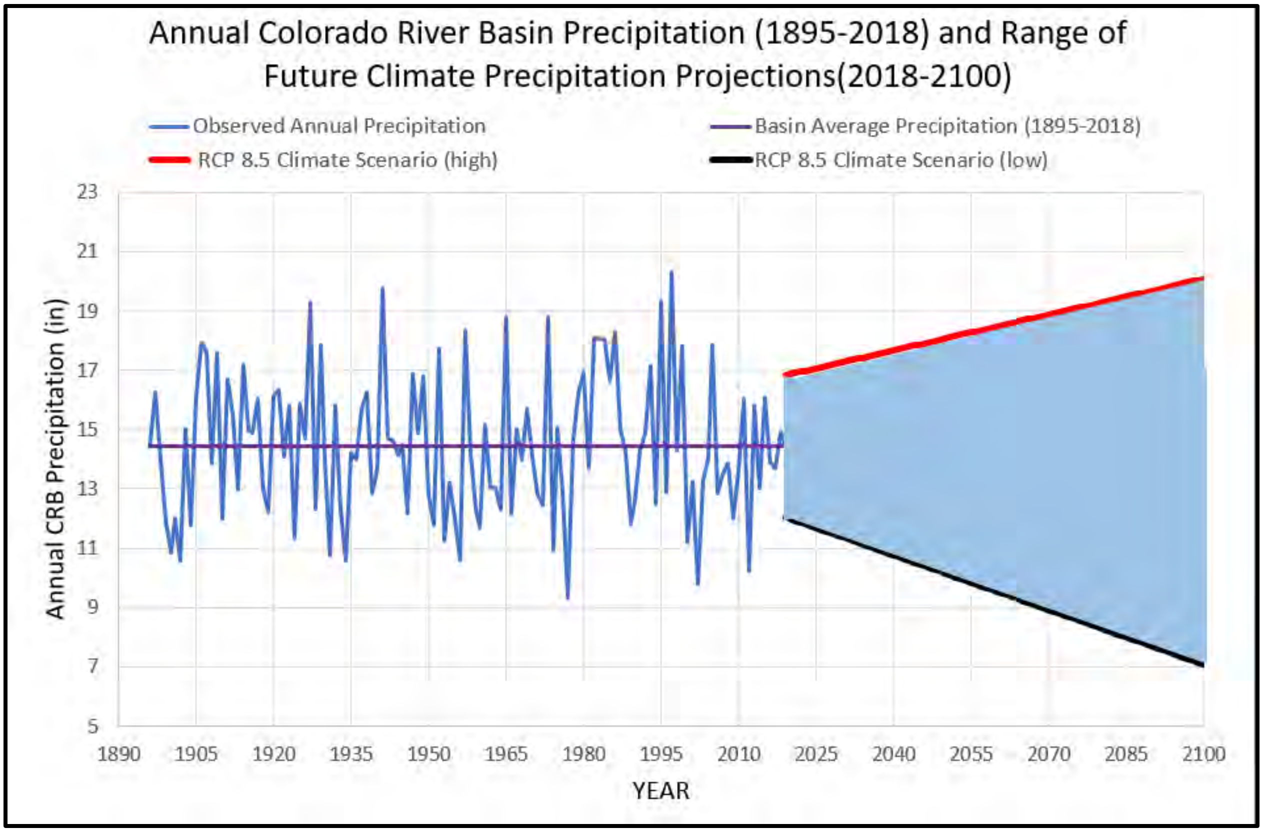
3.1 Colorado River Basin Climate Projections

A recent report developed as part of the USBR's 2016 SECURE Water Act report (USBR, 2016) identifies climate challenges the CRB could likely face. These include the following:

- On average, temperatures in the CRB are projected to increase by 5–6 °F during the 21st century, with slightly larger increases projected in the Upper Basin.
- In the CRB precipitation is projected to remain variable with a slight increase in the Upper Basin.
- In high-altitude and high-latitude areas of the CRB headwaters, snowpack is projected to increase during the 21st century, but at lower elevations warmer conditions are projected to transition snowfall to rainfall, producing more December–March runoff and less April–July runoff.

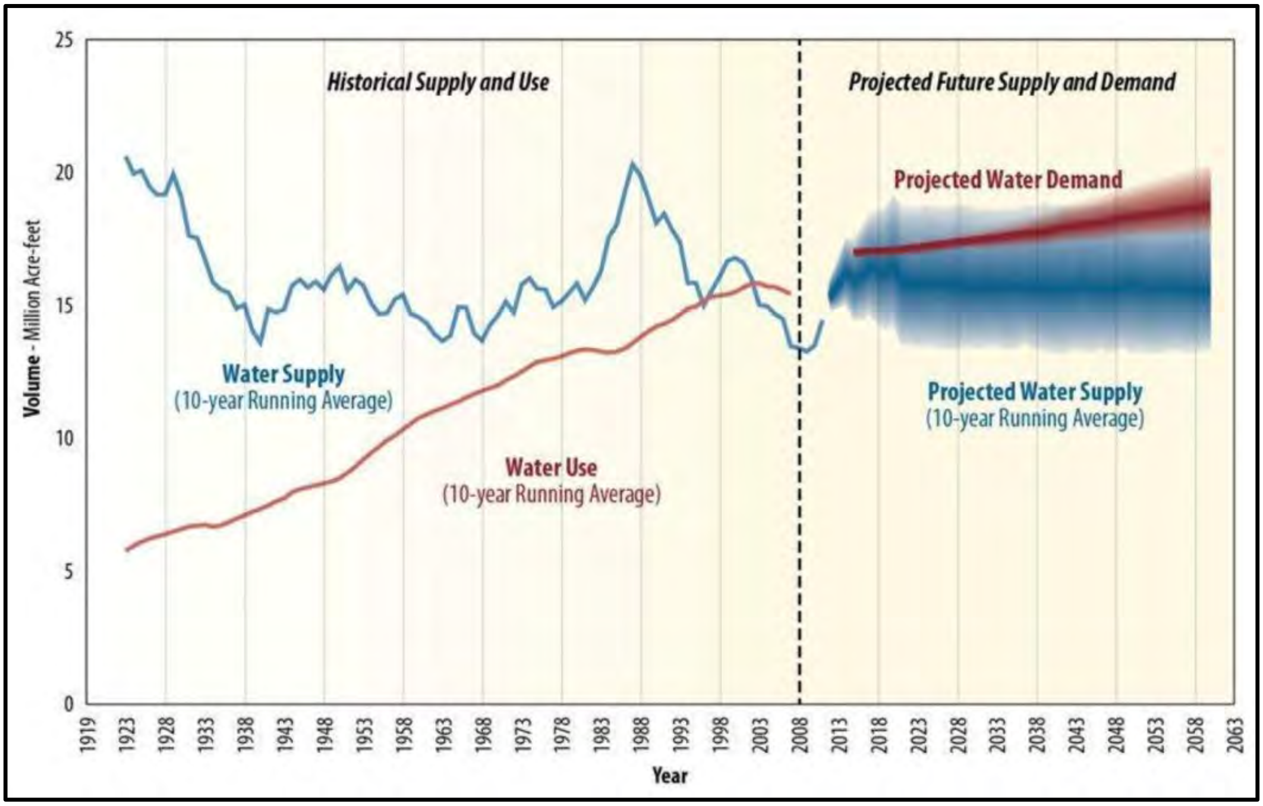
3.1.1 Precipitation and Hydrologic Flow Projections

GCM with their associated emissions scenarios (4.5 and 8.5), when back-checked using historic data, show significant skill in projecting future air temperatures, but, unfortunately, cannot show that same level of skill when it comes to precipitation in a given region. Therefore, the range of future precipitation outcomes usually has a much greater range than that associated with future air temperatures. Figure 11 shows this range of potential CRB precipitation outcomes as a result of the RCP 8.5 climate scenario. RCP 8.5, the scenario that represents the highest anticipated level of future emissions, shows the large range (shaded area) of precipitation outcomes associated with this projection. Figure 11 highlights the increased year-over-year variability, rather than some definitive quantification of an increase or decrease in precipitation through the year 2100. The initial variance in future precipitation represented in this chart is based on a standard deviation of 2.385 from the historic data. These future precipitation projections were from the USBR Colorado River Basin Water Supply and Demand Study (USBR, 2012).



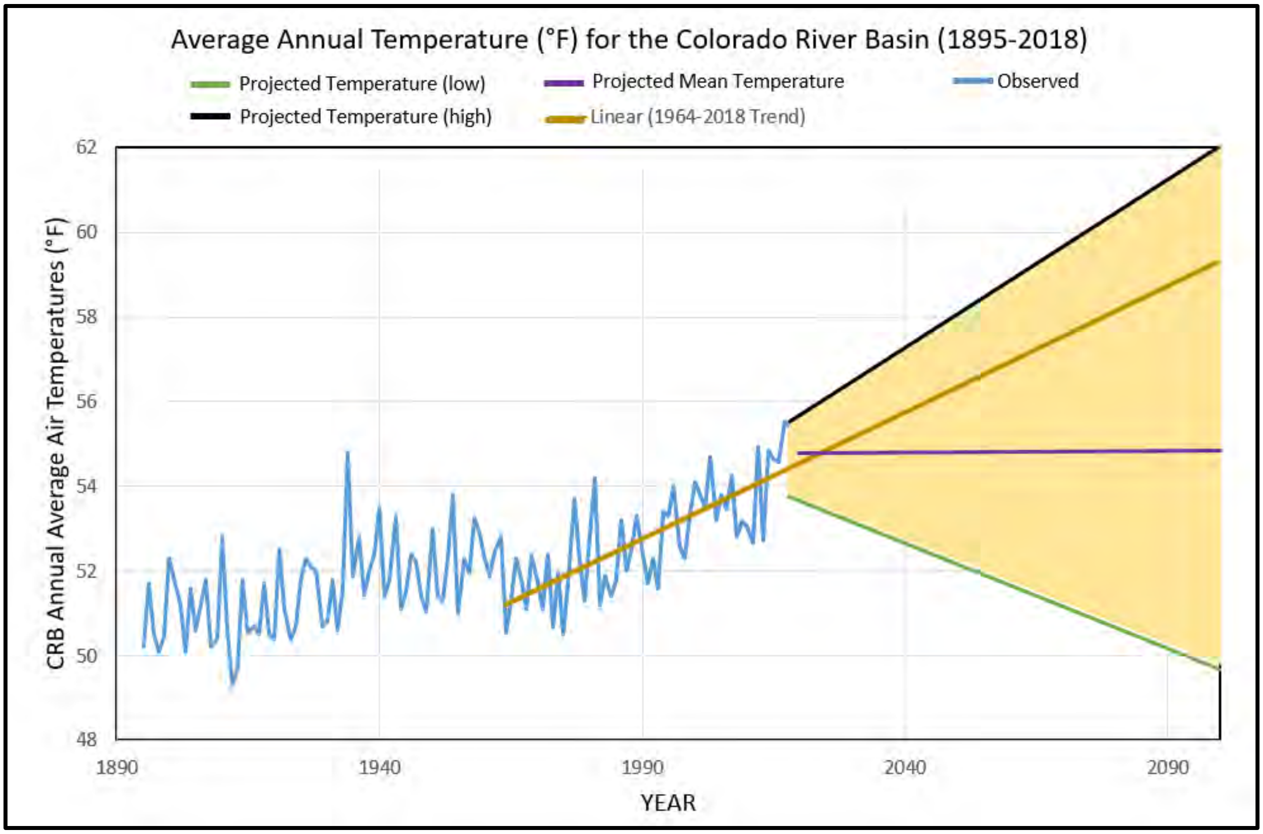
The climate model projections indicate that while the basin average precipitation is not necessarily expected to dramatically increase or decrease over time, the variability is expected to significantly increase with climate change. This would, under historic conditions, make for an increased water management challenge within the CRB but, as explained in Section 2.1.1., increased air temperatures that are expected to occur within the CRB are expected to tip the scale towards reduced flows regardless of the fact that average precipitation within the basin is expected to remain nearly the same.

Figure 12, from USBR 2016 SECURE Water Act Section 9503(c) report on CRB climate change and water (USBR, 2016), identifies the historic water supply and demand on the Colorado River and the anticipated range of future water supply and demand within the CRB. Based on the data as seen in Section 2.1.1 (Figure 4), these USBR projected trends indicate a slightly greater year-over-year variability than in the historic past.



3.1.2 Temperature Projections

Air temperature trends in the CRB have been steadily on the rise over the last 120 years (Figure 6) but have significantly increased in the basin during the last 40 years. Climate projections indicate that under RCP 4.5 (low) emissions scenario temperatures are expected to increase through approximately 2060 and then begin slowly decreasing thereafter, while the RCP 8.5 (high) scenario indicates an acceleration in the historic trend of warming temperatures in the basin. Figure 13, using data from the 2012 USBR CRB study (USBR, 2012) shows the observed annual air temperatures from the CRB from 1895-2018, as well as the trend from 1964-2018 extrapolated out to the year 2100. Climate projections (RCP 4.5 and 8.5) have been combined on this chart to show the large range (shaded area) of potential outcomes associated with these projections. The historic trend (1964-2018) displayed on this chart provides an excellent perspective to projected outcomes from the global climate modeling data. The initial range (2018) of future basin air temperature outcomes is based on the standard deviation (1.29) from the POR 1895-2018.



3.2 Lower Santa Cruz River Basin (Tucson Water Service Area) Climate Projections

This section considers climate projections based on both the preliminary findings of the ongoing USBR study in the Lower Santa Cruz River Basin (LSCRB) and those of other, earlier studies.

3.2.1 USBR Lower Santa Cruz River Basin Study Methodology

The USBR is currently engaged in the development of a Climate and Surface Water Analysis as part of the LSCRB study, which is one portion of a three-part study that includes the West Salt River Basin Study and the Eloy Maricopa-Stanfield Basin Study. During a recent presentation to the Citizens' Water Advisory Committee (CWAC) Technical Planning and Policy (TPP) Subcommittee on December 10, 2020 the USBR (USBR, 2020) provided a summary of their findings-to-date on this project in regard to climate outcomes in the region. Although this study is not expected to be complete until late 2021, preliminary findings are being released so that decisions can be made regarding long-term planning and policy.

The LSCRB study utilizes a combination of several modeling techniques and methodologies to derive projected impacts to water in the basin based on future scenarios that involved Global Climate Models (GCM), surface hydrologic modeling, groundwater modeling, socio-economic trends and drivers (demand), all within the realm of the Central Arizona Project (CAP) service area model. A schematic of the interaction between these models can be seen in Figure 14.

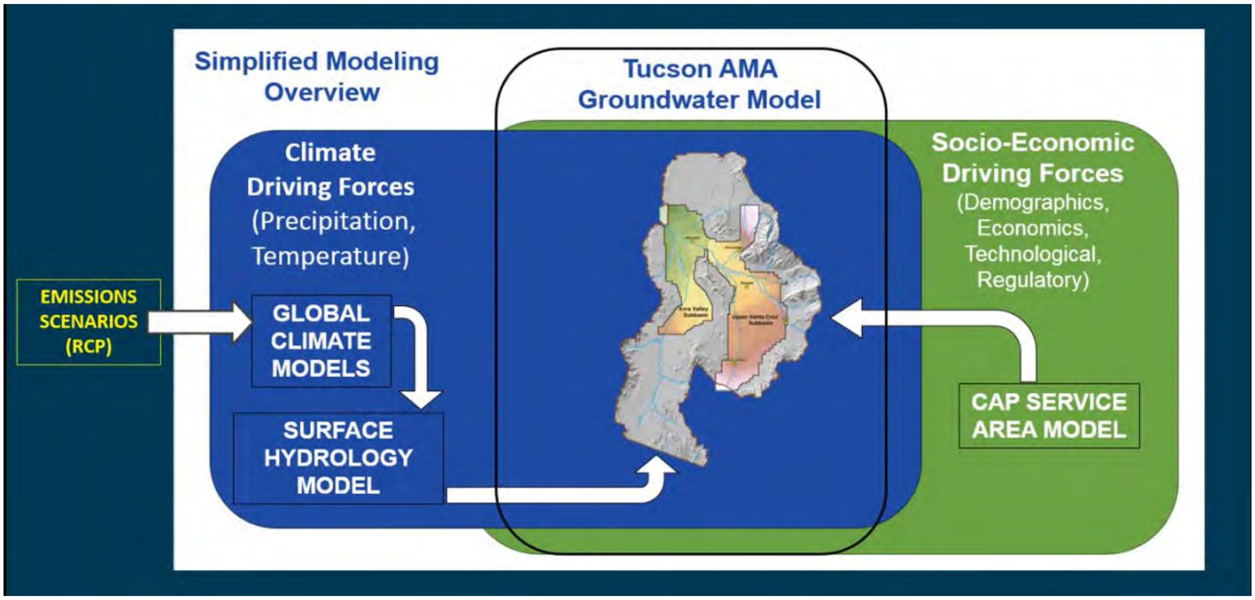


Figure 14. Schematic showing the combination of model methodologies used to develop future water-related outcomes within the Lower Santa Cruz River Basin (USBR, 2020).

The study is based on six future scenarios that consider a risk matrix of potential future impacts fromu three future emissions scenarios; best case, worse case, and current case, and three future growth (demand) scnearios; slow- compact, medium official, rapid-outward. This risk matrix can be seen in Figure 15, which indicates lowest risk in the lower left hand corner moving to highest risk in the upper right hand corner.

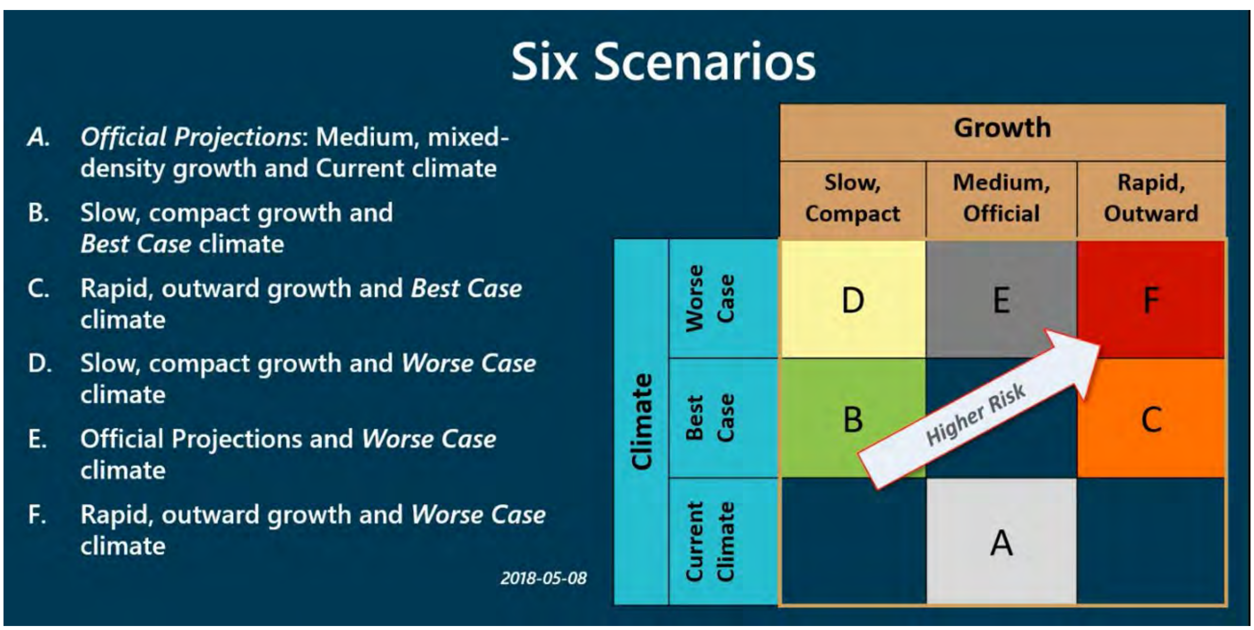


Figure 15. Risk matrix based on future climate and growth scenarios with the LSCRB (USBR, 2020).

LSCRB Study Air Temperature and Precipitation Projections

As identified in Section 3.2.1, the LSCRB study utilizes the current climate, a best case scenario, roughly equivalent to RCP 2.5, and a worse case scenario, roughly equivalent to RCP 8.5. These various scenarios and model projections yielded the changes as seen in Table 2, which include seasonal considerations during the dry season, wet season, and monsoon season, as well as considerations for the various future growth scenarios (Figure 15). Unlike many of the previous studies regarding climate projections within the region (Section 3.2.2) that provided a range of future outcomes for a given year, the LSCRB study provided specific outcomes for a range of years (i.e. 2030's).

Some of the highlights from the projected precipitation and temperature changes identified in Table 2 include the reduction in annual precipitation, especially in the worse case scenario, which is contrary to the long-term historic trend identified in Section 2.2.1. Contrary to this projection's disagreement with the historic precipitation trend, projected annual average temperatures in the region are expected to be very similar to those projected through the extrapolation of the historic temperature trends as seen in Figure 10 (Section 2.2.3).

Table 2. Projected basin-averaged precipitation and temperature changes at future time scales relative to 1970–1999 averages.

Projected Basin-Averaged Precipitation and Temperature (Relative to 1970-1999)

	Best Case 2030s	Best Case 2060s	Worse Case 2030s	Worse Case 2060s
Change in Total Annual Precipitation	0.32″	-0.85″	-4.34″	-3.90″
Change in Average Monsoon Precipitation	0.80″	-0.87″	-2.38″	-1.57″
Change in Average Winter Precipitation	-0.21″	0.57″	-2.25″	-2.38″
Precipitation RSD* Historical: Best = 20.3%, Worse = 17.3%	21.6%	28.5%	18.9%	30.4%
Change in Average Annual Temperature	2.94°F	3.83°F	3.41°F	5.12°F
Change in Average Dry Season Temperature	2.59°F	2.31°F	3.44°F	3.34°F
Change in Average Monsoon Temperature	1.96°F	3.52°F	4.24°F	5.81°F
Change in Average Winter Temperature	1.88°F	1.85°F	2.45°F	3.20°F

*Relative standard deviation (RSD), calculated by normalizing the standard deviation to the mean of the 30-year period and presenting as a percentage

3.2.2 TWSA Climate Projections Based on Other Regional Studies

This section provides an additional viewpoint on future climate projections specfic to the TWSA from a variety of peer-reviewed sources over the last 12 years. These projections serve a two-fold purpose of providing a perspective on how projections and methodologies change over time as climate science evolves, and an opportunity to understand the importance of exploring new methodologies such as those used in the USBR LSCRB study.

Precipitation Projections

Precipitation in the TWSA is projected to remain at about the same long-term historic trend of slowly increasing precipitation, but with increasing precipitation intensities. Figure 16 shows the observed trends (1895-2018) and climate projections represented by the full range of RCP 8.5 scenario outcomes associated with precipitation in the TWSA from 1895-2100 (Vose et al. 2017). Like the other projections, either in the local region or the greater CRB, a slightly increasing trend in precipitation is expected with year-over-year variability in annual precipitation becoming quite significant.

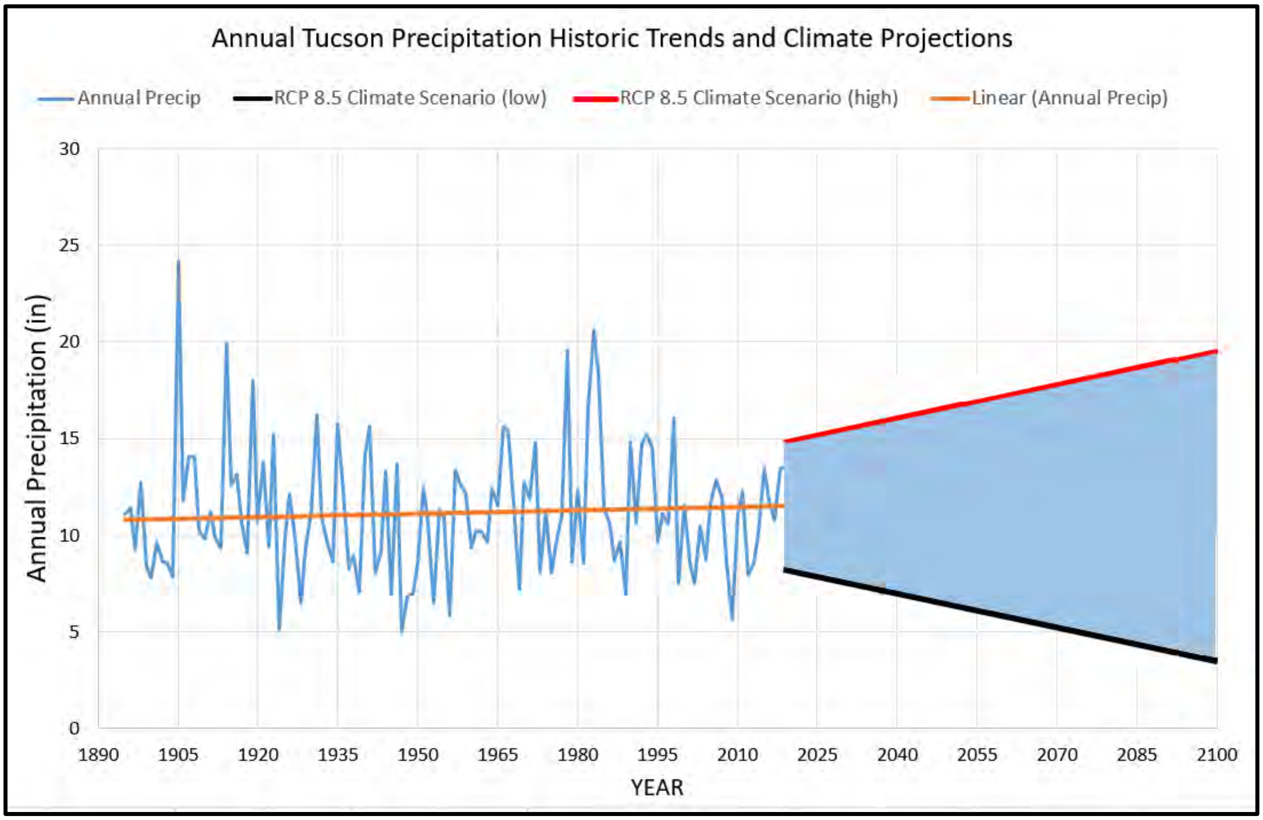


Figure 16. Historic observed and projected trends in annual Tucson precipitation from 1895–2100. Sources NCDC, 2020 and Vose et al., 2017.

While annual precipitation is expected to increase, as seen in Section 2.2.2., more of this precipitation is expected to come in the form of intense, short-duration rain showers or thundershowers. This presents a difficult challenge to stormwater capture and management as system capacity will need to be able to handle these intense, short-duration events going forward. This finding will be further detailed in Section 4.

Increases in precipitation intensities are expected to be particularly noticeable during the southwest Monsoon season. Study and modeling (CLIMAS, 2010) of the impacts of climate change on the southwest Monsoon season point to the following series of qualifying statements:

- Most climate projections indicate an increase in the duration and intensity of the Monsoon season.
- Increased heating as a result of climate change is expected to increase available atmospheric moisture. 3.5%/1°F (Clausius-Claperyon).

- GCM project a northward migration of the Jetstream, which favors monsoonal development earlier in the season.
- Increased heating should strengthen the thermal low at the surface, while entrenching the upper level area of high pressure over the four corner region, which will result in stronger and longer southwest Monsoon season.

GCM run for the IPCC 4th Assessment Report (IPCC, 2007) showed an almost across-the-board consensus that an increase in precipitation intensities is not only expected during the summer monsoon season, but, also, to some degree during the winter wet season as well. Figure 17 identifies the various GCM that were run as part of a similar analysis (Lin et al., 2008) that investigated the anticipated change in regional precipitation by season. The black line near the bottom of the spaghetti diagram in Figure 17 represent the observed precipitation data. This figure indicates that the GCM predict both an earlier and more robust monsoon season.

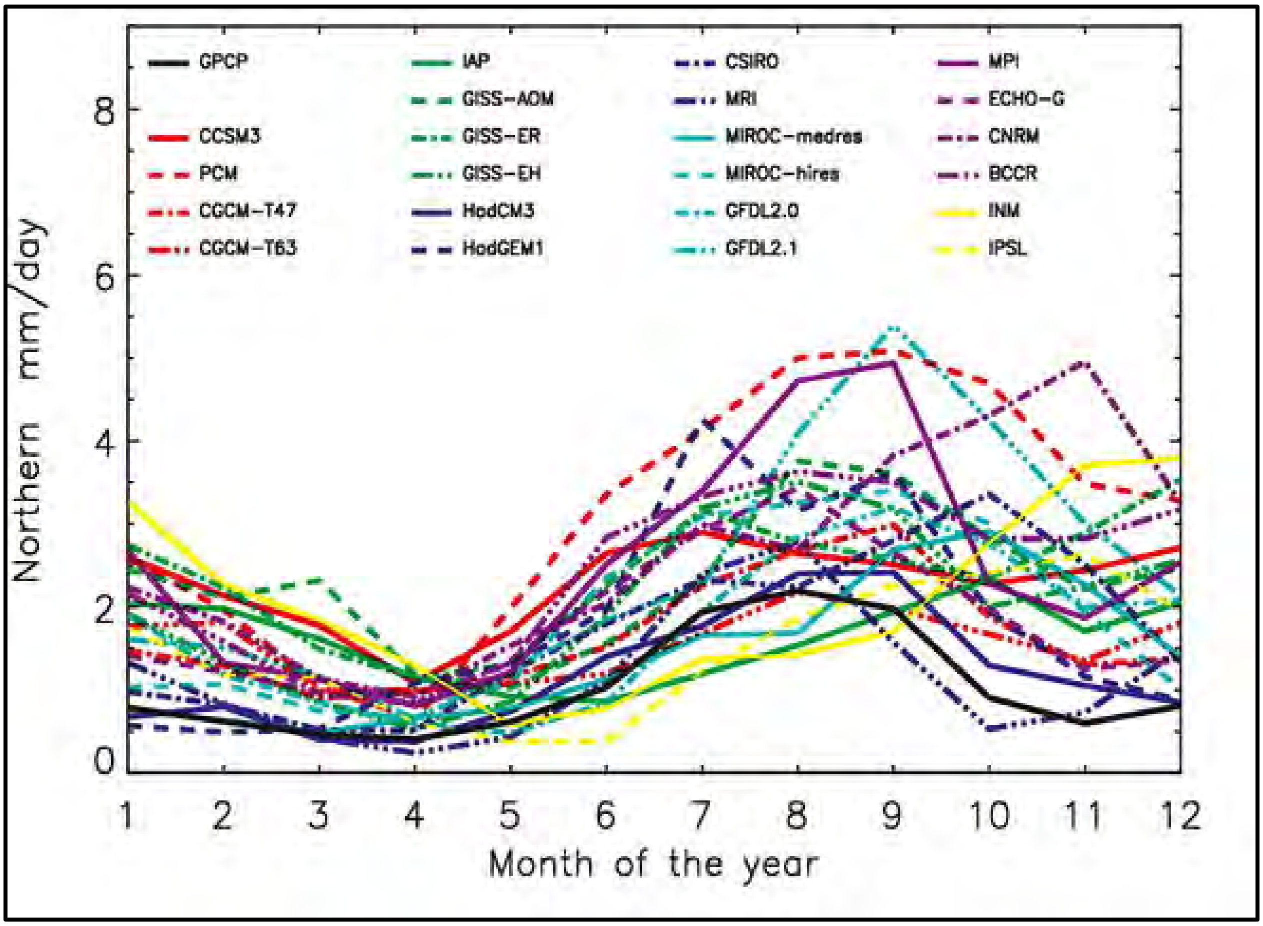


Figure 17. Projected precipitation by month in the southwestern U.S. associated with various GCM. Black line represents the observed precipitation data. Source: Lin et al., 2008.

The projection of future water surface flows, as recently reported in preliminary findings of the USBR Climate and Surface Water Analyses summary for the Lower Santa Cruz River study (USBR, 2019), are expected to show an increasing number of no-flow days in local rivers and streams (i.e. Davidson Canyon, Santa Cruz River nr Nogales, Sabino Creek). This number of no-flow days is expected to see a significant increase in the months of April, May and August, primarily due to increasing air temperatures. This study indicated that the number of no-flow days would be dramatically higher under the RCP 8.5 scenario versus the RCP 4.5 scenario, particularly by the year 2060.

Air Temperature Projections

As seen in the study of historic trends air temperature change within the CRB (Section 2.1.2) and the TWSA (Section 2.2.3), projected temperatures are expected to continue and/or accelerate this already increasing trend. Unlike the precipitation trends, the projected temperature trends show a very significant difference between the two future scenarios (RCP 4.5 and 8.5). Based on data from the NCA (NCA, 2018), TWSA annual air temperature are expected to increase by the temperatures indicated in Table 3 at the time scales identified in this table. These increasing temperatures in the TWSA can be seen graphically depicted in Figure 18.

Table 3. Projected annual average air temperature increase for TWSA for 2035, 2050, 2100 (NCA, 2018).

Projected Annual Average Air Temperature Increase for TW Service Region			
Scenario	Year		
	2035	2050	2100
RCP 4.5	2.11	3.72	4.25
RCP 8.5	2.3	4.8	10.63

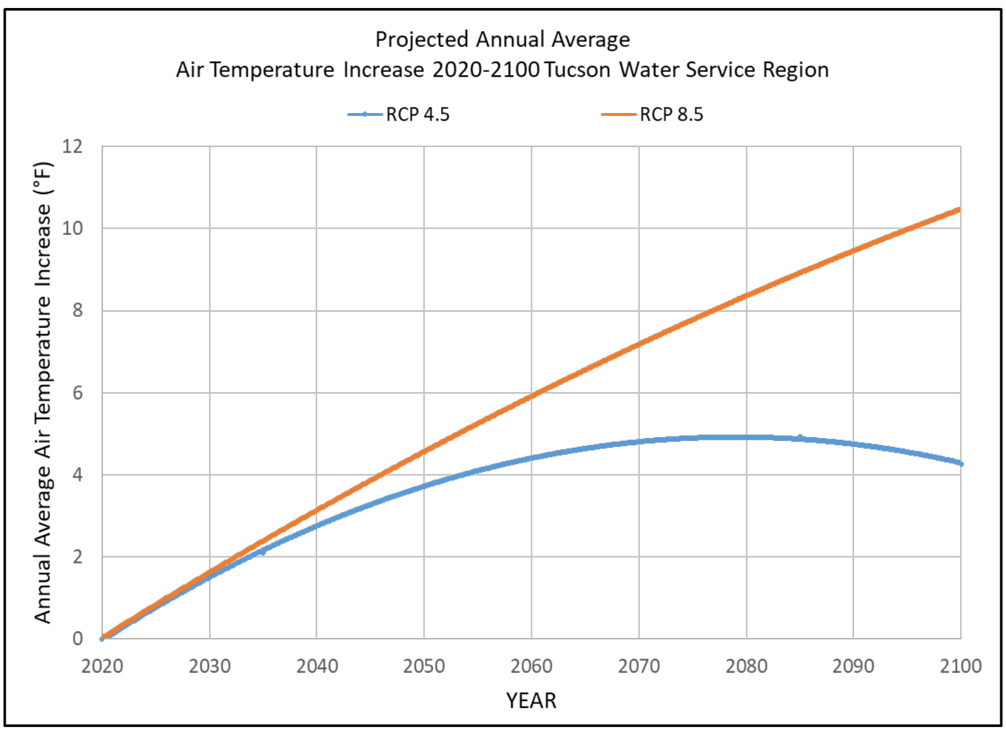


Figure 18. Projected annual average air temperature for TWSA 2020–2100 under RCP 4.5 and 8.5. Data source NCA, 2018.

One of the outcomes of these air temperature climate projections that cannot be seen in Figure 18 will be the increased number of extremely hot days (e.g. heat waves over 105°F). These days had increased 17.2 days a year since 1970 in Tucson by the year 2018 to 30 days/year. Based on the air temperature projections for annual average temperature in Figure 18, this increase in extremely hot temperatures is not only expected to continue but should accelerate through at least 2080 for RCP 4.5 and past 2100 for RCP 8.5. One of the comparisons that climate scientists use in order to explain what climate projections mean is the analogy that is drawn from a climate projection and observed climate data from another city or state. Thus, based on the climate projections for air temperature in the TWSA, Tucson should feel like Phoenix currently does (e.g. approximately 30 days of 110°F days/year) by the year 2050.

4 Summary of Tucson Water Climate Change Impacts

In the prior sections, all the expected changes in climate parameters have been detailed and quantified. This section is devoted to identifying the potential impacts of these changes to the Tucson Water system with considerations for both supply and demand.

4.1 Impacts of Climate Change to the Colorado River Basin and the CAP

As seen in the historic trends in precipitation in Section 2.1.1 and the projected trends in the CRB in Section 3.1.1, precipitation is expected to increase slightly in the CRB. This is in sharp contrast to the current 20-year drought, the increasing air temperatures, and the rapidly decreasing flow volumes in the basin over time. A recent study (Udall, 2017) has indicated that flows, on average across the CRB, are expected to decrease 4% for every 1°F of increasing temperature. As per the literature review in the appendix of this report, this is not the only research into the impacts of climate change on CRB flows, but it is the only one that quantifies the correlation between air temperatures and CRB flows.

Based on the historic trend extrapolation in Figure 13, this would indicate a reduction in CRB flows of approximately 20% by the year 2100, either through an extrapolation of the 1964-2019 trend or through the RCP 8.5 projection. Figure 12 indicates that CRB flow volumes are projected to be quite variable within a wide range of possible outcomes, while demand continues to increase.

4.1.1 CRB Impacts

The Colorado River Compact is a 1922 agreement regarding the amount of CRB water the seven U.S. states in the basin receive (Figure 1). In 1928, as part of the Boulder Canyon Project Act, the current specific annual allotments in the Lower Basin (California, Arizona, and Nevada) were established. These are equal to 7.5 MAF/year with Arizona below Lees Ferry receiving 2.8 MAF. This same amount (7.5 MAF) is allocated to the Upper Basin states of Colorado, Utah, Wyoming, New Mexico, and Arizona above Lees Ferry. According to the original compact agreement, if the Upper Basin does not deliver the required allotment (technically, 7.5 to 8.25 MAF), it would force the upper basin into managing water (i.e. releases from Flaming Gorge Reservoir) in a way as to meet the original allotment.

In 2019, the City of Tucson received its full allocation from the CAP of 144,191 AF and provided 91,616 AF in total potable water deliveries to Tucson Water customers. Tucson recharges their entire CAP allocation and recovers about two-thirds of it to meet customer demand on an annual basis. The remaining third is stored underground for future use. Tucson is able to save a third of their annual CAP allotment every year because their conservation program has been successful at managing demand. More information about the conservation program can be found in the “Water Conservation Program 10-Year Savings Projection” technical memo for the One Water 2100 master plan. More information about Tucson Water's CAP savings and groundwater supply can be found the "Water Use Projections" technical memo for the One Water 2100 master plan.

An accounting of the future impacts for water and environmental resources was developed (USBR, 2016) that are expected to have potential impacts in the CRB in the future. They are as follows:

- Snowpack runoff in the Upper CRB is expected to occur earlier in the spring, which will force a change in operational rule curves for the major reservoirs downstream in order to better manage releases later in the year.
- Spring and early summer runoff reductions could translate into less water supply for meeting irrigation demands and adversely impact hydropower operations at reservoirs.
- Warming could also lead to significant reservoir evaporation, increased agricultural water demands and losses during water conveyance and irrigation.
- Growing demands in the Colorado River system, coupled with the potential for reduced supplies due to climate change, may put water users and resources relying on the Colorado River at risk of prolonged water shortages in the future.

On April 16, 2019 the Colorado River Drought Contingency Plan Authorization Act became federal law. This law (H.R. 2030) overlaid the 2007 interim guidelines or what is known as the Seven States Agreement (DOI, 2007), which were a plan for operating Lake Mead and Lake Powell in coordination to stave off dramatic drops in water levels at either reservoir. The DCP is an agreement among the seven states of the Colorado River Basin that take the steps necessary to protect Lake Mead in the event of a shortage declaration on the Colorado River. The plan is made up of two drought contingency plans; one for the Upper Colorado River above Lees Ferry, and one for the Lower Colorado River below Lees Ferry. It is based on USBR updates to its projections each month, but the April report and the August report are the most critical in determining how much water will be released from Lake Powell and Lake Mead in the coming year. The elevation levels forecasted to be in each of those reservoirs at the end of each year trigger those releases.

Climate change has been identified as one of the drivers for the DCP. The James E. Rogers College of Law at the University of Arizona (Whitehill, 2019) identifies the DCP as, “an idea to give up more, concrete quantities of water now before we reach critical shortage levels in order to minimize the risk of losing even more water at unpredictable levels in the future".

The DCP, although complex and dependent on many different factors coming together, has been viewed by Federal and State lawmakers and local stakeholders as a big step forward towards dealing with water shortages in the southwestern U.S. According to a review of the plan at the University of Arizona College of Law, (Whitehill, 2019), the DCP is made up of three key mechanisms for addressing water shortages:

> Under the new DCP, the cuts in water supply are spread across multiple users, in accordance with three main mechanisms. The first is "mitigation water." Because the 2007 Guidelines list agriculture as the lowest priority user, farmers and other entities that face cuts will receive mitigation water, so the cuts are not as extreme. Right now, farmers in the Agriculture Excess Pool get 275,000 AF of water per year. Without mitigation water, farmers would see that CAP water completely cut under the Tier 1 shortages. Under the new plan, for three years (2020-2022), the farmers using the Agriculture Excess Pool would receive 105,000 AF of water per year. This mitigation water will come from cities that otherwise would have banked the water underground, the private water company EPCOR, and CAP owned water that is currently stored in Lake Mead and Lake Pleasant. Along with the mitigation water, Pinal County agriculture will receive funding to build groundwater infrastructure so it can rely less on CAP water in the future
>
> The second mechanism is monetary compensation to those who contribute some of their allotted water to mitigate the losses of other users. Over the length of the new DCP (2020-2026), the Gila River Indian Community will receive $60 million to forgo most of the NIA water it would otherwise be allotted.
>
> The third mechanism is offsets, which involves trading credit for the water stored in Lake Mead instead of that water being used between different water agencies and other entities. The goal is to leave more water in Lake Mead so that additional cuts will not be needed down the road. In exchange for leaving 10,000 acres of farmland fallow, tribes will receive $30 million over three years. This will result in 150,000 AF of water staying in Lake Mead. The total offsets under the DCP will be 400,000 af over the six years of the plan.

On June 25, 2020, the Arizona Department of Water Resources (ADWR) and the CAP reconvened the Lower Basin Drought Contingency Plan (LBDCPO) Steering Committee delegates to form the Arizona Reconsultation Committee (ARC). The ARC will develop an Arizona perspective on the reconsultation of the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Power and Lake Mead, which are known as the aforementioned 2007 Guidelines or Seven States Agreement (DOI, 2007).

The ARC will play an important role formulating Arizona-centric input for the long-term management of the Colorado River system, which is expected to be developed by the U.S. Secretary of the Interior by the end of the year 2026. As detailed during the ARC Meeting 2, on September 17, 2020, the following initial key issues are at the forefront of these planning discussions:

- Balance the need for certainty with the need for flexibility to address changing conditions and circumstances
- Differing perspectives on mitigation post-2026
- Consider balancing perspectives on ICS storage and releases to avoid interstate impacts to priorities and user
- Desire to discuss the role and opportunities for senior priority users to offer water to junior priority users

Thus, as per the first bullet, which expresses the need for a flexible plan to address changing conditions and circumstances, understanding climate change and climate variability are going to be paramount to decision support for this effort. In order to address these needs, the ARC has created a Modeling and Analysis Workgroup (MAWG). This group is leading the implementation of a framework that will be used to identify and develop basin scale hydrologic models for demands and depletions, use behaviors, operations, priorities and initial model visualizations. Initial scenario development is expected to begin in April 2021.

4.1.2 CRB Demand impacts

Agriculture is a major component of the CRB's economy with over 3.5 million acres of cropland in production each year (Cohen et al. 2013), of which, as of 2012, 1.8 million acres were irrigated (Laituri, 2012). Of this cropland area, approximately 60 percent of the acreage supports forage crops and pasture, which are used to support the livestock industry (Cohen, et al., 2013).

Increasing air temperatures are expected to reduce CRB flows due to increased evaporation and evapotranspiration, but these same increased air temperatures will also force water demand higher, especially as it relates to agriculture in the basin. In addition to anticipated losses to evaporation, irrigators will likely have to divert more water to grow the same types and quantities of crops due to higher evapotranspiration rates. Additionally, the timing of planting and harvesting will need to be altered to accommodate both longer growing seasons and earlier snowmelt in the headwaters of the CRB. Changes in runoff caused by increased evaporation and evapotranspiration coupled with variable precipitation patterns is predicted to produce an 8-10 percent decrease in CRB inflows by the year 2075 (Christensen et al., 2007).

4.2 Impacts of Climate Change to the Tucson Water Service Area

As noted in Section 4.1, renewable water supply from the CAP makes up a large portion of the City's overall water portfolio. The rest of the portfolio is made up of groundwater/recharge and its sources supplies including, remediated water, recycled water, and, to an increasing degree, water harvesting (active and passive stormwater collection). The following section will detail possible impacts to each of these water supply sources in Tucson as a result of climate change, as well as provide an overview of potential impacts to water demand in the TWSA.

4.2.1 Water Supply Impacts – Groundwater/Recharge

Groundwater recharge via CAP deliveries from the Colorado River is a significant source of water supply for the City of Tucson. In a report by the City from 2018 (City of Tucson, 2018), the status and quality of the groundwater supply is discussed. This paper details the successful turnaround that occurred within the groundwater system as a result of a very proactive approach to recharge. The map in Figure 19 (City of Tucson, 2018) shows the increase or decrease in water levels that has occurred in the Tucson/Avra Valley aquifer from 2000-2016 in the Tucson region. This trend has reversed the groundwater overdraft that had been occurring since the 1940's to the early 2000's.

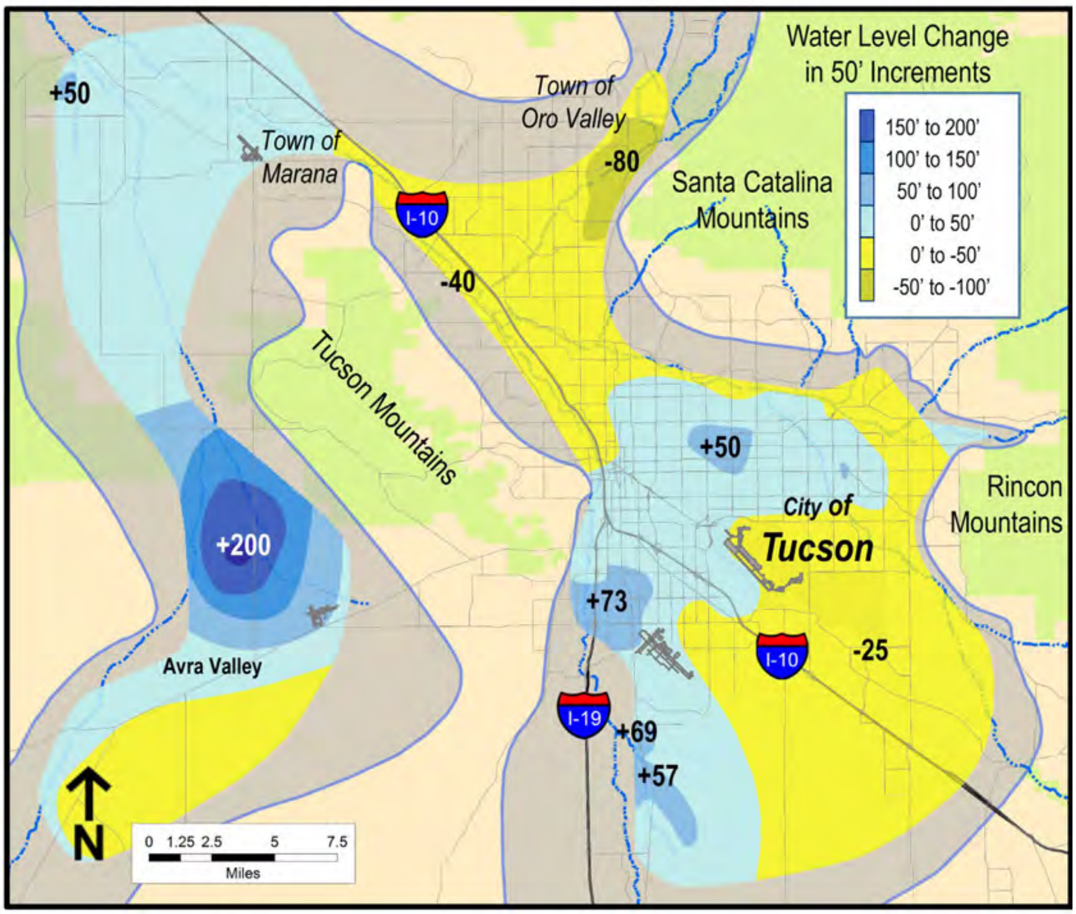


Figure 19. Map showing the change in water levels (ft.) in the Tucson/Avra Valley aquifers.

Based on the climate trends and projected climate parameters reported in the Sections 2 and 3, respectively, the climate change impacts to the City's groundwater and groundwater recharge program are expected to be a result of temperature-related impacts to the CRB and the local demand equation. While both the CRB that produces the CAP water as part of the groundwater recharge program, and the TWSA are expected to see a slightly increasing annual precipitation, air temperatures are expected to greatly impact evaporation, evapotranspiration, soil moisture, and demand in those regions.

The impact of increasing temperatures is expected to produce a small overall decrease in both naturally infiltrating groundwater and water that is awaiting recharge in recharge facilities (i.e. Clearwater facility) and other sources within the TWSA. This would be the result of increased evaporation due to increasing air temperatures. Based on the Clausius-Clapeyron equation, this increase in evaporation should be equivalent to approximately 3.5% per 1°F increase in air temperatures. As per the Penman Equation for evaporation, this approximation could vary considerably based on other factors (i.e. solar radiation, wind, dewpoint, etc.), but represents a middle-of-the-road value. Using this anticipated increase in evaporation combined with the historic trend in annual average air temperatures extrapolated from the data in Figure 10, this reduction would be 14.4% by the year 2100. Based on the projected temperature change projected in Figure 16, this would result in a 13% (RCP 4.5) or a 14.8% (RCP 8.5) reduction in water available for recharge by 2050, and a 13.5% (RCP 4.5) or a 37% (RCP 8.5) reduction by 2100.

In a relatively recent paper concerning the aspects of climate change and its potential impact on groundwater recharge (Meixner, et al., 2015), the author identifies that climate impacts depend on the following:

- Basin structure, depth to water
- Aquifer recharge type: streambed, mountain front recharge, agricultural and municipal return flows, etc.
- Groundwater/surface water interactions
- Temperature, ET
- Intensity and seasonality of precipitation and resulting runoff
- Channel morphology, erosion, flooding
- Changes in land use and technology
- Changes in vegetation

Thus, mitigation efforts should be geared towards addressing these issues within the Tucson/Avra Valley recharge and recovery basins; CAVSARP and SAVSARP. Fortunately, the City's proactive efforts toward basin recharge (improvements in depth to water) have been successful during the last 20 years of drought in the region. As pointed out previously in this section, while the City of Tucson has been proactive in addressing the components on this list, the one in regard to temperature/evapotranspiration is one that will be very difficult, if not impossible, to mitigate.

4.2.2 Water Supply Impacts – Stormwater Capture (Water Harvesting)

As the City has already realized, rain and stormwater harvesting has numerous benefits and is a potential source of increased future water supplies for the region. The Water Harvesting Guidance Manual (City of Tucson, 2005) is still applicable today, but probably could use an update to both enhance community involvement and provide guidance for the future of water harvesting in the region.

As discussed in Section 2.2.2, precipitation intensities have already begun to change in the region and are expected to continue to become more intense with continued climate change in the future. This presents a distinct capacity problem as stormwater capture becomes a bigger part of Tucson's water portfolio. Stormwater capture can range from a 50-gallon barrel under a downspout to retention/percolation/infiltration basins to large above ground storage facilities. These types of infrastructure can provide a significant source of water supply in the region but can also be overwhelmed in extreme precipitation events. Therefore, infrastructure for stormwater capture may need to be upsized to accommodate for more intense precipitation events.

4.2.3 Water Supply Impacts – Remediated Water/Recycled Water

Water remediation as a source of water supply for the City comes from the Tucson Airport Remediation Project/Advanced Oxidation Process (TARP/AOP) Treatment Facility. This is primarily a closed system, so it is unlikely that this system will undergo any significant impact from climate change other than that related to the impact of increased air temperatures on the oxidation process (which may require adjusting the hydrogen peroxide levels).

Recycled water is primarily a closed system, as well, until the end product reaches its destination as a source for irrigation water or groundwater recharge. At this point in its processing, it becomes vulnerable to increased evaporation from anticipated increases in air temperature in the region. Thus, the same amount of recycled water that is being produced today, is expected to not have the same irrigation capabilities in the future. Additionally, the overall impact of evaporation and evapotranspiration on the end user is likely to produce a reduction in return flows to the system.

As with all of the water supply infrastructure with the TWSA, recycled or remediated water will need to be conveyed through pipes or conduits. As noted in Section 4.2.2., precipitation intensities are expected to increase as the climate in the region becomes warmer. These increasing precipitation intensities are likely to produce an elevated flood risk that could damage water supply conveyance such as that associated with remediated or recycled water. This would be particularly true in situations where these pipes cross washes or arroyos.

4.2.4 Water Supply impacts – Water Quality

The City is fortunate to have a very large aquifer for groundwater storage. The usual sources of water quality issues as a result of climate change; stormwater runoff, erosion and sedimentation, and harmful algae blooms (EPA, 2019) are all threats that have a much greater impact on surface water supplies than that associated with groundwater sources. Again, increasing air temperatures, which result in increased surface water temperatures (ratio is 0.6°F to 0.8°F of water temperature rise per 1°F air temperature rise), are the biggest culprit, but minimal water quality impacts are expected to the TWSA now and into the future.

As active and passive stormwater capture have gained popularity around the country, and particularly in the arid southwestern U.S., concerns regarding water quality issues have increased as well. While climate change is expected to increase the likelihood that stormwater capture programs continue to expand, it may also need to an expansion of stormwater treatment techniques so that water quality issues do not become a problem (San Diego Coastkeeper, 2020). Accommodations for potential issues with water quality will need to be considered as the use of stormwater capture grows as a water supply source in the TWSA.

4.2.5 Water Supply Impacts – Drought and Mega-drought Impacts

As reported earlier in Section 2.1.1, and graphically depicted in the climate reconstruction in Figure 4, several multi-decadal (mega-) droughts have occurred in the southwestern U.S. in the past 1000 years. A recent study by Columbia University (Steiger, et al., 2019) investigated the physics behind these phenomena and their initiation in and impact on global weather patterns. They found that mega-droughts were associated with a significant cooling of the Pacific Ocean waters as a result of radiative forcing (less energy from the sun) as represented by a reconstruction of the NINO3.4 index from the year 800 to the year 2000.

The NINO3.4 index is a "hydro-climate" index that basically represents energy within the global system in a given region. This energy exists primarily as heat energy stored in the oceans (both sea surface and sub-surface temperatures are a large component of these values). During the period between the years 800 to 1600, the reconstructions found that there were multiple periods of years with very low NINO3.4 index values that were associated with 14 periods of multi-decadal droughts in the southwestern U.S.

These periods of cool Pacific waters, much cooler than today's La Nina periods, produced dry, stable conditions over the region, and very little precipitation fell for long multi-decadal periods. So, are they likely to return? This question was not answered within the referenced document, but based on current climate trends, it is likely that any future multi-decadal periods of low NINO3.4 values in the Pacific as a result of radiative forcing would be offset by a warming environment as a result of global climate change. Thus, it is possible that global climate change could play a role in limiting future mega-droughts in the southwestern U.S.

Impacts to the City from a mega-drought are not expected to be immediately felt as their groundwater aquifer could produce water for many decades when combined with increased water conservation practices. However, a drought in the southwestern U.S. lasting for 50 years or more would, eventually, force the City into a situation where water imports from faraway sources may be the only option.

4.2.6 Water Demand impacts – Physical, Social, and Behavioral

Physical water demand is expected to increase as the atmosphere warms in the TWSA. In a 2013 report in the Journal of Physical Geography (Balling and Cubaque, 2013), estimates of the increase in the per capita water demand by the year 2050 was expected to be an increase of 3% in the Phoenix area. This report only applies to residential water use in the Phoenix region, which is not supplied by Tucson Water.

Agricultural water demand is expected to increase as well. A study (Kosa, 2009) investigating the relationship of air temperature (X) to generalized evapotranspiration (Y) found that this relationship can be represented by the equation:

$$y = -0.028x^2 + 1.7608x - 22.932$$

If this were to be applied to the TWSA, based on the historic TWSA air temperature trends (Figure 9) and the projected TWSA air temperature trends, Section 3.2.2, Table 3 and Figure 18, the resultant increase in evapotranspiration expected in the TWSA is 0.04 inches/day for the historic trend by the year 2100, 0.042 inches/day for RCP 4.5 by the year 2100, and 0.087 inches/day for RCP 8.5 by the year 2100. These numbers seem quite small, but they represent a per day rate over many acres of irrigated plantings in the region.

Climate change is expected to impact water demand through changes in social behavior, primarily as it relates to health issues because of increased air temperatures and heat waves. The Center for Disease Control (CDC, 2016) identifies an air temperature of 95°F as the temperature at which health problems are likely to occur within a community/society, particularly within the more vulnerable populace. An increase in the number of extremely hot days is expected to be a consequence of climate change and is expected to have a significant impact on water usage during these extremely hot periods; possibly for both physiological and psychological reasons. Figure 20 identifies the historic trend (1895-2019) in the number of 100°F days in the TWSR. While the trend shows a steady increase in the number of 100°F days over time, the same inflection point that showed up in the temperature graphs in Figure 9 is plainly seen around 1964 in the number of 100°F days. Figure 21 shows an extrapolation for this same trend out to the year 2100. Thus, if the historic trend were to continue in the absence of any consideration for climate change, the number of 100°F days in Tucson would be expected to reach approximately 76 days/year by the year 2100.

Additionally, these increasing air temperatures are expected to make an impact on water demand during all seasons (i.e. winter wet, dry, and monsoon), but are expected to be particularly impactful during the end of the winter wet season. Warming during this time of year is expected to decrease soil moisture during the months of March and April, at a time when most plants and agriculture need it the most. As reported in the preliminary findings for the USBR Lower Santa Cruz River study (USBR, 2019), while hotter weather would normally increase evapotranspiration, reduced soil moisture during this time is expected to reduce evapotranspiration due to lack soil moisture.

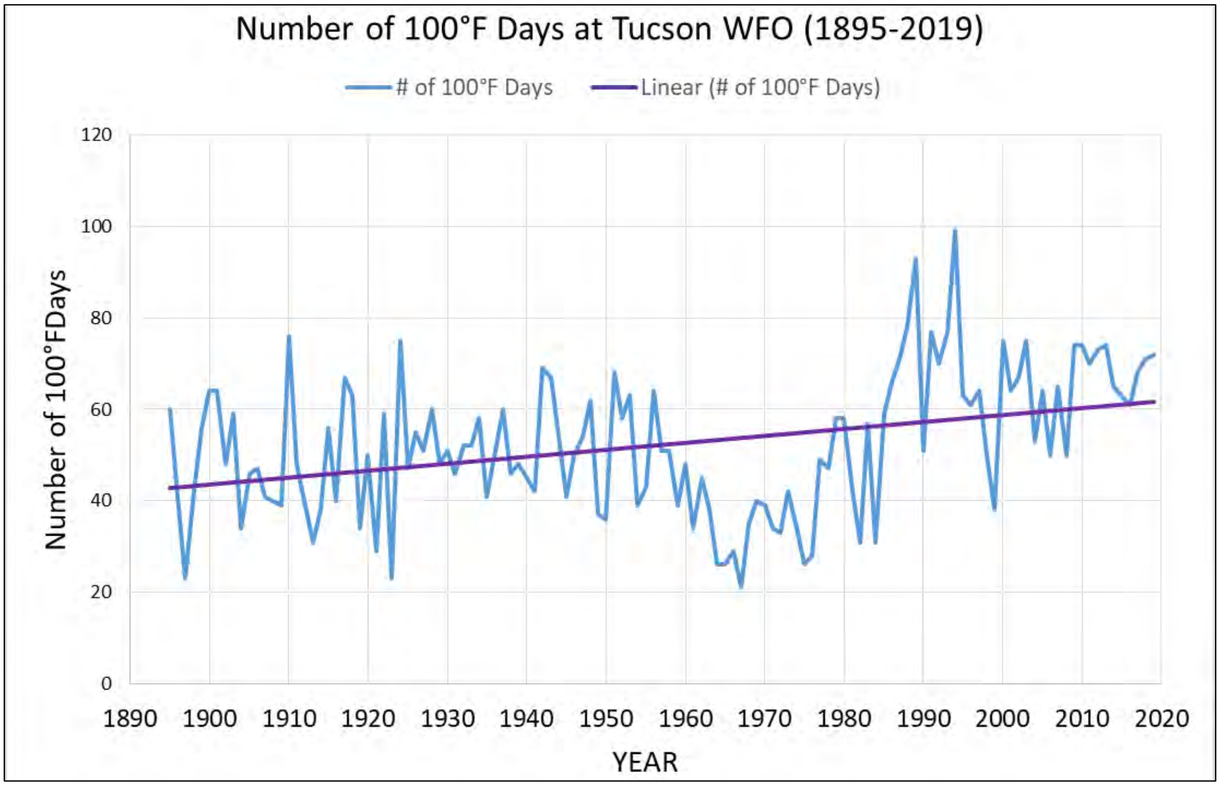


Figure 20. Observed number of 100°F days at Tucson National Weather Service Weather Forecast Office (WFO) 1895–2019.

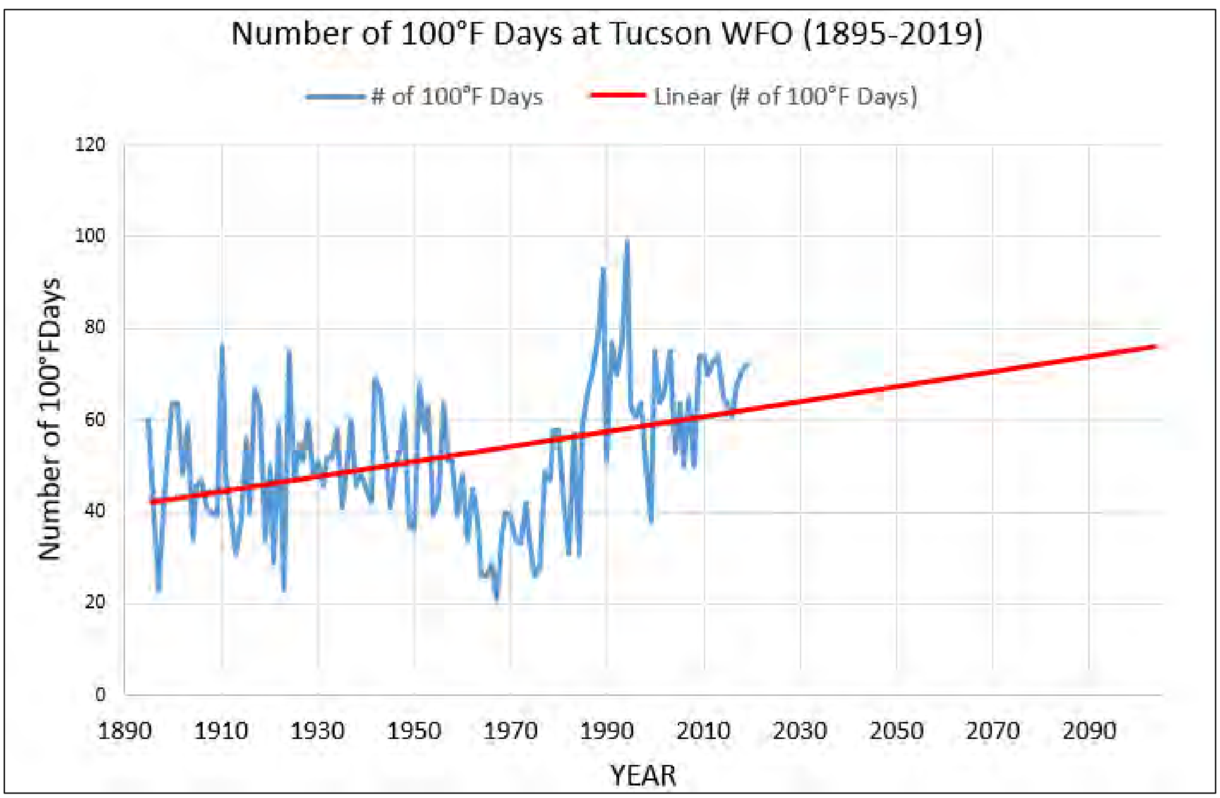


Figure 21. Extrapolation of number of observed 100°F days in Tucson National Weather Service Weather Forecast Office (WFO) (1895–2019) to the year 2100 (red line).

5 Conclusion

The impacts of climate change are expected to provide an iterative challenge to Tucson Water's efforts to formulate the One Water 2100 Master Plan and during its implementation in the future. While recent observed climate trends show significant changes from the long-term historic record, climate projections, particularly those associated with water availability, indicate that a pro-active response will be necessary to mitigate potential water management impacts. As identified in the objectives for the recent USBR LSCRB Study (USBR, 2020), physical water resources infrastructure are going to be needed to mitigate supply and demand imbalances, and strategies are going to be needed to improve water reliability for municipal, industry, agriculture, and environmental sectors through the year 2060.

Fortunately, through the combined efforts of the Federal (i.e. USBR, USACE, DOI, etc.), State (i.e. ADWR, ARC, CAP), and Local stakeholders (i.e. Tucson Water) , the right questions are being asked and solutions are being discussed, modeled, vetted, and developed in what thus far has proven to be a collegial environment. The next steps towards water supply resilience will come from all levels of government and will require input from groups such as ARC's Modeling and Analysis Workgroup to provide the highest level of decision support for initial mitigation efforts.

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National Climate Assessment (NCA). 2018. *Fourth National Climate Assessment (AR4: Chapter 25 Southwest.* U.S. Global Change Research Program, Washington D.C. *Website: https://nca2018.globalchange.gov/chapter/25/*

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Steiger, N. J. et al. 2019. *Oceanic and Radiative Foring of Medieval Megadroughts in the American Southwest*. Science Advances 24 Jul 2019:Vol. 5, no. 7, eaax0087 DOI: 10.1126/sciadv.aax0087

Udall, B. and J. Overpeck. 2017. *The twenty‐first century Colorado River hot drought and implications for the future*. Water Resouces Research. *Website: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016WR019638*

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United States Bureau of Reclamation (USBR), 2012. *Colorado River Basin Water Supply and Demand Study - Technical Report A-Scenario Development. 18 pages. Website: http://www.riversimulator.org/Resources/USBR/BasinStudy/Final/03TechnicalAReportScenarioDevelo pment.pdf*

United States Bureau of Reclamation (USBR). 2016. *2016 SECURE Water Act Report - Colorado River Basin Fact Sheet. Website: https://www.usbr.gov/climate/secure/docs/2016secure/factsheet/ColoradoRiverBasinFactSheet.pdf*

United States Bureau of Reclamation (USBR). 2019. Colorado River Basin Drought Contingency Plans. Website: https://www.usbr.gov/dcp/. Washington, D.C. May 2019.

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Website: https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/20191121climate.pdf

United States Bureau of Reclamation (USBR), 2020. *Climate and Surface Water Analysis Summary - Lower Santa Cruz River Study.* Presentation by Lindsay Bearup, December 10, 2020 - Preliminary findings.
Website: *https://www.tucsonaz.gov/files/clerks/uploads/bccfiles/31639.MP3*

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Appendix A. Climate Change Literature Review

This literature review is provided as a precursor to the analysis of the anticipated impacts of climate change on the Tucson Water system. Among the multiple anticipated effects of climate change within the southwestern U.S. are the long-term change in precipitation variability and air temperatures. These changes are expected to result in impacts to both water supply and demand in the region. This literature review will investigate significant study of these anticipated impacts as a basis of reference for this study. As with many climate science literature reviews, although there is a need for geographic specificity, climate change is a global phenomenon. Thus, this literature review covers local and regional, as well as important global research and study efforts regarding this topic.

Summary of Local, Regional, and Global Climate Change Literature

Balling, R.C., Cubaque, H.C. 2009 Estimating Future Residential Water Consumption in Phoenix, Arizona Based on Simulated Changes in Climate, Physical Geography, 30:4, 308-323, DOI: 10.2747/0272-3646.30.4.308. Previous studies have shown that residential water consumption in Phoenix, Arizona is significantly related to changes in climate, although that sensitivity varies substantially from one census tract to another. In this investigation, the authors determine the empirical relationship between water consumption and variations in temperature and precipitation. They found the sensitivity of water consumption to either climate variable is positively related to the percent of land covered in mesic irrigated landscaping, mean household income, lot size, and percent of single-family residential lots containing swimming pools. They used estimated changes in temperature and precipitation for 50 model-scenario combinations presented by the IPCC, and they determined that mean water consumption should increase by an average of over 3% by ~2050, but the climate-induced change in consumption varies considerably across census tracts.

Website: https://www.tandfonline.com/doi/abs/10.2747/0272-3646.30.4.308 (requires access).

Beller-Simms, N., E. Brown, L. Fillmore, K. Metchis, K. Ozekin, C. Ternieden, K. Lackey. 2014. *Water/Wastewater Utilities and Extreme Climate and Weather Events: Case Studies on Community Response, Lessons Learned, Adaptation, and Planning Needs for the Future*. Water Environment Research Foundation. This report summarizes that extreme climate and weather events are occurring more frequently and with more intensity across the nation. They often leave communities, and the water utilities that serve them, reeling from costly aftermath. These extreme events have the potential to disrupt water services including drinking water supply, wastewater conveyance and treatment, and stormwater management.

This report is intended to facilitate peer-to-peer sharing on how water resource managers are coping with extreme events and building resiliency. Research was conducted at six local workshops, organized to include participants that experienced different types of extreme events throughout a river basin or watershed. The localities included:

Apalachicola-Chattahoochee-Flint River Basin, Georgia, Central Texas, Lower Missouri River Basin, Kansas and Missouri, National Capital Area, Russian River Basin, California, Tidewater Area, Virginia.

Website: *https://www.waterrf.org/research/projects/waterwastewater-utilities-and-extreme-climate-and-weather-events-case-studies-0*

Brown, C. and R.L. Wilby. 2012. *An alternate approach to assessing climate risks*. Eos Transactions American Geophysical Union, Volume 93. This paper concerns the inconsistencies and variations that come out of the analysis of Global Climate Models (GCM) during the course of a climate risk analysis and how those methodologies can be improved through the use of varying alternatives to GCM-based analyses. This paper states that, "Climate scenarios can be generated parametrically or stochastically to explore uncertainty in climate variables that affect the system of interest [Prudhomme at al., 2010; Brown et al., 2011]. This allows sampling changes in climate that include but are not constrained by the range of GCM projections. The definition of scenarios can be developed as part of a stakeholder-driven, negotiated process, and climate projections can be used in this process [Hallegatte et al., 2012]. In other words, institutional knowledge of from a given stakeholder can assist in developing a more efficient, and, perhaps, negotiated process for the use of climate projections.

Website: *https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2012EO410001*

City of Tucson, 2018. *Status and Quality of the Aquifer.* Tucson Water, September 2018. This document provides an overview of the condition of the groundwater aquifer and the various supplements to the system from existing groundwater, CRB water (CAP), remediated water (TARP plant), recycled water, and stormwater from active and passive systems. A comparison of the state of the system to what the condition of the system was 1998 is proffered. Maps are provided showing the level changes in aquifer water during the period 2000-2016.

Website: *https://www.tucsonaz.gov/files/water/docs/Aquifer.pdf*

Chief, K., A. Meadow, and K. Whyte. 2016. *Engaging Southwestern Tribes in Sustainable Water Resources Topics and Management*. Water, 8, 350. This paper has three objectives:

1. To provide an overview of the context of current indigenous water management issues, especially for the U.S. federally recognized tribes in the Southwestern United States.
2. To synthesize approaches to engage indigenous persons, communities, and governments on water resources topics and management.
3. To compare the successes of engaging Southwestern tribes in five examples to highlight some significant activities for collaborating with tribes on water resources research and management.

For the five select cases of collaboration involving Southwestern tribes, the success of external researchers with the tribes involved comprehensive engagement of diverse tribal audience from grassroots level to central tribal government, tribal oversight, on-going dialogue, transparency of data, and reporting back. There is a strong recognition of the importance of engaging tribal participants in water management discussions particularly with pressing impacts of drought, climate change, and mining and defining water rights.

Website: https://www.mdpi.com/2073-4441/8/8/350

Climate Assessment for the Southwest (CLIMAS), University of Arizona. 2010. Author: Truebe, S. The Southwest Monsoon Under Climate Change: *What the Models Tell (and Don't Tell) Us*. Climate Assessment for the Southwest (CLIMAS). A brief review of the global climate model output as it pertains to impacts on the SW monsoon. This was a blog post that summarized the current (at the time) understanding of what to expect in regards to changes in the SW monsoon.

Website: https://climas.arizona.edu/blog/southwest-monsoon-under-climate-change-what-models-tell-and-don%E2%80%99t-tell-us

Climate Central. 2019. *American Warming: The Fastest-Warming Cities and States in the U.S.* Research brief by Climate Central Published April 17, 2019. This article highlights the fact that in April 1970, Americans celebrated the first Earth Day, an event meant to heighten public awareness of of environmental protection. Since then, humanity has dumped an enormous amount of heat-trapping gas into the atmosphere. Atmospheric CO2 concentrations rose by more than twice as much in the half century after the first Earth Day than they did in the entire century before 1970. There is now more CO2 in the atmosphere than at any point in at least the last two million years.

Humanity's greenhouse gases have made the world hotter. That warming is at the root of many of climate change's dangers, from droughts and sea level rise to heatwaves and agricultural problems. Warming is increasing the frequency and intensity of extreme weather, damaging public health, stressing food and water supplies, shifting seasons and ecosystems, boosting sea levels, damaging infrastructure and local economies, and threatening ways of life.

Website: https://www.climatecentral.org/news/report-american-warming-us-heats-up-earth-day

Crimmins, M., D. Ferguson, A. Meadow, and J. Weiss. 2017. *Discerning "Flavors" of Drought Using Climate Extremes Indices*. Journal of Applied Meteorology and Climatology, Volume 56. This study reviewed numerous climate extremes indices to investigate historical hydroclimatic variability across tribal lands of the Four Corners region in the southwestern United States over the period of 1950–2014. Five extremes indices were identified that provided additional insight into interannual hydroclimatic variability. Results from this study indicate that operational drought monitoring and historical drought assessments in arid and semiarid regions would benefit from the additional insight that daily-based hydroclimatic extremes indices provide, especially in light of expected climate change–driven changes to the hydrologic cycle.

Website: https://journals.ametsoc.org/doi/10.1175/JAMC-D-16-0270.1

Dascher, E., J. Kang, G. Hustvedt. 2014. *Water sustainability: Environmental attitude, drought attitude and motivation*. International Journal of Consumer Studies, 38. This study examined the relationships among US consumers' perceptions of drought severity, perceived importance of water conservation drivers, participation in water/energy conscious consumption, and perceived consumer effectiveness (PCE) in both general environmental issues and drought. A survey of 273 consumers in the US State of Texas was conducted during the most severe single-year drought in the region's history. Exploratory factor analysis, confirmatory factor analysis, and structural equation modelling were used for data analysis. The results of this study support the importance of PCE in sustainable consumer behavior and suggest that PCE for a specific issue has a more direct impact on relevant consumer behavior than PCE for a generalized issue. The results of this study also suggest that policy makers should focus upon water restrictions and educational campaigns as part of their demand side management of water resources rather than providing incentives for water conservation technologies. Lastly, the exploratory variable used to measure water/energy conscious consumption has been validated in this study and suggests that at least a partial percentage of consumers are consciously making water/energy purchase decisions within a larger framework of reduced resource availability.

Website: *https://www.researchgate.net/publication/263670573_Water_sustainability_Environmental_attitude_drought_attitude_and_motivation*

Davis, T. 2018. *Long drought makes outlook for Tucson's share of CAP water grim*. Arizona Daily Star. This article summaries the U.S. Bureau of Reclamations longer-range outlooks for Lake Mead and the Central Arizona Project (CAP). At the time of the article, they predicted the CAP, which provides drinking water to Tucson and Phoenix, would have over a 50 percent shortage in 2020 and over 60 percent in 2021 through 2023. These shortages would cut CAP deliveries by about 20 percent, and would impact groups such as the Central Arizona farmers, Arizona Water Bank, and Central Arizona Groundwater Replenishment District.

Website: https://tucson.com/news/local/long-drought-makes-outlook-for-tucson-s-share-of-cap/article_a6880ebc-16a5-5468-944f-f2bd167de8e2.html

Demaria, E., P. Hazenberg, R. Scott, M. Meles, M. Nichols, D. Goodrich. 2019. *Intensification of the North American Monsoon Rainfall as Observed From a Long-Term High-Density Gauge Network*. Geophysical Research Letters. This study addresses the challenge of detecting temporal changes in rainfall intensities in response to climatic change due to highly variable and localized nature of rainfall during the North American Monsoon in southwestern United States and northwestern Mexico. The study uses the dense, subdaily, and daily observations from 59 rain gauges located in southeastern Arizona. It was found there was intensification of monsoon subdaily rainfall intensities starting in the mid-1970s that has not been observed in previous studies or simulated with high-resolution climate models. The results highlight the need for long-term, high spatiotemporal observations to detect environmental responses to a changing climate in highly variable environments and show that analyses based on limited observations or gridded data sets fail to capture temporal changes potentially leading to erroneous conclusions.

Website: https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019GL082461

Eden, S., E. Canfield. 2019. *Water Harvesting Resurges in Tucson*. WEF Stormwater Institute – Stormwater Management, Volume 7, Issue 2. Water harvesting has been used in the Tucson, Arizona region since prehistoric times and is now in resurgence. Within the past 30 years, Tucson has become a leader in desert rainwater and stormwater capture to build resilience and address growing concerns about water scarcity. Beginning with grassroots efforts focused on collective impacts of individual and neighborhood actions, a new attitude toward rainfall as a resource is flourishing. Local programs encourage citizen participation and support small-scale, distributed infrastructure, with an emphasis on retrofitting properties and roadways, while a large-scale stormwater harvesting project collects enough water to irrigate a regional sports park.

Website: https://wrrc.arizona.edu/sites/wrrc.arizona.edu/files/attachment/tucson-leads-way.pdf

Environmental Protection Agency (EPA). 2019. *Climate Impacts on Water Quality.* The adaptation strategies provided in this document are intended to inform and assist communities in identifying potential alternatives. They are illustrative and are presented to help communities consider possible ways to address anticipated current and future climate threats to contaminated site management.

Website: *https://www.epa.gov/arc-x/climate-impacts-water-quality*

Ferguson, D., M.Finucane, V.Keener, and G. Owen. 2016. *Evaluation to advance science policy: lessons from Pacific RISA and CLIMAS*. In Climate in Context: Science and Society Partnering for Adaptation, Chapter 10. Chichester, West Sussex: John Wiley & Sons Ltd. This chapter discusses the evaluation activities Pacific Regional Integrated Sciences and Assessments (RISA) and the Climate Assessment for the Southwest (CLIMAS) and providing examples of metrics and methods for evaluating the programs that are implemented in a complex, real-world environment. It argues that to inform science policy across scales, evaluations should be designed so that results are meaningful and legitimate, and, at the same time, also allow for the highly iterative and adaptive nature of the environments in which RISA work is done and utilized. Lessons learned from the evaluation initiatives are also described.

Website: https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118474785.ch10

Finster, M. 2016. *Climate Change and the Wastewater Sector*. Risk and Infrastructure Science Center, Argonne National Laboratory. This presentation, which was based on a research paper from Argonne National Labs, provided an overview of the anticipated impacts of climate change, observed climate trends, anticipated impacts to the wastewater industry and an accounting of potential system vulnerabilities. A case study regarding the impacts of extreme storms (Superstorm Sandy) and its impact on the New Jersey region's wastewater treatment systems were given as an example. The presentation was concluded with a summary of potential adaptation tools and a diatribe on the implications and cost efficiencies of infrastructure planning.

Website: N/A

Frisvold, G. 2017. *A Colorado River Shortage Declaration: Planning, Responses, and Consequences.* Climate Assessment for the Southwest (CLIMAS). Based on interstate and international agreements, a Colorado River shortage declaration would reduce surface water deliveries to primarily to Central Arizona, with nearly all the cuts applied to agriculture, representing a 25%–40% reduction in surface water to the region's farms. The U.S. Bureau of Reclamation provides forecasts of the probability of a shortage declaration based on Lake Mead water levels. Little is known about whether early warning systems are meeting farmers' needs and what a shortage would mean for income, jobs, and groundwater use in rural economies. The study will assess how stakeholder groups currently use Colorado River supply forecasts in decision-making and what contingencies they are making in the event of a shortage declaration, the economic consequences of a shortage declaration on agriculture and the local economies in central Arizona, and potential impacts of a shortage declaration on groundwater pumping and water levels in central Arizona Active Management Areas.

Website: https://climas.arizona.edu/research/colorado-river-shortage-declaration-planning-responses-and-consequences

Frisvold, G. 2019. *Climate Policies as Water Policies, Applied Methods for Agriculture and Natural Resource Management*. Climate Assessment for the Southwest (CLIMAS). This study uses an updated version of the U.S. Agricultural Resource Model (USARM)—a multi-region U.S. agricultural sector programming model—to examine effects of climate change mitigation policies on U.S. water resources. One scenario considers effects of increasing prices of energy and energy-intensive inputs (primarily fertilizers) through a carbon tax or cap-and-trade program. A second scenario combines the first scenario with an agricultural offset program where farmers are paid to retire cropland for carbon sequestration. The consequences of climate mitigation policies for agricultural water use and pollution control have received relatively little attention in part because—unlike USARM—many national agricultural sector models do not explicitly include water as an input. USARM also allows for input substitution among seven inputs in a CES framework, while accounting for all major crops as well most specialty crops, federal commodity programs, and crop exports. Major results are as follows. First, climate mitigation policies have scope to significantly reduce agricultural water use. Whether domestic offsets are included has little effect on the total amount of water conserved, but has a large effect on which parts of the country the conservation takes place. Second, either carbon taxes or cap-and-trade combined with domestic offsets combines two policies often modeled as potential solutions to the hypoxic "dead zone" in the Gulf of Mexico—increased fertilizer prices and land retirement. Climate policies may have unanticipated, near-term, environmental benefits by addressing the hypoxia problem. Third, while domestic offsets reduce total fertilizer and agricultural chemical use, they increase their use per acre. Particularly in watersheds with significant land retirement, there could be unintended intensive margin effects where fertilizer and chemical use are increased. Despite this last, cautionary finding, a key insight into decision makers is that climate policies can have unanticipated, near-term benefits of water pollution control and water conservation that could be included in benefit-cost analyses of climate policy proposals.

Website: https://climas.arizona.edu/publication/book-chapter/climate-policies-water-policies

Garfin, G, S. LeRoy, D. Martin, M. Hammersley, A. Youberg, and R. Quay. 2016. *Managing for Future Risks of Fire, Extreme Precipitation, and Post-fire Flooding. Report to the U.S. Bureau of Reclamation*, from the project Enhancing Water Supply Reliability. Tucson, AZ: Institute of the Environment, University of Arizona. This report summarizes a workshop conducted September 22–23, 2014 in Las Vegas, Nevada to discuss research and management needs related to severe fires and post-fire flooding in the Intermountain West. Workshop participants included scientists, resource managers, and urban planners. The main purpose of this workshop was to further the understanding of the scientific and management decision-making research needs and gaps at the confluence of wildfire, post-fire floods, and extreme precipitation. Participants accomplished this by sharing lessons learned and best practices from case studies, through group discussions identifying research and management needs, and through the suggestions of participants to inform the development of a toolkit of processes and products to inform water and floodplain managers. Research, data, and management needs were identified by workshop participants in areas related to: extreme precipitation, fire ecology, flooding and sediment transport, water supply and reservoir infrastructure, and water quality.

*Website: https://www.researchgate.net/publication/308962175_Garfin_G_S_LeRoy_D_Martin_M_Hammersley_A_Youberg_and_R_Quay_2016_Managing_for_Future_Risks_of_Fire_Extreme_Precipitation_and_Post-fire_Flooding_Report_to_the_US_Bureau_of_Reclamation_from_the_project_*

Garfin, G., A. Comrie, B. Colby, G. Frisvold, J. Weiss. 2012. *Climate Change Analysis for the City of Tucson*. Climate Assessment for the Southwest. This is vulnerability assessment for the City of Tucson and its contractors related to anticipated climate change impacts. Studies are intended to estimate projections of future climate and hydrology of both the Tucson Basin and Colorado River surface water supplies that are part of Tucson Water's water resources portfolio. Researchers will also compile research related to: Tucson energy-water nexus issues, Tucson's urban heat island, risk related to selected diseases, local food security, and projected impacts and risks related to urban ecosystems and ecosystems surrounding the City. CLIMAS researchers and University of Arizona researchers will synthesize this research on vulnerability assessment and adaptation-related economic research pertaining to Tucson and southern Arizona.

Temperature and precipitation projections were made for the City of Tucson for 1950-2099. These include maps of extreme temperature risk; flood risk; and combinations of flood risk and socio-economic status and extreme temperature risk and socio-economic status. The projections and maps aid the City of Tucson Office of Sustainable Development, and the City's Climate Change Committee in anticipating and planning for future risk.

Website: https://climas.arizona.edu/research/climate-change-analysis-city-tucson

Garfin, G., S. LeRoy, and H. Jones. 2017. *Developing an Integrated Heat Health Information System for Long-Term Resilience to Climate and Weather Extremes in the El Paso-Juárez-Las Cruces Region*. Tucson, AZ: Institute of the Environment. This paper summarizes a workshop held in El Paso, Texas, on July 13, 2016. The workshop was conducted as part of the National Integrated Heat Health Information System (NIHHIS) initiative and served as the formal launch of the NIHHIS Southwest regional pilot. Participants included government, practitioner, and academic communities from Mexico and the United States. The purpose was to discuss the intersection of the region's climate and weather with factors affecting public health risks related to extreme heat.

Workshop participants provides a number of recommendations related to heat health resilience, which include:

1. Vulnerability assessment and data synthesis and analysis are key priorities for further actions to improve understanding of extreme heat risks.
2. Medical data is the most needed information. An improved understanding of the relationship between heat parameters and interventions is the biggest hurdle for improving policy
3. Forecast communication and research related to forecast lead time are key action priorities.
4. Communicating to vulnerable populations and increasing trust in organizations that deliver heat health messages should be prioritized.
5. Collaboration and capacity-building planning and process are the highest priorities for enhancing capacity and developing and deploying training on heat health issues, preparedness, and response.

Website: https://repository.library.noaa.gov/view/noaa/13067

Garfin, G., C. Scott, M. Wilder, R. Varady, and R. Merideth. *Metrics for assessing adaptive capacity and water security: Common challenges, diverging contexts, emerging consensus*. Current Opinion in Environmental Sustainability, Volume 21. This paper reviews conceptual framings and empirical findings of the thirteen articles related to the assessment of adaptive capacity and water security remains elusive, due to flaws in guiding concepts, paucity or inadequacy of data, and multiple difficulties in measuring the effectiveness of management prescriptions at scales relevant to decision-making. The paper has three conclusions:

1. A systematic cross-comparisons of metrics, using the same models and indicators, are needed to validate the reliability of evaluation instruments for adaptive capacity and water security.
2. The robustness of metrics to applications across multiple scales of analysis can be enhanced by a 'metrics plus' approach that combines well-designed quantitative metrics with in-depth qualitative methods that provide rich context and local knowledge.
3. Changes in the governance of science–policy can address deficits in public participation, foster knowledge exchange, and encourage the co-development of

adaptive processes and approaches (e.g., risk-based framing) that move beyond development and use of static indicators and metrics.

Website: https://www.sciencedirect.com/science/article/abs/pii/S187734351630077X

Georgakakos, A., P. Fleming, M. Dettinger, et al. 2014. *Climate Change Impacts in the U.S.: The Third National Climate Assessment*. This 20-page booklet provides a high-level compendium of climate change impacts in the United States. The overview covers the most important impacts at the national level, but does not attempt to provide a comprehensive summary of the entire assessment. Numbered references can be found in the Highlights. To supplement this Overview, regional fact sheets are available that offer highlights from each of the eight regions (i.e. northeast, southeast and Caribbean, Midwest, Great Plains, southwest, northwest, Alaska and Hawaii and Pacific Islands).

Website: N/A

Hirschman, D., D. Caraco, S. Drescher. 2011. *Adapting Stormwater Management for Climate Change*. Watershed Sciences Bulletin. This paper focused on the significant variability associated with climate change projections and how that variability plays into stormwater design factors. This study was focused on the South Carolina coastal region and dealt with the projection of future sea level rise, increased storm intensities, drought and a shift in plant communities. Green Infrastructure and Low Impact Development strategies were offered as potential adaptation solutions to stormwater issues.

Website: N/A

Howard, J. 2019. *Megadroughts could return to southwestern U.S*. National Geographic. This article summaries a recent study from Science Advances where scientists understand the causes of the megadroughts common during the medieval period. They also predict more megadroughts in the future with climate change. Their analysis identifies three main factors causing megadroughts in the American Southwest: Cooling water temperatures in the Pacific Ocean, warming water in the Atlantic Ocean, and radiative forcing. It was found that during periods of positive radiative forcing (warming in the American Southwest led to the series of megadroughts during the medieval period.

Website: https://www.nationalgeographic.com/environment/2019/07/megadroughts-could-return-southwestern-us/#close

Hydros Consulting Inc. 2018. *Colorado River Risk Study: Executive Summary.* Submitted to the Colorado River District and Project Partners, August 1, 2018. This paper summarizes the findings of the risk study for the Upper CRB as it relates to water flows to the Lower CRB and Lake Powell. It states that The Colorado River Basin is in the midst of a drought that began in 2000 and continues today. Average naturalized flows at Lee Ferry during this period are approximately 12.6 maf (million acre-feet), or 4.0 maf annually less than would be needed to meet the full compact allotments of the seven basin states and to the Mexican Treaty obligation to Mexico. Recent droughts have significantly reduced storage levels in Lake Powell. If these droughts were to repeat themselves today, the ability of Lake Powell to satisfy its compact-obligation and power-generation purposes would be threatened (Figure 1). Drought Contingency Plans (DCP) are being developed for both the Upper and Lower Basins (See Hydros 2015 report "Summary Report on Contingency Planning in the Colorado River Basin"). While those plans, if implemented, would reduce the risk of a compact deficit or critically low storage levels at Lake Powell, they do not completely eliminate the risk for the Upper Basin States.

Website: *https://waterinfo.org/wp-content/uploads/2018/10/West-Slope-BRT-Risk-Study-Executive-Summary-Phases-I-and-II.pdf*

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B.Averyt, M. Tignor and H. L. Miller (eds.)]. Cambridge University Press, Cambridge,United Kingdom and New York, NY, USA, 996 pp. This Synthesis Report (SYR) distils and integrates the findings of the three Working Group contributions to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), the most comprehensive assessment of climate change undertaken thus far by the IPCC: Climate Change *2013*: The Physical Science Basis; Climate Change *2014*: Impacts, Adaptation, and Vulnerability; and Climate Change *2014*: Mitigation of Climate Change. The SYR also incorporates the findings of two Special Reports on Renewable Energy Sources and Climate Change Mitigation (*2011*) and on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (*2011*).

Jacobs, K., J. Buizer, and S. Moser. 2016. *The Third US National Climate Assessment: Innovations in Science and Engagement*. Climatic Change, 135. This paper discusses lessons learned from the Third US National Climate Assessment (NCA3). The author's intent of discussing lessons leanred is that those sponsoring, designing, and assisting in assessments at the regional, national and international levels can benefit from this experience.

Website: https://link.springer.com/article/10.1007/s10584-016-1621-5

LADPW, USACE, USBR. 2014. *Los Angeles Basin Stormwater Conservation Study – Task 4 Existing Infrastructure Response & Operations Guidelines Analysis*. Reclamation: Managing Water in the West. The purpose of Task 4 was to assess the response of existing infrastructure and analyze the operation guidelines under both the current and future climate conditions. It is important to recognize that this effort relies upon the existing water conservation and flood control network as the baseline condition. This evaluation included a ranking assessment of the current and future stormwater volumes conserved or discharged, and impacts to the water conservation and flood control system. Six climate scenarios were chosen from a broad range of 47 initial scenarios. From this scenarios various runoff scenarios were created to test infrastructure response and operations.

Website: https://www.usbr.gov/lc/socal/basinstudies/LABasinStudyFinalTask4Report.pdf

Lin, C.-Y., W.-C. Chen, S. C. Liu, Y. A. Liou, G. R. Liu, and T. H. Lin (2008), *Numerical study of the impact of urbanization on the precipitation over Taiwan*, Atmos. Environ.,42, 2934–2947, doi:10.1016/j.atmosenv.2007.12.054. This landmark

study regarding the impact of urbanization on precipitation was found to have significant correlations to the City of Tucson's evolving precipitation regime. It states that a highly developed industry and a large population density have turned the western plain of Taiwan into a mega-suburb with many cities and small towns and countless factories, and roads. As a result, the western plain is experiencing a regional heat-island effect. The MM5 mesoscale model was conducted in order to study and evaluate the impacts of the heat-island effect on regional weather, including thunderstorms, over Taiwan. According to land use data provided by the US Geological Survey (USGS), we assumed three different urban sizes in the simulation study to theoretically evaluate the impact of urbanization on the precipitation.

Website: *https://www.sciencedirect.com/science/article/abs/pii/S1352231007011995*

Meadow, A., Z. Guido, M. Crimmins, and J. Mcleod. 2016. *From principles to action: Applying the National Research Council's Principles for Effective Decision Support to the Federal Emergency Management Agency's Watch Office*. Climate Services, Volume 1. This paper discusses application of the National Research Council (NRC) proposed six principles for effective decision support via a collaborative project between the Federal Emergency Management Agency Region R9 (FEMA R9), the Western Region Headquarters of the National Weather Service (WR-NWS), and the Climate Assessment of the Southwest (CLIMAS). The goal of the project was to provide FEMA R9's Watch Office with climate information scaled to their temporal and spatial interests to aid them in assessing the potential risk of flood disasters. It was found that specific strategies and activities were needed in order to apply the principles effectively. By using a set of established collaborative research approaches, FEMA R9's information needs and WR-NWS's capacity to meet those needs were easier to assess. Barriers were encountered to transitioning the decision support tool from research to operations. This paper describes the methods for planning and executing a three-party collaborative effort to provide climate services, the decision support tool developed through this process, and the lessons that will be applied to future work and implications of the NRC principles for the broader field of climate services.

Website: https://www.sciencedirect.com/science/article/pii/S240588071530008X

Meixner, et al. 2016. *Implications of projected climate change for groundwater recharge in the western United States.* Journal of Hydrology 534 (2016) 124-138. This study notes that existing studies on the impacts of climate change on groundwater recharge are either global or basin/ location-specific. The global studies lack the specificity to inform decision making, while the local studies do little to clarify potential changes over large regions (major river basins, states, or groups of states), a scale often important in the development of water policy. An analysis of the potential impact of climate change on groundwater recharge across the western United States (west of 100° longitude) is presented synthesizing existing studies and applying current knowledge of recharge processes and amounts. Eight representative aquifers located across the region were evaluated. For each aquifer published recharge budget components were converted into four standard recharge mechanisms: diffuse, focused, irrigation, and mountain-systems recharge. Future changes in individual recharge mechanisms and total recharge were then estimated for each aquifer

Website: https://www.sciencedirect.com/science/article/pii/S0022169415009750

National Climate Assessment (NCA). 2018. *Fourth National Climate Assessment (AR4: Chapter 25 Southwest.* U.S. Global Change Research Program, Washington D.C. This, the fourth installment of the NCA, unequivocally states that long-term temperature observations are among the most consistent and widespread evidence of a warming planet. Global annually averaged temperature measured over both land and oceans has increased by about 1.8°F (1.0°C) according to a linear trend from 1901 to 2016, and by 1.2°F (0.65°C) for the period 1986–2015 as compared to 1901–1960. The last few years have also seen record-breaking, climate-related weather extremes. For example, since the Third National Climate Assessment was published,[1] 2014 became the warmest year on record globally; 2015 surpassed 2014 by a wide margin; and 2016 surpassed 2015. Sixteen of the last 17 years have been the warmest ever recorded by human observations.

For short periods of time, from a few years to a decade or so, the increase in global temperature can be temporarily slowed or even reversed by natural variability (see Box 2.1). Over the past decade, such a slowdown led to numerous assertions that global warming had stopped. No temperature records, however, show that long-term global warming has ceased or even substantially slowed over the past decade. Instead, global annual average temperatures for the period since 1986 are likely much higher and appear to have risen at a more rapid rate than for any similar climatological (20–30 year) time period in at least the last 1,700 years.

Website: https://nca2018.globalchange.gov/chapter/25/

National Oceanic and Atmospheric Administration. 2019. *U.S. Climate Resilience Toolkit: Water Utility Plans for Climate Uncertainty*. Determining which of your group's assets are most likely to be damaged or degraded by a climate threat can help your group decide where to start. One consideration in the decision is how close each asset may be to a tipping point—a point when incremental change in a system results in a new, irreversible response. Some people refer to tipping points as critical thresholds.

Look back to the potential or historical consequences you identified for each asset-hazard pair. In some cases, the consequence you described might be considered a tipping point. Looming tipping points aren't the only factor groups need to consider when deciding which assets to protect, but the potential for a large change in the system can elevate the level of concern for those assets.

Website: https://toolkit.climate.gov/case-studies/water-utility-plans-climate-uncertainty

O'Neill, J. A. 2010. *Climate Change's Impact on the Design of Water, Wastewater, and Stormwater Infrastructure*. This study briefly outlines actual climatic changes that have occurred and recently published predicted changes. It looks at the impacts these changes will have on water, wastewater, and stormwater infrastructure and provides recommendations to assist engineers and owners who are working to address these impacts. In addition, cautions are provided relating to evaluating and using current climate data, models, and studies for planning and design purposes. While societal and socioeconomic factors also impact the design of water, wastewater, and stormwater

infrastructure, this study only summarily covers those impacts associated with climate change.

Website: *http://hydrologydays.colostate.edu/Papers_2010/ONeill_paper.pdf*

Ortiz-Bobea, A., H. Wang, C.M. Carrillo, T.R. Ault. 2019. *Unpacking the climatic drivers of US agricultural yields*. Environmental Research Letters, Volume 14. This study links land surface model data and fine-scale weather information with a long panel of county-level yields for six major US crops (1981–2017) to understand their historical and future climatic drivers. A statistical approach was developed that flexibly characterizes the distinct intra-seasonal yield sensitivities to high-frequency fluctuations of soil moisture and temperature. Results suggest there is an important role of water stress in explaining historical yields. However, the models project the direct effect of temperature (interpreted as heat stress) remains the primary climatic driver of future yields under climate change.

Website: *https://iopscience.iop.org/article/10.1088/1748-9326/ab1e75*

Parris, A., G. Garfin, K. Dow, R. Meyer, and S. Close. 2016. *Climate in Context: Science and Society Partnering for Adaptation*. Chichester, West Sussex: John Wiley & Sons Ltd. This textbook describes what it takes to help scientists and stakeholders work together to "co-produce" climate science knowledge, policy, and action. This state-of-the-art synthesis reflects on lessons learned by RISA programs and provides a sober assessment of the challenges ahead. Through case studies from various US regions, this book provides lessons and guidance for organizations and individuals who want to work at the science-society interface on a range of climate challenges.

Website: *https://www.eastwestcenter.org/node/35728*

Pirnie, M. 2013. *Recycled Water Master Place, Volume I: Master Plan*. Tucson Water. The overall purpose of the Recycled Water Master Plan is to provide an integrated recycled water program that maximizes the benefits of the City's recycled water resource. This document provides information to City of Tucson decision makers, Tucson Water customers, and other stakeholders on the planned use of the City's recycled water both in its Reclaimed Water System (RWS) and through other means. In addition, the Recycled Water Master Plan provides a framework for next steps and continued activities that will help ensure the timely implementation of the necessary recycled water projects and programs. These in turn will help achieve Tucson Water's objectives, ensure the long-term sustainability of the Utility's water resources, and enable it to keep its commitment to "Water Reliability" for its customers.

Website:
https://www.tucsonaz.gov/files/water/docs/Volume_I_Recycled_Water_Master_Plan.pdf

Pouget L., B. Russo, I. Escaler, Á. Redaño, J. Ribalaygua, H. Theias. *CETaqua Water Technology Center*. Dept. of Astronomy and Meteorology, University of Barcelona. This paper presents a study on the impacts of climate change on extreme rainfall events for the city of Barcelona and describes how results were use to perform a flood risk assessment. In a first step, a statistical downscaling method was used to generate future rainfall time series at a daily time step. This analogue based downscaling method used the results of five Global Climate Models (GCMs) to produce time series corrected for extremes events at six raingauge stations of the urban area. In a second step, these data were used to create new Intensity Duration-Frequency (IDF) curves. A method based on fractal properties of rainfall was applied to downscale the future rainfall intensity from daily to hourly information. In a last step, current and future IDF curves were compared and design storm uplift factors were calculated for all the scenarios considered.

Website: N/A

Star, J., E. Rowland, M. Black, C. Enquist, G. Garfin, C. Hoffman, H. Hartmann, K. Jacobs, R. Moss, A. Waple. 2016. *Supporting adaptation decisions through scenario planning: Enabling the effective use of multiple methods*. Climate Risk Management, Volume 13. Supporting adaptation decisions through scenario planning: Enabling the effective use of multiple methods. This paper describes applications that combine previously distinct scenario methods in new and innovative ways. It draws on numerous recent independent case studies to illustrate emerging practices, such as far stronger connections between researcher-driven and participatory approaches and cycling between exploratory and normative perspectives. The paper concludes with a call for greater support for, and collaboration among, practitioners with the argument that mixed methods are most effective for decision-making in the context of climate change challenges.

Website: https://www.sciencedirect.com/science/article/pii/S2212096316300262

Steiger, N.J., J.E. Smerdon, B.I. Cook, R. Seager, A. Park Williams, E.R. Cook. 2019. *Oceanic and radiative forcing of medieval megadroughts in the American Southwest.* Science Advances, Volume 5. This study uses Paleo Hydrodynamics Data Assimilation product, in conjunction with radiative forcing estimates, to demonstrate that megadroughts in the American Southwest were driven by unusually frequent and cold central tropical Pacific sea surface temperature (SST) excursions in conjunction with anomalously warm Atlantic SSTs and a locally positive radiative forcing. This assessment of past megadroughts provides the first comprehensive theory for the causes of megadroughts and their clustering particularly during the Medieval era. This work also provides the first paleoclimatic support for the prediction that the risk of American Southwest megadroughts will markedly increase with global warming.

Website: https://advances.sciencemag.org/content/5/7/eaax0087

Udall, B. and J. Overpeck. 2017. *The twenty-first century Colorado River hot drought and implications for the future*. Water Resouces Research. This paper reviews annual Colorado River flows between 2000 and 2014. These flows averaged 19% below the 1906–1999 average, the worst 15-year drought on record. On average, at least one-third of this loss is due to unprecedented temperatures (0.9°C above the 1906–1999 average), confirming model-based analysis that continued warming will likely further reduce flows. There has been no observed trend toward greater precipitation in the Colorado Basin, nor are climate models in agreement that there should be a trend. Additionally, there is a significant risk of decadal and multi-decadal drought in the coming century, indicating that any increase in mean precipitation will likely be offset during periods of prolonged drought. Recently published estimates of Colorado River flow sensitivity to temperature, combined with a large number of recent climate model-based temperature projections, indicate that continued business-as-usual warming will drive temperature-induced declines in river flow, conservatively −20% by midcentury and −35% by end-century, with support for losses exceeding −30% at midcentury and −55% at end-century. Precipitation increases may moderate these declines somewhat, but to date no such increases are evident and there is no model agreement on future precipitation changes. These results, combined with the increasing likelihood of prolonged drought in the river basin. This suggests that future climate change impacts on the Colorado River flows will be much more serious than currently assumed, especially if substantial reductions in greenhouse gas emissions do not occur.

Website: *https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016WR019638*

United States Bureau of Reclamation (USBR), 2012. *Colorado River Basin Water Supply and Demand Study - Technical Report A-Scenario Development. 18 pages.* The Colorado River Basin Water Supply and Demand Study (Study), initiated in January 2010, was conducted by the Bureau of Reclamation's (Reclamation) Upper Colorado and Lower Colorado regions, and agencies representing the seven Colorado River Basin States (Basin States) in collaboration with stakeholders throughout the Colorado River Basin (Basin). The purpose of the Study is to define current and future imbalances in water supply and demand in the Basin and the adjacent areas of the Basin States that receive Colorado River water over the next 50 years (through 2060), and to develop and analyze adaptation and mitigation strategies to resolve those imbalances. The Study contains for major phases to accomplish this goal: Water Supply Assessment, Water Demand Assessment, System Reliability Analysis, and Development and Evaluation of Options and Strategies for Balancing Supply and Demand.

Website:
http://www.riversimulator.org/Resources/USBR/BasinStudy/Final/03TechnicalAReportScenarioDevelopment.pdf

United States Bureau of Reclamation (USBR). 2016. *2016 SECURE Water Act Report - Colorado River Basin Fact Sheet.* This document summarizes the findings of the 2016 SECURE Water Act Report at is relates to new findings since the 2012 Colorado River Basin Water Supply and Demand Study. This fact sheet provided guidance for future changes in climate and hydrology of the CRB, as well as findings regarding future impacts for water and environmental resources in the CRB. This document is the synthesis of a much large report, but provided the necessary concentration of overarching findings regarding climate change and the CRB.

Website:
https://www.usbr.gov/climate/secure/docs/2016secure/factsheet/ColoradoRiverBasinFactSheet.pdf

United States Bureau of Reclamation (USBR), 2019. *Climate and Surface Water Analysis Summary - Lower Santa Cruz River Study.* Presentation by Lindsay Bearup, November 21, 2019 - Preliminary findings. This online presentation provided insight into the preliminary findings of the climate and surface water analysis performed as part of the Lower Santa Cruz River Basin study by the USBR. It includes the understanding of a best case scenario for the basin where relatively minimal change in

seasonal precipitation occurs, but in the worst case scenario, total precipitation decreases in the monsoon and winter wet seasons. Precipitation becomes increasingly variable. it provides rather detailed information regarding the expected increase in the number of no-flow days on 28 of the local/regional streams and rivers.

Website: *https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/20191121climate.pdf*

U.S. EPA Climate Adaptation Working Group. 2013. Water and Wastewater Utility Climate Change Mitigation and Adaptation Efforts in EPA Region 3 – Climate Adaptation Implementation Plan. Washington D.C. In February 2013, the EPA released its draft Climate Change Adaptation Plan to the public for review and comment. This plan relies on peer-reviewed scientific information and expert judgment to identify vulnerabilities to EPA's mission and goals from climate change. The plan also presents 10 priority actions that EPA will take to ensure that its programs, policies, rules, and operations will remain effective under future climatic conditions. The priority placed on mainstreaming climate adaptation within EPA complements efforts to encourage and mainstream adaptation planning across the entire federal government.

This report, specific to California and the rest of EPA Region 9, listed the following criteria for these, aforementioned priority actions:

- Does the action target one of the most severe and immediate vulnerabilities?
- Does the action focus on one of the most vulnerable populations and/or geographic areas?
- Does EPA Region 9 have the capacity (personnel and funding resources) and ability (knowledge, skills, and authority) to take the action and contribute to a solution?
- Is this a priority action for our partners (federal/state/territory/tribal/local government and nongovernment) and are they able to work with us towards a solution?
- Does the action support and align with other EPA Region 9 priorities and actions?

This paper is a guidebook or "how to" primer for addressing the impacts of climate change and does not delve into the technical analysis of impacts or adaptations.

Website: *https://www.epa.gov/sites/production/files/2016-04/documents/final_2013_nwp_climate_highlights_report_print_file.pdf*

University of Arizona, Tucson. 2015. S*cenario Planning for Climate Change Adaptation Decision Making: The State of the Art Workshop Report*. Center for Climate Adaptation Science and Solutions. This report summarizes the activities and outcomes of the March 31-April 1, 2015 workshop, "Scenario Planning for Climate Change Adaptation Decision Making: The State of the Art" at the University of Arizona. This workshop was focused on understanding alternative approaches to scenario planning, lessons learned in using them, and ways of extending and combining the approaches that are currently in use.

Decision-makers and managers are increasingly being asked to make decisions in the context of uncertainty, with climate change adding new sources of complexity. We've observed that scenario planning is being used as means of providing managers with insights into options for responding appropriately to change in the near and long term. The increasing use of scenario planning prompts some questions, such as:

- What is the state-of-the-art in scenario development?
- How can uncertainty within scenarios be communicated effectively to stakeholders and what types of scenarios are appropriate and beneficial to pursue in a given context?
- In using scenario planning methods: What works where, when, and why?
- How can the effectiveness and utility of scenario planning processes be enhanced?

The workshop explored lessons learned in applications of specific scenario planning techniques as well as connections between the different methods that have emerged, with respect to how they frame uncertainty and how they function in a decision support context. We also discussed several alternative science-based approaches and modes of engaging stakeholders in scenario planning, while promoting scholarly work to assess the state of the art.

Website: https://www.ccass.arizona.edu/sites/default/files/Scenario%20Planning%20Workshop%20Report.pdf

University Corporation for Atmospheric Research. (UCAR). 2011. *Urban Heat Islands.* Boulder, CO. This webpage provides a brief overview of heat islands and how they are related to global warming. An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surroundings. They are formed when vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. Temperatures are therefore increased due to the new surfaces absorbing heat and displacing the natural cooling effects of vegetation. Although heat islands explain more local-scale temperature increase, they may contribute to larger-scale global warming by increasing demand for air conditioning, which results in additional power plant emissions of heat-trapping greenhouse gases.

Website: https://scied.ucar.edu/longcontent/urban-heat-islands

US Department of Agriculture - Agricultural Research Service. 2019. *Monsoon rains have become more intense in the southwest in recent decades*. ScienceDaily. This article provides a high level summary on how monsoon rains have become more intense in the southwest in recent decades, according to a study recently published by Agricultural Research Service scientists.

Website: https://www.sciencedaily.com/releases/2019/07/190723110528.htm

Vano, et al. 2014. *Understanding Uncertainties in Future Colorado River Streamflow.* Journal of Meteorology - American Meteorological Society. Bulletin of the AMS, January 2014. This syntheses report is a study of CRB streamflow projections that examines methodological and model differences and their implications for water management in the basin. It identifies the Colorado River is the primary water source for more than 30 million people in seven rapidly growing, mostly arid American states and Mexico. And, further states that the Colorado River water supply system, which consists

of two large reservoirs (Lakes Mead and Powell) and numerous smaller reservoirs, is already stressed because of growing water demand and an ongoing drought that is outside the historical norm of twentieth-century climate variability. Concerns have been voiced that this recent prolonged drought could be a harbinger of a permanent shift to a drier climate.

Website: *https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-12-00228.1?version=meter+at+null&module=meter-Links&pgtype=article&contentId=&mediaId=&referrer=&priority=true&action=click&contentCollection=meter-links-click*

Vose, R.S., D.R. Easterling, K.E. Kunkel, A.N. LeGrande, M.F. Wehner. 2017. ***Temperature changes in the United States*****. Climate Science Special Report: Fourth National Climate Assessment, Volume I**. The Climate Science Special Report (CSSR) is designed to be an authoritative assessment of the science of climate change, with a focus on the United States, to serve as the foundation for efforts to assess climate-related risks and inform decision-making about responses. In accordance with this purpose, it does not include an assessment of literature on climate change mitigation, adaptation, economic valuation, or societal responses, nor does it include policy recommendations.

As Volume I of NCA4, CSSR serves several purposes, including providing 1) an updated detailed analysis of the findings of how climate change is affecting weather and climate across the United States; 2) an executive summary and other CSSR materials that provide the basis for the discussion of climate science found in the second volume of the NCA4; and 3) foundational information and projections for climate change, including extremes, to improve “end-to-end” consistency in sectoral, regional, and resilience analyses within the second volume. CSSR integrates and evaluates the findings on climate science and discusses the uncertainties associated with these findings. It analyzes current trends in climate change, both human-induced and natural, and projects major trends to the end of this century. As an assessment and analysis of the science, this report provides important input to the development of other parts of NCA4, and their primary focus on the human welfare, societal, economic, and environmental elements of climate change.

Website: https://science2017.globalchange.gov/chapter/6/

Wall, T., A. Meadow, and A. Horangic. 2017. ***Developing Evaluation Indicators to Improve the Process of Coproducing Usable Climate Science*****. Weather, Climate, and Society, Volume 9**. This paper combined information three sources to develop an evaluative framework that consists of 45 indicators grouped into context; process; and output, outcome, and impact indicators. These sources include:

1. Identifying the key principles in coproducing knowledge from the existing literature
2. Examined how usable climate research is currently evaluated by federal agencies.
3. Interviewed experienced climate science integrators. Interviews focused on which activities, actions, and conditions they believe most influence the process and outcomes of knowledge coproduction.

The indicators were then tested using two case studies. Results of the tests helped identify lessons about the process of evaluating the coproduction of knowledge and collaboratively producing climate knowledge.

Website: *https://journals.ametsoc.org/doi/pdf/10.1175/WCAS-D-16-0008.1*

Wilder, M., D. Liverman, L. Bellante, and T. Osborne. *Southwest climate gap: poverty and environmental justice in the US Southwest.* Local Environment, Volume 21. This paper examines the climate and poverty relationship in the Southwest US (Arizona and New Mexico). This was completed using multi-scaled analysis across three indicators of climate vulnerability, focusing on connections to health, food, and energy during the period of 2010 to 2012. A significant Southwest climate gap was identified based on census data and interview findings about climate vulnerability, especially relating to high levels of poverty, health disparities, and increasing costs for energy, water, and food. It was found that grassroots and community organizations have mobilized to respond to climate and social vulnerability, yet resources for mitigation and adaptation are insufficient given the high level of need. The author's recommend that more research is needed to understand the social and spatial characteristics of climate risk and how low-income populations embody and experience climate risk and adapt to a changing climate.

Website: *https://www.tandfonline.com/doi/full/10.1080/13549839.2015.1116063?scroll=top&needAccess=true*

Woodhouse, C.A., D.M. Meko, C.A. Baisan, T. Knight, J.J. Lukas, M.K. Hughes, M.W. Salzer. 2007. *Medieval Drought in the Upper Colorado River Basin.* Geophysical Research Letters 34, L10705. New tree-ring records of ring-width from remnant preserved wood are analyzed to extend the record of reconstructed annual flows of the Colorado River at Lee Ferry into the Medieval Climate Anomaly, when epic droughts are hypothesized from other paleoclimatic evidence to have affected various parts of western North America. The most extreme low-frequency feature of the new reconstruction, covering A.D. 762-2005, is a hydrologic drought in the mid-1100s. The drought is characterized by a decrease of more than 15% in mean annual flow averaged over 25 years, and by the absence of high annual flows over a longer period of about six decades. The drought is consistent in timing with dry conditions inferred from tree-ring data in the Great Basin and Colorado Plateau, but regional differences in intensity emphasize the importance of basin-specific paleoclimatic data in quantifying likely effects of drought on water supply.

Website: *https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2007GL029988*

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Appendix B

ONE WATER 2100 GREENHOUSE GAS EMISSIONS INVENTORY

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
GREENHOUSE GAS INVENTORY

FINAL | SEPTEMBER 2021

TUCSON WATER
A proud part of the City of Tucson
One Water 2100 Master Plan

HDR

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1 Introduction

1.1 Purpose of Memo

This Greenhouse Gas (GHG) Inventory Technical Memo provides an inventory of Tucson Water (TW) GHG emissions for 2018, an overview of previous GHG inventories, and a trend analysis comparing the GHG inventories for TW from prior years to 2018. The Inventory Management Plan (IMP) includes a summary of data sources, emission factors, and detailed assumptions. These efforts play a crucial role in the upcoming City of Tucson (City) Climate Action and Adaptation Plan by establishing a more detailed GHG emission benchmark for TW to use to guide its efforts to support the City's goal of becoming carbon neutral by the year 2030 (City of Tucson 2020, Resolution No. 23222).

This is the first inventory to fully disaggregate accounting of TW GHG emissions by scope as defined by the World Resource Institute (WRI) in their GHG protocol (WRI 2004, 2011). The WRI definitions and methods are referenced as the basis for the ICLEI (International Council for Local Environmental Initiatives) Government Operations Protocol for GHG Accounting (ICLEI 2010). ICLEI is known by their acronym and is a global organization active in over 100 countries and working with more than 2500 local and regional governments. The ICLEI Protocol utilizes the WRI Protocol as a foundation and constructs a tailored methodology for use by local governments. This ICLEI Protocol is the international best practice in GHG emissions quantification for cities and was applied by HDR to perform this TW GHG inventory for 2018. Prior City GHG inventories were conducted by the Pima County Association of Governments (PAG) using ICLEI methods and provided limited reporting of TW's emissions by category or scope.

This GHG inventory will establish a baseline for TW's plan to contribute future utility emissions reductions to meet the City's carbon neutral goals. An additional purpose of this GHG inventory is to begin to develop the capacity to report GHG emissions as a City, annually.

The 2018 GHG inventory was developed in collaboration with TW representatives, with technical assistance provided by HDR. The IMP is included (Appendix A) to provide a framework for future TW GHG inventories.

1.2 Background on Tucson Water Supply

TW has delivered water to city of Tucson residents as a municipally owned and operated water utility since 1901. Until 1992, groundwater was the primary source of potable water supplied to customers. In 1992 TW initiated receipt of water diverted from the Colorado River via the Central Arizona Project (CAP). In 2001, rather than delivering CAP water direct to customer taps, the utility began to use CAP water to recharge the regional groundwater table via the Southern and Central Avra Valley Storage and Recovery Projects (named the Clearwater Program). The majority of potable water delivered to customers is now Colorado River water delivered via the CAP, as shown below in Figure 1-1 (TW 2004, 2008, 2012).

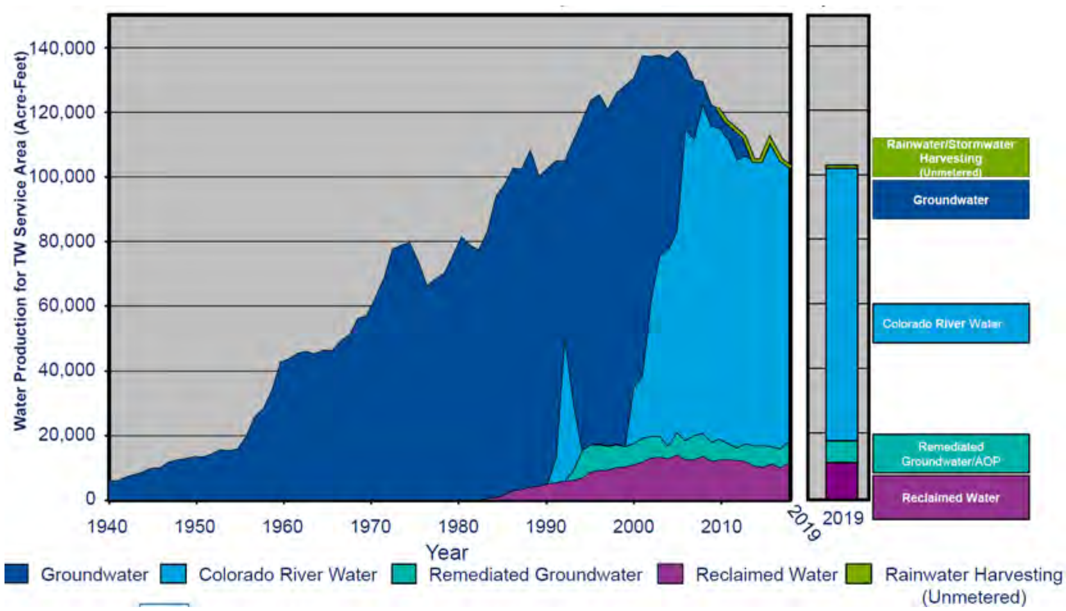

Figure 1-1. Tucson Water Production History for 1940–2019 (Source: TW 2021).

TW began receiving a partial allotment of water from CAP in 1992. Initially the CAP water was treated and then added to the distribution system, but that created issues in the service lines. Tucson Water began their recharge and recovery process in the early 2000s to avoid this problem. As the volume of recovered CAP water increased, energy use increased to move that water. The transition to CAP water as the primary potable water source in the service areas enables TW to keep as much water in the ground as possible to recharge the regional groundwater table.

TW also recycles non-potable water from reclaimed sources to use for irrigation, dust control, firefighting, industrial uses, and supporting wildlife habitat. When demand for reclaimed water is low, this water is recharged at the Sweetwater Recharge Facility, the Santa Cruz River Heritage Project, and the South Houghton Area Recharge Project.

2 2018 GHG Inventory

The 2018 (calendar year) TW GHG inventory estimates emissions using the *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* (ICLEI 2010), which is based upon definitions and methods in the WRI GHG Gas Protocol. This ICELI Protocol is an accepted international standard used to quantify and report GHG emissions from local governments. This inventory will enable TW to contribute their 2018 emissions to a City GHG inventory conducted in accordance with these internationally recognized GHG accounting and reporting principles.

In summarizing these emissions, efforts were taken to apply the WRI-defined principles of GHG accounting (2004), relevance, completeness, consistency, transparency, and accuracy. Emissions sources are described below, and in more detail in the IMP provided in Appendix A.

2.1 2018 TW Emissions by Scope

Calendar Year (CY) 2018 TW emissions of GHGs by source are provided in Figure 2-2. Table 2-1 categorizes source emissions by scope. For the definition of Scopes, the ICLEI protocol refers to the WRI *Greenhouse Gas Protocol Corporate Accounting and Reporting Standard* (2004). Identifying emissions by scope helps organizations understand which emissions they have the most control over to reduce.

Categorizing GHG emissions by scope provides detail on which emissions are direct emissions from the utility (Scope 1) or indirect emissions associated with utility operations but not under operational control of TW (Scope 2 and 3). A visualization of emissions scopes is provided below in Figure 2-1. TW emits Scope 1 emissions from their own activities, such as operation of utility-owned equipment, while Scope 2 and 3, indirect emissions, are either the emissions associated with TW purchased electricity (Scope 2), or other emissions from activities of external organizations such as energy used to deliver Colorado River water through the CAP system (Scope 3). Quantifying Scope 1 and 2 emissions helps TW understand what emissions they have control over to meet their emissions reduction goals.

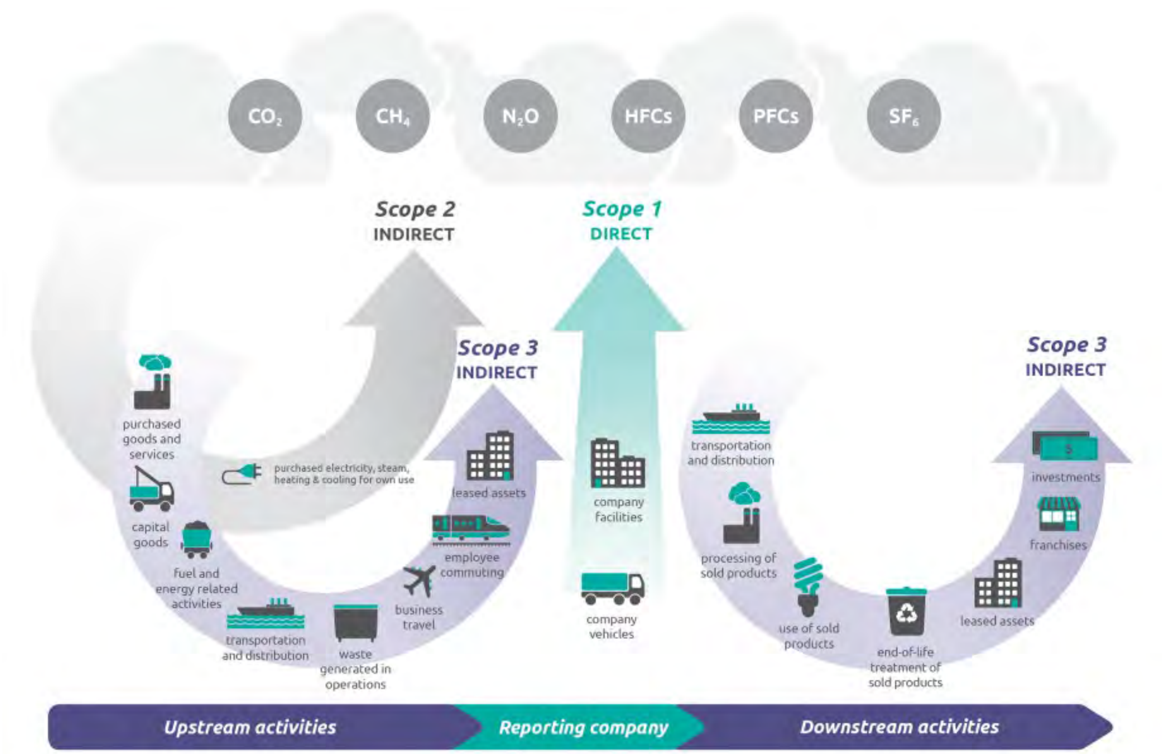

Figure 2-1. Scopes of GHG Emissions as Defined in the WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard (Source: WRI 2011)

While ICLEI encourages local governments to identify and measure Scope 3 sources to the extent possible, many of these emissions categories are optional, and only employee commute emissions are required following the ICLEI Reporting Standard (the ICLEI protocol details how local governments can report their emissions in Part IV and Appendix C of the protocol). Given the limited requirements to Scope 3 reporting, local governments are encouraged to focus on Scope 3 emissions that are relevant to their GHG programs and goals. Further details on scopes, emissions sources, and categories detailed in Table 2-1 are provided in the IMP (Appendix A).

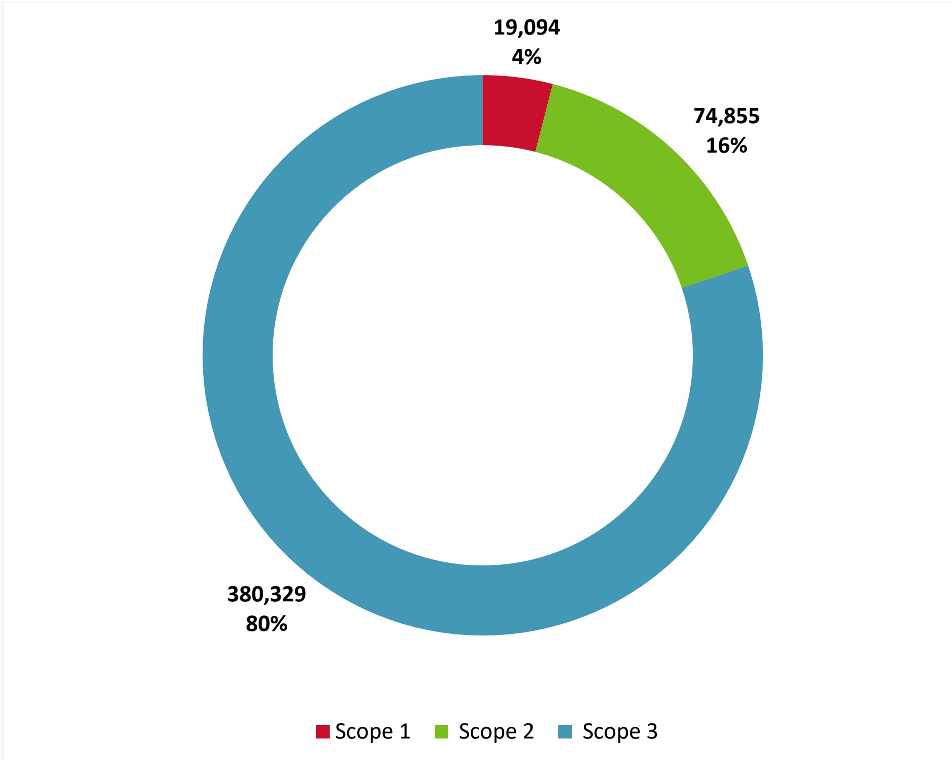

Figure 2-2. TW Emissions by Scope (MT CO_2e), 2018.

Emissions sources for each of the scopes are visualized in Figure 2-3 and quantified in Table 2-1. The following emissions sources were identified for this inventory:

Natural Gas (Scope 1)

- Emissions from natural gas provided by Southwest Gas (SWG) that is used by pumps, furnaces at TW offices, and equipment to extract, convey, treat, and deliver potable or reclaimed water.

Vehicle Fleet (Scope 1)

- Emissions from fuel used in TW-owned on-road and off-road vehicles and equipment.

Refrigerants (Scope 1)

- Emissions from replaced refrigerants that leaked from TW equipment (replaced fleet refrigerants not included).

TW Grid Supplied Electricity (Scope 2)

- Although TW uses some self-generated renewable (solar) electricity (0.5 percent of total electricity use) and purchases hydropower from Hoover Dam through the Arizona Power Authority (APA) (1.5 percent of total electricity use), the majority of the electricity used to deliver water is provided by Tucson Electric Power (TEP) and Trico Electric Cooperative (Trico), which comes from diversified non-renewable and renewable generation sources. In addition to this, a limited amount of hydroelectric power each year is provided to TW by the Bureau of Indian Affairs – San Carlos Irrigation Project to serve a remote site with a metered well and booster pump. Note the WAPA Hoover Dam power is delivered on Trico infrastructure and is accounted for as carbon-free in the emissions figure below (Figure 2-3).

CAP Grid Supplied Electricity (Scope 3)

- CAP operates a series of pump stations that deliver the City of Tucson allotment of Colorado River water to TW; although CAP owns and operates the pump stations that deliver the allotment, the utility tracks the emissions from electricity use associated with their operation.

Transmission and Distribution Loss (Scope 3)

- Emissions from the grid losses of TW purchased power.

TW Waste (Scope 3)

- Emissions associated with the generation of TW waste and recycling.

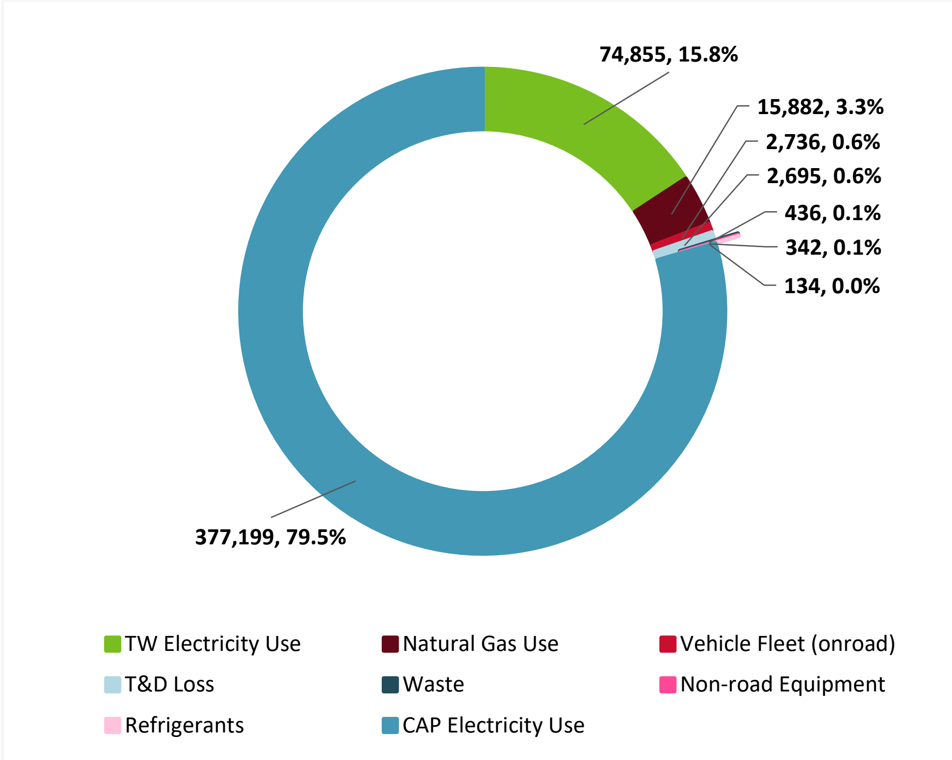

Figure 2-3. TW Emissions by Source (MT CO_2e), 2018.

Two emissions sources outside of the boundary of previous inventories completed by PAG for TW, fugitive emissions from refrigerants and transmission/distribution losses associated with TW consumed electricity, are also identified in Figure 2-3.

Table 2-1. 2018 TW GHG Emissions by Source and Scope.

Emissions Source	ICLEI Emissions Category	2018 Emissions (MT CO_2e)
Scope 1		
Natural Gas Use	Stationary Combustion	15,882
Vehicle Fleet (on-road)	Mobile Combustion	2,736
Vehicle Fleet (off-road)	Mobile Combustion	342
Refrigerants	Fugitive Emissions	139
Total Scope 1 Emissions		**19,100**
Scope 2		
TW Electricity Use	Purchased Electricity	74,855
Total Scope 2 Emissions		**74,855**

Emissions Source	ICLEI Emissions Category	2018 Emissions ($MT\ CO_2e$)
Scope 3[a]		
CAP Electricity Use to Transport Water to TW	Upstream Transportation of Materials and Fuels	377,199
Transmission and Distribution Losses from Consumed Electricity (AZ)	Transmission and Distribution Losses from Consumed Electricity	2,695
TW Waste	Waste Related Scope 3	436
Total Scope 3 Emissions		**380,329**
Subtotal		**474,278**

a) Employee commute is a recommended category of Scope 3 GHG emissions to include per the ICLEI (2010) protocol. TW employee commute data could not be disaggregated from the City commute survey, so it is not reported.

As shown above in Figure 2-3, the majority (80 percent) of TW 2018 emissions are Scope 3 emissions from the upstream electricity use associated with CAP (TW's water supply), while the remaining 20 percent are emissions from electricity and natural gas use, refrigerants, and the vehicle fleet.

2.2 Comparative Review of Select Capital Goods (Scope 3)

TW requested a comparative review of the relative climate impacts of select purchased capital goods within the TW supply chain. Chemicals and pipes, two major types of capital goods important to operation of a water supply agency, were the focus of this analysis. This comparative review is intended to help inform TW of the implications of their existing choices of materials purchases and could inform future purchasing decisions.

Given this review is comparative by material type, the GHG emissions associated with the 2018 purchase of pipes and chemicals were not calculated for the 2018 inventory. In a typical inventory, the GHG associated with capital goods would be based on the dollar spend annually for each category and calculated using WRI methods with relevant industry average GHG emission factors (i.e. emissions per dollar spent). WRI's recommended standard method is to use an Extended Input-Output (EEIO) model.

Life Cycle Assessment for Purchased and Capital Goods

This analysis relies upon a different calculational approach than is used in standard practice for a GHG inventory. For this comparison, Life Cycle Analysis (LCA) was used. LCA is an ISO 14040 normalized method for the assessment of products and systems from cradle-to-grave, which begins with raw materials extracted from the earth, and continues with product development, manufacturing, and disposal. LCA allows comparison between different materials or processes providing the same service or function.

The resulting metric is intended for use to understand the relative merits of alternative material types for pipes and for chemicals purchased by TW. This comparison is to represent the GHG or climate impact (using either embedded energy or embedded carbon) of alternative materials. As expected, embodied carbon can vary widely by electricity and fuel used during the life cycle. The embodied energy represents the energy consumed regardless of the source or carbon content. LCA includes:

- Cradle-to-Gate: Raw material production and transportation; pipe or chemical production
- Pipe or chemical transportation and installation
- Pipe or chemical use phase (including maintenance, repair and replacement)
- Pipe or chemical end-of-life phase
- Cradle-to-Grave in an LCA includes all of the above

HDR prepared a relative comparison of the life cycle attributes representing GHG as associated with each of chemicals and types of pipes based upon CY 2018 data for TW purchases. Data collected by TW for water supply pipe (by type, diameter size and total linear feet) and chemicals purchases for CY 2018 are summarized in the IMP in Appendix A, Section 7.4. The predominant types of pipe purchased by TW in 2018 are first, polyvinyl chloride (PVC), and second, ductile iron (DI). Lesser amounts of pipe types purchased were cement, high-density polyethylene (HDPE), copper, and steel. Water treatment chemicals purchased by TW in 2018 included ammonia, chlorine, hydrogen peroxide, sodium bisulfate and sulfuric acid. After 2018, chlorine is no longer purchased, and sodium hypochlorite is used instead.

Pipes

Based upon the review of available analyses of alternative pipe materials, credible results based upon standard LCA methods (WRI and ISO standards for products) were limited but available in one peer-reviewed report (Sustainable Solutions Corp. (SSC) 2017). These SSC results cover three of TW's pipe materials (HDPE, PVC and DI) and indicate that over the life cycle, cradle-to-grave (100-yr life cycle), PVC pipe material for 8-inch pipes (for DR18) have the lowest embodied energy followed by DI and HDPE. Over the life cycle PVC pipe material for 8-inch pipes (for DR25) have the lowest embodied energy followed by HDPE and DI. For 24-inch pipe material, the cradle-to-grave rank order of the embodied energy starting with the lowest, were prestressed concrete cylinder pipe (PCCP), PVC, DI, and HDPE. The results above include replacement of HDPE, DI and PCCP pressure pipes during the 100-year system design life. Even without replacement, these pipe materials still have greater total embodied energy over 100 years than PVC pipe.

Water Treatment Chemicals

Of the five chemicals TW continues to purchase on an annual basis, the largest quantities in rank order are sodium hypochlorite, sulfuric acid, hydrogen peroxide, ammonia, and sodium bisulfate.

There are LCA data gaps for the water industry in several processes, equipment, and chemicals commonly used in water treatment that are not specifically included in existing LCA databases (WEF 2013). Unfortunately, these data gaps for production of specific bulk chemicals have not recently been addressed.

An LCA (Cradle-to-Gate) for eleven typical water treatment chemicals was completed by WEF and indicating Global Warming Factors in grams CO_2 eq / kg. Of those chemicals, sodium hypochlorite and sulfuric acid were purchased by TW and are shown in italics in the table below. Based on an analysis using the WESTweb tool, a factor for chlorine was identified and is included below (WESTweb 2018). Thus, climate LCA factors are available for only these two of the five water treatment chemicals purchased by TW going forward beyond 2018.

With the available data, below in rank order, is a numerical comparison of the relative LCA carbon intensity of alternative types of water treatment chemicals. Sodium hypochlorite is about ½ as carbon intense as chlorine; so its use in replacement of chlorine post CY 2018 yields a GHG reduction. Chlorine's Global Warming Factor is significantly higher than sodium hypochlorite and sulfuric acid. However, a comparison to other TW chemical purchases of hydrogen peroxide, ammonia and sodium bisulfate is not possible without additional LCA factors.

Table 2-2. Comparison of Global Warming Factors for Water Treatment Chemicals

Water Treatment Chemical	Global Warming Factor ($g\ CO_2eq$ / kg)
Ammonium sulfate	2,370
Chlorine (from WESTweb)*	1,357
Phosphoric acid, 85% in H_2O	1,210
Hydrochloric acid	1,170
Sodium hydroxide, 50% in H_2O	*1,010*
Quicklime, milled, packed	982
Sodium hypochlorite, 15% in H_2O	763
Hydrochloric acid, 30% in H_2O	735
Iron (III) chloride, 40% in H_2O	617
Aluminum sulfate, powder (Alum)	458
Sulfuric acid, liquid	86

* Listed for comparison
Source: WEF 2013. WESTweb 2018.

3 Prior PAG Inventory Reports and Data

3.1 Review of PAG 1990–2017 Emissions Sources and Inventory Boundaries

Prior to this 2018 inventory, PAG completed three regional GHG inventories that included the emissions from TW as a component of a larger regional GHG inventory. These inventories estimated emissions using the *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* (ICLEI 2010), which is the same protocol used to estimate 2018 emissions above. As the process was being refined by PAG, different reporting strategies and emissions factors with regards to TW emissions were used in these inventories, which affected comparability year over year when reviewing TW total emissions. These differences are summarized in Table 3-1.

Table 3-1. Inventory Years, Publication Dates of PAG Inventories, and differences.

PAG Inventory Publication Date	Regional GHG Inventory Years	PAG GHG Inventory Differences
October 2014	1990-2012	• Used separate emissions factors for TEP and Trico Electricity. • CAP emissions *not* reported in TW total emissions. • Potable and reclaimed water emissions reported *separate (and by utility)*.
February 2017	2012-2014	• Assumed Trico emissions factor is the *same* as TEP. • CAP emissions *are* reported in TW total emissions. • Potable and reclaimed water emissions reported *separate.*
June 2019	2012-2017	• Assumed Trico emissions factor is the *same* as TEP. • CAP emissions *are* reported in TW total emissions. • Potable and reclaimed water emissions reported *together (as shown in* Table 2-1*).*

Source: PAG 2014, 2017, 2019.

Each of PAG's regional GHG inventories were aggregated from three subsets, one each for the Tucson Community (City Community), Pima County Government Operations (County Government), and the City of Tucson Operations (City Government). The City Government subset inventory included emissions associated with the operation of TW.

3.2 Review of PAG Tucson Water GHG Inventories 1990–2017

The result of the three regional inventories that estimated TW GHG emissions to date are summarized in Table 3-2. GHG emissions are summarized by HDR in the format reported in the most recent inventory (PAG 2019).

Table 3-2. PAG Estimated TW GHG Emissions per calendar year (2000–2017)

Emissions ($MT\ CO_2e$)	2000[a]	2005[a]	2010[a]	2012[d]	2013[d]	2014[d]	2015[d]	2016[d]	2017[d]
TW Grid Supplied Electricity[b]	101,622	104,467	103,270	103,427	98,588	95,578	90,113	91,705	77,628
TW Fossil Fuel Usage (Natural Gas Use)	12,720	24,599	22,552	24,636	22,029	14,968	11,995	11,306	21,856
CAP Grid Supplied Electricity[c]	29,218	184,061	253,521	390,220	377,493	387,402	412,461	418,268	342,686
Tucson Water Subtotal	**143,560**	**313,127**	**385,343**	**518,283**	**498,110**	**497,948**	**514,569**	**521,279**	**442,170**

a. Emissions were aggregated for 2000, 2005, 2010 to match the three categories of the most recent 2012–2017 PAG inventory (published 2019).
b. As detailed in Table 3-1 the methodology in the 1990–2012 PAG Inventory (PAG 2014) used separate EFs to estimate electricity use emissions from Trico and TEP.
c. CAP emissions were not included in the total for TW in the 1990–2012 PAG Inventory but are included in this table.
d. Emissions as shown in the 2012–2017 PAG Inventory (PAG 2019).

3.3 Review of PAG Emissions Sources (1990–2017)

TW Grid Supplied Electricity

- Emissions associated with TW consumed electricity provided by TEP and TRICO.

TW Fossil Fuel Usage

- Emissions from natural gas consumed by TW. Provided by SWG. Fossil fuel usage from the TW fleet or during employee commute is not included in this metric, as these categories were not disaggregated specific to the utility in previous inventories (PAG 2014, 2017, 2019).

CAP Grid Supplied Electricity

- Emissions from electricity associated with CAP transmission of water to TW.

In addition to these emissions sources, City waste emissions were reported in previous PAG inventories (PAG 2014, 2017, 2019), but were not disaggregated specific to the utility and therefore are not reported here.

4 Emissions Trends

4.1 2018 TW GHG Emissions Using PAG Categories

For comparison with previous years, GHG emissions for 2018 are summarized in Table 4-1 using the emissions sources and boundaries delineated in the most recent PAG inventory (2019). This omits some of the emissions sources identified in Section 2, but is helpful for comparing emissions to prior years.

2018 GHG Inventory Using PAG (2019) Boundaries

Table 4-1. 2018 TW GHG Emissions.

Emissions Source	2018 Emissions (MT CO_2e)	2018 Energy Use (MMBtu)
TW Grid Supplied Electricity	74,855	412,575
TW Fossil Fuel Usage (Natural Gas Use)	15,882	299,018
CAP Grid Supplied Electricity	377,199	1,200,045
TW Subtotal	**467,936**	**1,911,638**

Using the boundaries from previous inventories, the majority (80 percent) of TW's 2018 emissions are associated with the CAP, while the remaining emissions (20 percent) are emissions from TW natural gas or electricity use.

4.2 TW Emissions to Date (1990–2018)

Given this is the first inventory completed for TW to include disaggregation by scope of GHG emissions, there are no previous years' data available for comparison to all the emissions sources identified in Table 2-1. To examine trends, Figure 4-1 compares 2018 emissions to previous PAG results by grouping emissions sources using the PAG methodology detailed in Section 3.

Using the boundaries (inventory methodology) defined by PAG, emissions increased between the years of 2017 and 2018 by 6 percent and have varied by about 15 percent since 2012. Detailed information for comparison with previous PAG inventories is provided below in Table 4-2.

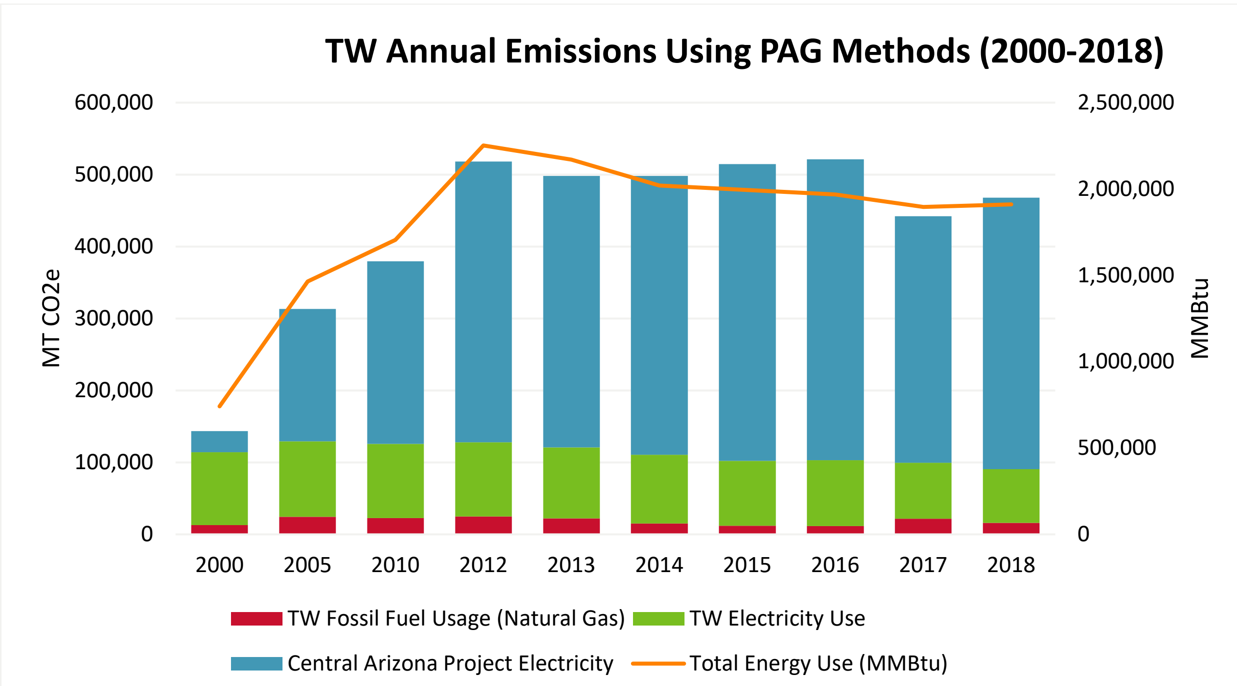

Figure 4-1. TW Annual Emissions and trends from 2000–-2018. Note, to be comparable with previous inventory this figure estimates 2018 emissions using the PAG methodology.

In future years with the refined data collection process described in the IMP (Appendix A), trends in GHG emissions could be tracked by scope to show progress toward TW's emissions reductions goals.

City of Tucson Carbon Reduction Targets

The City of Tucson has a goal of carbon neutrality in operations by the year 2030 (Tucson City Council Resolution No. 23222). The Tucson City Council declared this goal in a Climate Emergency Declaration adopted in September 2020.

Table 4-2. TW GHG Emissions 2000–2018 (Using PAG Format Since Previous Years Unavailable By Scope).

Emissions ($MT\ CO_2e$)	2000[a]	2005[a]	2010[a]	2012[d]	2013[d]	2014[d]	2015[d]	2016[d]	2017[d]	2018[e]
TW Grid Supplied Electricity	101,622	104,467	103,270	103,427	98,588	95,578	90,113	91,705	77,628	74,855
TW Fossil Fuel Usage (Natural Gas Use)	12,720	24,599	22,552	24,636	22,029	14,968	11,995	11,306	21,856	15,882
CAP Grid Supplied Electricity	29,218	184,061	253,521	390,220	377,493	387,402	412,461	418,268	342,686	377,199
Tucson Water Annual GHG Subtotal	**143,560**	**313,127**	**385,343**	**518,283**	**498,110**	**497,948**	**514,569**	**521,279**	**442,170**	**467,936**

a. Emissions were combined for 2000, 2005, 2010 to match the format of the most recent 2012–2017 PAG inventory (published 2019).
b. As detailed in Table 2-1 the methodology in the 1990–2012 PAG Inventory (PAG 2014) used separate EFs to estimate electricity use emissions from Trico and TEP.
c. CAP emissions were not included in the total for TW in the 1990–2012 PAG Inventory.
d. Emissions as shown in the 2012–2017 PAG Inventory (PAG 2019).
e. Only comparable emissions sources listed representing about 98.5% of reported emissions by scope; see Table 2-1 for complete 2018 GHG inventory.

Anticipated Carbon Intensity Reductions from Electric Utilities

To meet statewide mandates (ACC 2021) and stakeholder concerns, both TEP and Trico plan to incorporate more renewable energy into their future generation portfolio (TEP 2020, TRICO 2019). The current Arizona standard is a mandate of 15 percent renewable energy supply from regulated utilities by 2025, which Trico has already met and TEP is planning to exceed by 2030, detailed in Table 4-3. This will result in a reduction of the carbon intensity of energy provided to TW in the future. A breakdown of Scope 1 and 2 energy sources is shown in Figure 4-2.

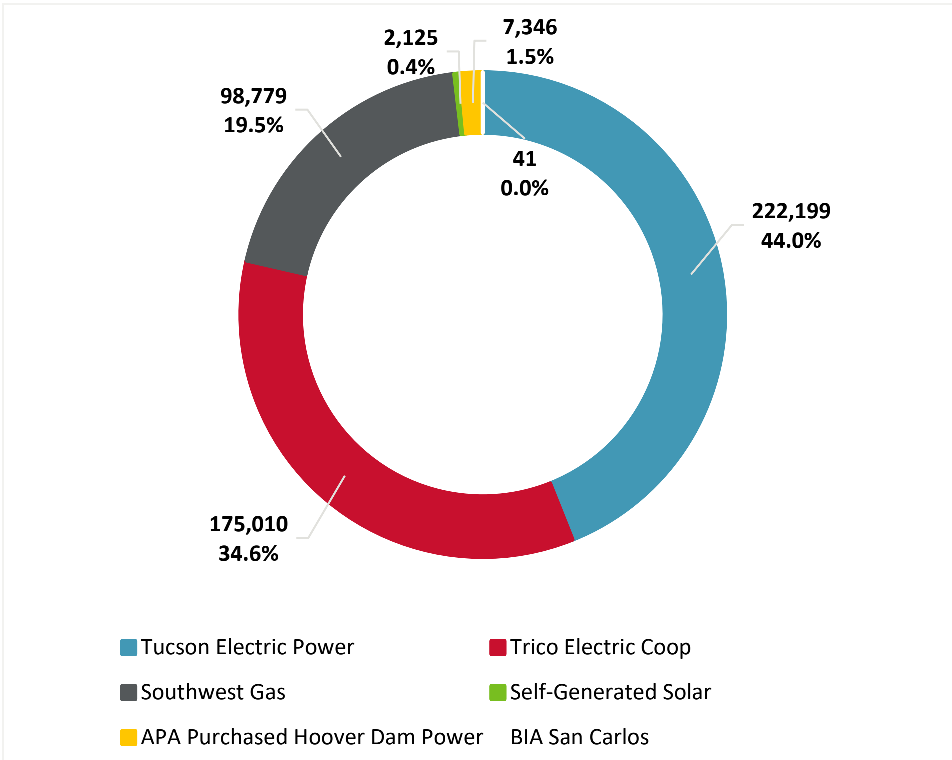

Figure 4-2. TW 2018 Electricity and Natural Gas Use (MMBtu)

As detailed in the figure, 80 percent of the Scope 1 and 2 energy demand for TW are provided by Trico and TEP. The current and future renewable portfolio targets for these two companies are provided in Table 4-3.

Table 4-3. TEP and TRICO Existing and Future Generation Capacity

Electricity Generation Capacity[a]	2018 TEP	2030 TEP Goal	2018 TRICO	2030 TRICO[b] Goal
Coal	34%	13%	38%	n/a
Natural Gas	56%	42%	40%	n/a

Electricity Generation Capacity[a]	2018 TEP	2030 TEP Goal	2018 TRICO	2030 TRICO[b] Goal
Renewables	10%	45%	16%	n/a
Hydropower	0%	0%	6%	n/a

a. Assuming 2020 generation detailed by TEP 2020, Trico 2021 is similar to 2018 generation.
b. Meets existing Arizona RPS standard of 15 percent by 2025, but future standards could require additional incorporation of renewables.

As Trico and TEP incorporate more renewables into their portfolios the carbon intensity of energy provided to TW will decrease. In addition, it is anticipated that CAP GHG emissions will decrease following the replacement of high carbon emitting electricity with the decommissioning of the coal-fired Navajo Generating Station in November 2019 (CAP 2020). Further carbon reduction or mitigation options for TW to reduce emissions to achieve the City's 2030 goal will be discussed in future technical memos referring to this baseline document.

5 Summary

Although TW has completed GHG inventories back to 2000, previous inventory years emissions are not categorized by scope, as recommended by the ICLEI Local Governments Reporting Standard (Appendix C of ICLEI 2010). The information to complete an inventory by scope to internationally recognized reporting and accounting principles has been provided in this technical memo, along with an additional IMP (Appendix A) to provide guidance to replicate an inventory by scope in future years.

To compare this inventory to previous years, a retrospective analysis would be required to categorize historical emissions by scope to keep the existing TW baseline, or the 2018 GHG Inventory in this memo could be established as a new baseline to identify clear GHG mitigation options to reach the utility's goal of carbon neutrality by 2030.

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Appendix A. Inventory Management Plan

Contents

Tables

Figures

1 Introduction

An Inventory Management Plan is provided in this section to provide an overview of the methodology, data sources, emission factors, and assumptions used to complete the 2018 Tucson Water (TW) Greenhouse Gas (GHG) Inventory. Questions regarding the 2018 TW GHG Inventory or Inventory Management Plan should be directed to:

Jaimie Galayda
Lead Planner | Tucson Water
(520) 289-7577
Jaimie.Galayda@tucsonaz.gov

2 Boundary Conditions

2.1 Organization Boundary

TW GHG Inventory emissions are reported by calendar year (CY). The TW GHG inventory boundary follows an operational control approach, which encompass all activities where TW has direct control of day-to-day decision making, which is generally within the TW water service area boundary shown below in Figure 1.

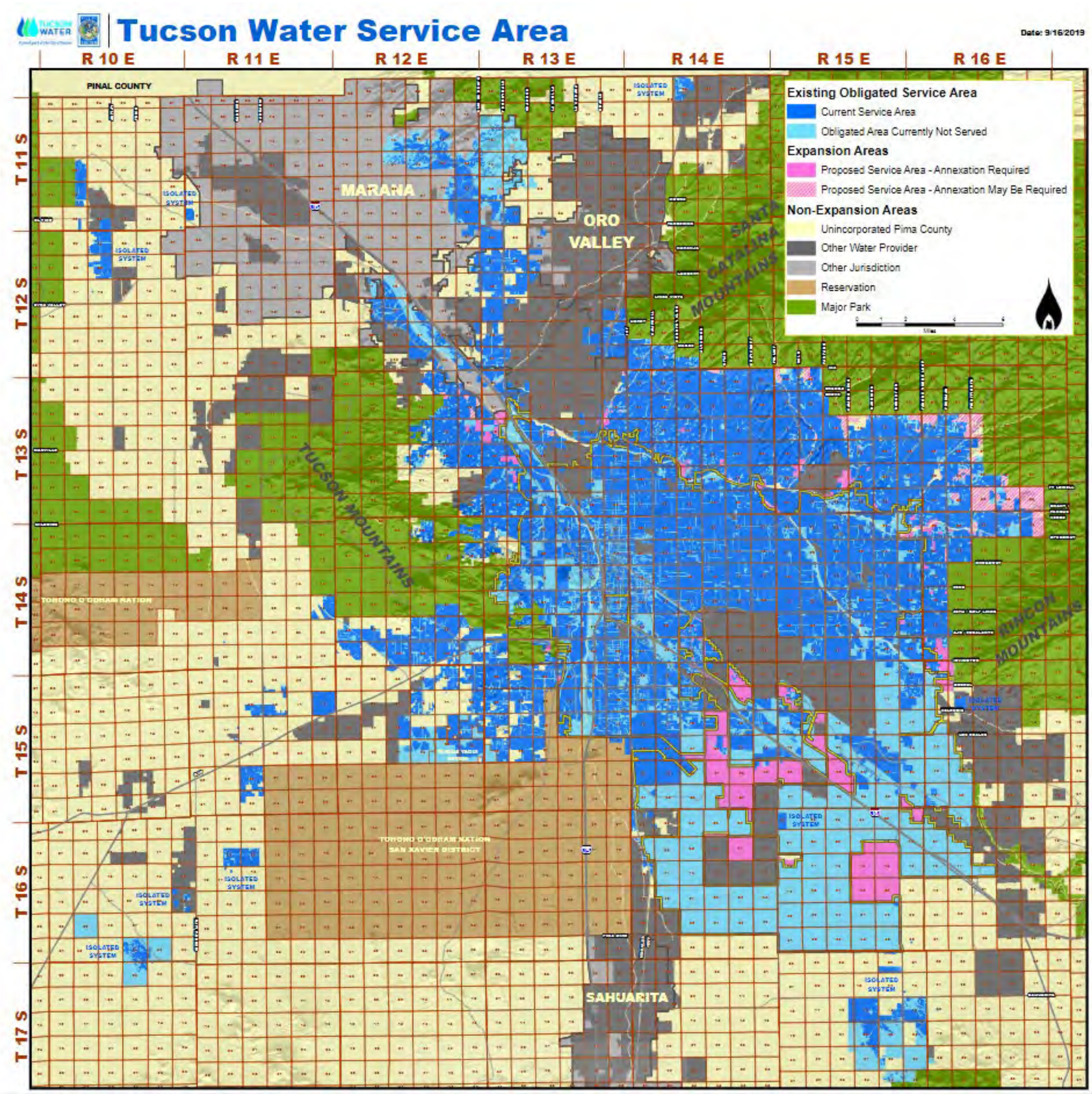

Figure 1: Map of Tucson Water Service Area by Township, Section, and Range.

This includes areas where the utility has full authority to affect change and introduce and implement operating policies that affect GHG emissions, including:

- Treatment Plants
- Pump Stations
- Booster Pumps
- Wells
- Administrative Offices
- Vehicles Used in Operations

- Generated Waste
- Purchased Goods and Services

TW reviewed potential emission sources for all six major GHGs as identified by the United States Environmental Protection Agency (EPA 2020a). Relevant GHGs are detailed in Table 1.

Table 1. Relevance of EPA Identified GHGs to TW Operations.

EPA Identified GHG[1]	Relevance to TW Operations
Carbon dioxide (CO_2)	*Relevant.* Produced from the combustion of fossil fuels.
Methane (CH_4)	
Nitrous oxide (N_2O)	
Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs)	*Relevant.* Fluorinated gas emissions are often the result of leaking refrigerants. Refrigerants are used in TW administrative and operations buildings, such as well houses. The TW vehicle fleet also uses refrigerants.
Sulfur hexafluoride (SF_6)	*Not Relevant.* SF_6 is primarily used by the electric power industry to insulate high-voltage circuit breakers.[1]
Nitrogen trifluoride (NF_3)	*Not Relevant.* NF_3 is used in a relatively small number of industrial processes, primarily produced in the manufacture of semiconductors and LCD panels, and certain types of solar panels and chemical lasers.[2]

1. EPA 2020a
2. WRI 2013

Within the organizational boundary of the TW GHG Inventory emissions sources were identified for CO_2, CH_4, N_2O, and from fluorinated gases (refrigerants). The TW GHG Inventory uses International Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) of global warming potential for CH_4 and N_2O to be consistent with 2020 EPA guidance (EPA 2020b).

2.2 Operational Boundary

The TW inventory follows the Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories (ICLEI 2010), with emissions reported in accordance with the World Resource Institute (WRI) Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (WRI 2004 and 2011) where appropriate. Note that the ICELI protocol refers users to the WRI standard for the definition of scopes and methods.

Previous TW GHG boundaries detailed in the 2012–2017 Pima County Association of Governments (PAG) Regional GHG Inventory TW did not disaggregate which City of Tucson emissions are attributed to TW from facilities, fleet, public lighting, district energy, water, or employee commuting. In addition to this, TW emissions were not categorized by scope. The 2018 inventory categorizes emissions by scope and includes additional relevant emissions sources that can be disaggregated from City of Tucson data. For comparison with previous years, emissions are also provided using the boundary from PAG inventories. Note that TW did not have full control of the PAG inventory and assumptions for the utility's emissions.

The WRI Standard categorizes direct and indirect emissions as Scope 1, 2, and 3. Direct emissions are Scope 1 emissions, while Scope 2 and 3 emissions are indirect. A visual of this information by category is shown in Figure 2. Direct emissions are emissions that an organization emits from their own activities, such as operation of utility-owned equipment, while indirect emissions are emissions from activities of external organizations, such as generation of electricity or energy used to move water by the Central Arizona Project (CAP).

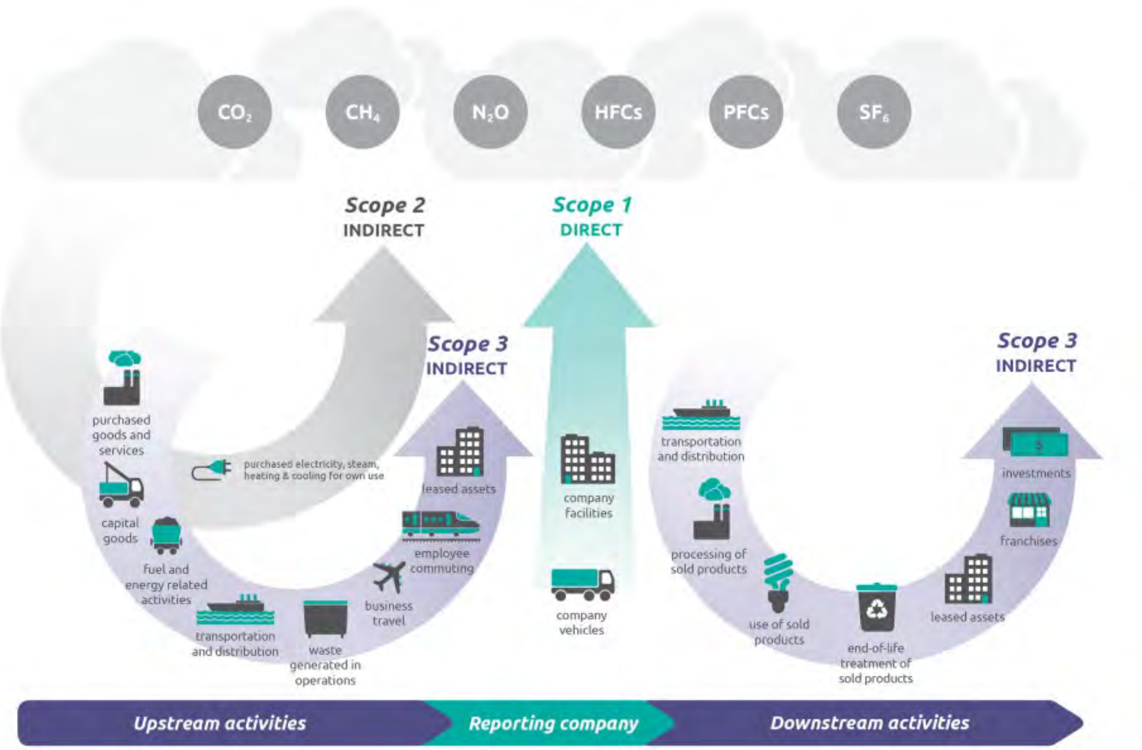

Figure 2. Scopes of GHG Emissions as Defined in the WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard (Source: WRI 2011)

Relevant TW emissions categories and sources by scope are detailed in Table 2.

Table 2. TW Emissions Sources, Scopes

2018 Emissions Source	Scope	Emissions Source[1]	2018 Activity Data
Natural Gas Use	1	Stationary Combustion	299,018 MMBtu[2]
TW Vehicle Fleet (on-road)	1	Mobile Combustion	33,592 Gallons Diesel[3] 271,514 Gallons Gasoline[3] 180 Gallons Ethanol[3]
TW Vehicle Fleet (off-road)	1	Mobile Combustion	31,598 Gallons Diesel[3] 1 Gallon Gasoline[3]
Refrigerants	1	Fugitive Emissions	77 Pounds R22 8 Pounds R407C 7 Pounds R410A 50 Pounds R422B
Electricity Use (TW Operations)	2	Purchased Electricity	116,416 MWh[2,5]
Upstream (CAP) Water	3	Upstream Transportation of Materials and Fuels	351,713 MWh[4]
Waste from Operations	3	Waste Generated in Operations	665 Short Tons Landfilled[6] 188 Short Tons Recycled[6]
T&D Loss from Purchased Electricity	3	Utility T&D Loss	2,695 MWh5[5,7]

1. ICELI 2010
2. Values provided by Tucson Water from the EnergyCAP system, for electricity only includes carbon emitting electricity use
3. Value provided from City of Tucson Fleet Services
4. Electricity to deliver the water provided from the Central Arizona Project
5. Only includes purchased electricity from TEP, Trico. Bureau of Indian Affairs (BIA) electricity is delivered by the Western Area Power Administration (WAPA). According to WAPA's electricity customer list (2021a). WAPA provides predominantly hydropower generation at federal facilities and purchases power as needed (2021b). For CY 2018 the split as reported by WAPA is 93% (hydro) to 7% other sources (2021b). Thus, since the BIA power is predominantly hydro, and BIA electricity is 0.01% percent of TW's electricity use, these emissions are considered *de minimis* (See IMP for definition of term). A calculation of the GHG emissions associated for WAPA purchased power was not included.
6. Value provided from Environmental and General Services Department
7. 3.6% Transmission and Distribution Energy Loss reported for Arizona in 2018 (EIA 2020)

3 Reporting Principles

The TW GHG inventory is developed in accordance with the ICELI Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories. ICLEI relies upon and refers to the scopes and methods defined in the WRI Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (Corporate Standard), and the WRI Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

Development of the GHG inventory is based on the following core GHG accounting and reporting principles (defined in WRI 2004):

Relevance. Developing a GHG inventory that appropriately reflects TW's GHG emissions.

Completeness. Accounting for and reporting on all GHG emission sources and activities within the inventory boundary, with clear disclosure and justification for exclusions.

Consistency. Using consistent methodologies to allow for meaningful comparisons of emissions over time. Documenting changes to the data, boundary, or other relevant factors.

Transparency. Addressing emission sources in a factual and coherent manner, supported by clear documentation of source data, assumptions, and calculation methodologies.

Accuracy. Applying best practices to systematically estimate GHG emissions as accurate as reasonable and minimize uncertainties as far as practicable.

4 GHG Emissions Sources and Factors

Emissions factors for each identified emissions source and quantification methodologies are detailed in Table 3.

Table 3. TW Emissions Source, Factors, and Quantification Methodology.

2018 Emissions Source (Unit)	Emissions Factor (GHGs / Unit)	Quantification Methodology[1]
Scope 1		
Combustion of Natural Gas –Operations (MMBtu)	53.1 kg CO_2e 1.00 g CH_4 0.10 g N_2O	$MT\ CO_2e = Natural\ Gas\ Use * EPA\ EF_{CO_2,N_2O,CH_4} * GWP_{N2O,CH4} * Unit\ Conversion$
On-Road Vehicle Fleet (Gallons)	10.21 kg CO_2 (Diesel) 8.78 kg CO_2 (Gasoline) 5.75 kg CO_2 (Ethanol) Different CH_4 and N_20 per make/model	$MT\ CO_2e = Total\ Fuel\ Use * EPA\ EF_{CO_2,N_2O,CH_4} * GWP_{N2O,CH4} * Unit\ Conversion$
Off-Road Vehicle Fleet (Gallons)		
Refrigerants (Pounds)	1870 CO_2e (R22) 1774 CO_2e (R407C) 2088 CO_2e (R410A) 2526 CO_2e (R422b)	$MT\ CO_2e = Refridgerant\ Weight\ (lbs) * GWP * Unit\ Conversion$
Scope 2		
Electricity Use – Operations (MWh)	0.643 tons CO_2e	$MT\ CO_2e = TEP\ EF_{CO_2,N_2O,CH_4} * mWh\ Purchased * GWP_{N2O,CH4} * Unit\ Conversion$
Scope 3		
Upstream (CAP) Water (MWh)	1.072 CO_2e[2]	$MT\ CO_2e = Navajo\ Generating\ Station\ EF_{CO_2,} * mWh\ Purchased * Unit\ Conversion$

Waste from Operations (Short Tons)	0.63 Metric Tons CO_2e / Short Tons (Municipal Solid Waste) 0.09 Metric Tons CO_2e / Short Tons (Mixed Recycling)	$MT\ CO_2e = (EPA\ EF * Short\ Tons\ Municpal\ Solid\ Waste\ or\ Mixed\ Recycling)$
T&D Loss From Purchased Electricity (MWh)	3.6% of TW-consumed electricity from utilities	$MT\ CO_2e = TEP\ EF_{CO_2,N_2O,CH_4} * mWh\ Purchased * GWP_{N2O,CH4} * EIA\ EF * Unit\ Conversion$

1. EPA emissions factors detailed in EPA 2020b. Global Warming Potential (GWP) values are from theAR4.
2. Emissions factor estimated from EIA energy use and EPA emissions Data (EIA 2020, EPA 2020a)

5 Scope 1 Emissions Sources

5.1 Stationary Combustion

Definition

The ICELI *Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories* Standard (2010) defines stationary combustion as fuel used to "produce electricity, steam, heat or power using equipment in a fixed location." Stationary combustion for TW is limited to combustion of natural gas to heat offices or operate equipment. Depending on use emissions are categorized within either the ICELI defined Water Delivery or Buildings categories. The WRI *Greenhouse Gas Protocol Corporate Accounting and Reporting Standard* (2004) defines this emissions source as Scope 1.

2018 Data Source and Analysis for Inventory

Natural gas use was estimated using utility bills from Southwest Gas (SWG) for CY 2018. This information was collected from the Tucson Utility Management System (which uses EnergyCAP software) and provided to HDR as a spreadsheet. This included all the natural gas used to heat occupied office space. To estimate emissions per MMBtu an emissions factor was used from the 2020 EPA guidance for GHG inventories (EPA 2020b).

Since the EnergyCAP data were aggregated, additional information was required to apportion natural gas use between office space and water delivery. For future city-wide inventories it is recommended this apportionment be completed to help disaggregate GHG emissions in the ICELI defined categories.

5.2 Mobile Combustion

Definition

The ICELI standard (2010) defines mobile combustion as "fuels in fleet transportation sources (e.g., cars, trucks, marine vessels, and planes) and emissions from off-road equipment such as in construction, agriculture and forestry." Emissions are categories such as "on-road" or "off-road," where "on-road" fleet vehicles are those such as sedans, pickup trucks, dump trucks that see a majority of street use and "off-road" vehicles are other mobile equipment such as small engine components and construction equipment.

Mobile combustion for TW is limited to fuel use for City-owned fleet and non-road equipment for the ICELI defined Water Delivery and Vehicle Fleet emissions categories. The WRI standard (2004) defines this emissions source as Scope 1.

2018 Data Source and Analysis for Inventory

On-road vehicle fleet fuel usage was provided to HDR in an Excel spreadsheet from the City Fleet Services department. A separate spreadsheet was provided with make/model information and the two datasets were related to one another by HDR. After joining the spreadsheets, gallons of fuel for diesel, gasoline, and ethanol were totaled. Based on discussion with TW staff, it is assumed that DRP (undefined diesel) fuel has an equivalent emissions profile to diesel fuel, allowing these fuels to be totaled together. Note: after combining these data, some vehicles were determined to be off-road after the make/model was discovered. To estimate GHG emissions per gallon of fuel consumed, EPA emissions factors for gasoline, diesel, and ethanol were used (EPA 2020b).

To estimate indirect CH_4 and N_2O emissions for the on-road vehicle fleet EPA emissions factors based on mileage data depending on the vehicle make/model were used (EPA 2020b). This was completed for 70 percent of the vehicles in the data provided; for the other 30 percent of vehicles, the make/model could not be determined from the data provided. To estimate the emissions, the weighted average of the made/model of the rest of the on-road vehicle fleet was applied to these vehicles. It is assumed the indirect emissions associated with this assumption would only result in a small (less than 10 metric tons) difference if these data were available and is thus below the TW *de-minimus* threshold (the minimum threshold to require further analysis, defined by the ICELI to be <5 percent of total emissions). A complete spreadsheet with fuel usage and vehicle make/model could avoid the need to make this assumption in future reporting years.

For off-road vehicles, gallons of fuel used in 2018 was determined using with data from fuel pumps that track the dispersal of fuel, which were provided to HDR by TW. Total gallons of fuel were provided from the Fleet Services database for these categories. It is assumed that fuel dispensed from fuel truck 5900 is representative of all fuel dispersed to "off-road" vehicles. Emissions per gallon were estimated by applying the EPA defined "off-road construction/mining" emissions factor.

5.3 Fugitive Emissions

Definition

ICELI defines fugitive emissions as emissions that "…are not physically controlled but result from intentional or unintentional releases, commonly arising from the production, processing, transmission, storage, and use of fuels and other substances, often through joints, seals, packing, gaskets, etc. (e.g., HFCs from refrigeration leaks, SF_6 from electrical power distributors, and CH_4 from solid waste landfills)." Fugitive emissions for TW are limited to refrigeration leaks for the ICELI defined Water Delivery emissions category. The WRI Protocol (2004) defines this emissions source as Scope 1.

2018 Data Source and Analysis for Inventory

Refrigerants used by TW in 2018 were provided from a City-maintained database but did not include refrigerant losses from TW-owned vehicles. It is assumed that added refrigerants to TW systems are replacing refrigerants that were released to the atmosphere. An emissions factor for each refrigerant was provided from 2020 EPA data (EPA 2020b) or from the California Air Resources Board "High-GWP Refrigerants" database (2020).

6 Scope 2 Emissions Sources

6.1 Purchased Electricity

Definition

TW emissions associated with the consumption of purchased electricity are relevant to the ICELI defined Water Delivery and Buildings and Other Facilities emissions categories. The WRI standard (2004) defines this emissions source as Scope 2.

2018 Data Source and Analysis for Inventory

Annual electricity use from TW operations was estimated using utility bills provided from TEP, Trico, and the Bureau of Indian Affairs (BIA) San Carlos Irrigation District for calendar year 2018. This information was collected from the Tucson Utility Management System and provided to HDR as a separate spreadsheet for each utility in MMBtus. Data were converted to kWh and combined into one spreadsheet grouped by utility. Electricity billed was subtracted from total used to determine solar electricity generated and consumed at the Hayden Udall Treatment Plant and Reclaimed Plant.

In October of 2017 TW signed a contract with the Arizona Power Authority to purchase renewable hydroelectric power generated by the Hoover Dam until September of 2067. TW is allocated approximately 2,725,000 kWh each year. This electricity and associated T&D losses are assumed to be carbon-free in the 2018 TW inventory. This power is delivered to TW through Trico transmission and distribution infrastructure. APA invoices paid by TW for CY 2018 were provided to HDR to confirm the amount of power delivered. This power is assumed to be consumed through the Trico CAVSARP master meter in the EnergyCAP data provided to HDR (Personal Communication TW 2021). To account for this, a portion of the electricity consumed from Trico equal to the total APA purchased power consumed is assumed to be carbon free (2,153,000 kWh) in 2018.

Although additional solar energy is generated at CAVSARP from two solar arrays, TW entered two 25-year power purchase contracts (in 2011 and 2013) with Trico to sell the electricity generated along with the Renewable Energy Credit (RECs). A REC is a market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. RECs are issued for each one megawatt-hour (MWh) of electricity that is generated and delivered to the electricity grid from a renewable energy resource. RECs are the accepted legal instrument through which renewable energy generation and use claims are substantiated in the U.S. renewable energy market (EPA 2021). Since the RECs from TW's solar generation were sold to Trico, TW is unable to claim the electricity is renewable in their accounting of GHG since TW does not legally own the RECs for this solar electricity generation. The contracts for sale of the RECs to Trico expire as shown in Table 4, which provides a detailed summary of solar generation and REC ownership.

Table 4: Solar Electricity Generated and Ownership of Renewable Energy Credits (2018)

Solar Generating Facility Location	kWh Generated	kWh Solar Consumed by TW	Ownership of RECs
Hayden Udall Treatment Plant	408,134	408,134	TW
Reclaimed (Water) Plant	214,543	214,543	TW
CAVSARP 1	2,100,144	0	Trico (until 2036) TW (after 2036)
CAVSARP 2	7,354,068	0	Trico (until 2038) TW (after 2038)

An emissions factor for TEPs 2018 electricity mix was reported online by TEP to the Edison Electric Institute (EEI 2019) and utilized in this inventory. A PAG representative confirmed with Trico that the TEP emissions factor would also be appropriate for the GHG emissions from their utility generation for the CY 2018 (PAG 2021). Given that BIA electricity is only 0.01 percent of TW's electricity in 2018 (*de minimis*) and BIA's supply is purchased from Western Area Power Administration (primarily large-scale hydro), it is assumed this electricity does not emit carbon.

The utility management system data was categorized by building name and code. Further analysis is required to apportion electricity use between office space and water delivery uses. If possible, for future city-wide inventories we recommend this be completed to help categorize emissions in the ICELI defined categories (Buildings, Water Delivery). In addition to these four facilities (R_710_OTHER_PUMP-ELRIO-2, R_710_OTHER_PUMP-ELRIO-1, R_710_OTHER_WELLSITE-B-047A, R_710_OTHER_IRR_CASEPARK) attributed to streets and parks were removed from the dataset.

7 Scope 3 Emissions Sources

7.1 Upstream Transportation of Materials and Fuels

Definition

The electricity associated with the extraction and conveyance of CAP water to TW is categorized by ICELI (2010) as supply chain emissions associated with the Upstream Transportation of Materials and Fuels. The ICELI standard (2010) defines this emissions source as Scope 3 since these emissions are outside the control of TW.

2018 Data Source and Analysis for Inventory

TW began receiving a partial allotment of water from CAP in 1990, which increased in volume until the full allotment was received in recent years. As volume increased, energy use increased to convey that water. The CY 2018 electricity to deliver TW's allotment of CAP water is provided to TW from CAP. It is assumed the Navajo Generating Station (NGS) generated all of the electricity used to deliver CAP Colorado River water to TW in CY 2018. Given that NGS is being retired and CAP has begun to diversify their generation sources, it is recommended in future inventory years that CAP be requested to provide a more detailed breakdown of generation sources, and complete their own carbon intensity analysis to create an annual or monthly emissions factor (CAP 2020).

To estimate the emissions associated with this upstream electricity usage an emissions factor was created by dividing CY 2018 NGS generation in kWh reported to the EIA (2020a) by GHG emissions reported to the EPA (2020a). This estimation was validated by PAG staff to be similar to how previous emissions factors were calculated for CAP electricity (PAG 2021).

7.2 Waste Generation from Operations

Definition

The ICELI standard (2010) defines emissions local government waste that is not disposed of in a government-owned landfill as supply chain waste related Scope 3 emissions.

2018 Data Source and Analysis for Inventory

Tonnage of transactions for municipal waste and recycling collection was provided to TW from the Environmental and General Services Department. Emissions factors for municipal solid waste and mixed recyclables were applied to the tonnage of the two waste streams for 2018 (EPA 2020b). It is assumed all municipal solid waste was disposed of at Los Reales Landfill, which has a gas collection system for fugitive methane (TEP 2021).). Future data collection could include further waste characterization and more detailed tracking of disposal and/or recycling by TW of materials such as water meters, brass, copper, and insulating wire.

7.3 Transmission and Distribution Losses

Definition

The ICELI standard (2010) provides the option for governments to report the electricity lost during the transmission and distribution of electricity. For TW these emissions are categorized into the ICELI defined Water Delivery, Buildings and Other Facilities categories. The WRI standard (2011) defines this emissions source as Scope 3.

2018 Data Source and Analysis for Inventory

Transmission and distribution loss data were estimated by multiplying carbon-emitting electricity use by the average loss for the state of Arizona (EIA 2020b).

7.4 Purchased Products and Capital Goods

Definition

The ICELI standard (2010) provides the option for governments to report upstream emissions (embodied carbon) associated with the production of purchased equipment, or materials. For TW these emissions are categorized into the ICELI defined Water Delivery, Buildings, and Other Facilities categories. The WRI standard (2011) defines this emissions source as Scope 3.

Purchased products and capital goods are separated into two categories per the WRI 2011 protocol:

1. **Capital Goods:** All upstream (cradle-to-gate) emissions from the production of products not immediately consumed but used in the process of providing water to customers (pipes, mechanical equipment, office equipment, computers, vehicles, etc.).
2. **Purchased Goods:** All upstream emissions from the production of products not reported above, such as those that are immediately consumed (chemicals, batteries, other "one-time" use materials during operations).

2018 Data Source and Comparative Analysis

In a typical inventory, the GHG associated with purchased and capital goods would be based on the dollar spend annually for each category of goods and calculated using WRI methods with relevant industry average emission factors (i.e., emissions per dollar spent). WRI's recommended standard method is to use an Extended Input-Output (EEIO) model

Since this is the initial GHG inventory by scope for TW, a more comparative review of the embedded carbon or carbon intensity of selected purchased and capital goods from their supply chain is provided in this section. TW requested a focus upon purchased and capital goods, and a relative analysis of two major materials types important to their operations as a water supply agency, i.e., chemicals and pipes. Methodology for Comparative Analysis

This methodology relies upon a different calculational approach than the standard practice for a GHG inventory. For this comparison, Life Cycle Analysis (LCA) was used. LCA is an ISO 14040 normalized method for the assessment of products and systems from cradle-to-grave, which begins with raw materials extracted from the earth, and continues with product development, manufacturing, and disposal. LCA allows comparison between different materials or processes providing the same service or function. The resulting metric is for TW's use to understand the relative impacts on a climate or GHG basis of alternative material types for pipes and for chemicals, as purchased by TW.

The LCA method generates a factor for climate or GHG in embodied carbon (CO_2e), alternatively, the precursor to this is embodied energy and can be utilized. As expected, embodied carbon for a product can vary widely by electricity and fuel types used during the life cycle. The embodied energy represents the energy consumed regardless of the source or carbon content and is represented in joules (J). The boundaries for LCA are described below.

HDR prepared a relative comparison of life cycle attributes associated with each of chemicals and pipes based upon CY 2018 data for TW purchases. Data collected by TW for purchases of water supply pipe (by type, diameter size and total feet) and chemicals (by weight) for CY 2018 are summarized below in Table 5. The predominant types of pipe purchased by TW in 2018 are PVC and ductile iron, respectively. Lesser amounts of pipe types purchased were cement, HDPE, copper and steel. Water treatment chemicals purchased by TW in 2018 included ammonia, chlorine, hydrogen peroxide, sodium bisulfate and sulfuric acid.

Table 5. Water Supply Pipe and Chemicals Purchased by TW, CY 2018

Product Type Purchased (2018)		
Maintenance Pipe	**Diameter (in)**	**Length (ft)**
Cement Asbestos (CA)	12	33
Concrete Cylinder (CC)	NA	NA
Copper Pipe (CU)	2	43
Ductile Iron (DI)	4	1,879
Ductile Iron (DI)	6	8,578
Ductile Iron (DI)	8	7,813
Ductile Iron (DI)	12	1,359
Ductile Iron (DI)	16	495
Ductile Iron (DI)	24	811
High Density Polyethylene (HDPE)	4	22
Polyvinyl chloride (PVC)	2	96
Polyvinyl chloride (PVC)	4	3,924
Polyvinyl chloride (PVC)	6	24,758
Polyvinyl chloride (PVC)	8	60,122
Polyvinyl chloride (PVC)	10	26
Polyvinyl chloride (PVC)	12	16,776
Polyvinyl chloride (PVC)	16	2,325
Steel (STL)	4	28
Chemicals		**Gals/yr**

Ammonia		15,000
Chlorine		220,000
Hydrogen Peroxide		35,000
Sodium Bisulfate		7,200
Sulfuric Acid		36,000

Sources – Pipe: Bill Burris, Water Program, TW.
Chemicals: Michael Moraga, Water Quality & Operations Division;
David Villalovos, Water Plant. Both TW.

Water Supply Pipeline Material

A review of comparisons of water pipe materials yielded a small number of studies that were primarily sponsored by water pipe manufacturers. In these comparisons of pipe materials, the methodologies relied upon were non-standard, and the conclusions were highly variable from study to study, i.e., the results favored the pipe material represented by the sponsoring pipe manufacturer.

For this report, HDR selected the results of an LCA review that was:

a) based upon international standard methods referenced by the WRI;

b) utilized a calculation methodology that is based upon product evaluation methods under ISO 14040 standards that require transparency; and,

c) peer reviewed.

The study, *Life Cycle Assessment of PVC Water and Sewer Pipe and Comparative Sustainability Analysis of Pipe Materials* (Sustainable Solutions Corp. [SSC] 2017), also makes reference to the 2015 Environmental Product Declaration for PVC Pipe, which complies with ISO 14025 standards and was independently certified by global health organization NSF International.

This study reported embodied energy in MJ/100 ft pipe and that metric is a general surrogate for carbon intensity. Embodied energy is a reasonable surrogate for embodied carbon or carbon intensity, since when converted from energy to carbon, the result is primarily associated with carbon dioxide emissions from non-renewable energy. To convert embodied energy to embodied carbon would require setting a carbon emissions factor for each pipe material. The carbon emissions factor for each pipe material will vary based upon how raw material is sourced, how the pipe is manufactured, the carbon intensity of the electricity (power content label) and other fuels used during production or manufacturing.

Table 6 shows the Cradle-to-Gate phase is a relative comparison of the embodied energy of pipes by material type and diameter.

Table 6. Cradle-to-Gate Embodied Energy for Alternative Water Supply Pipe Materials (Pressure pipe category)

Comparable Products	Standard	Embodied Energy (MJ/100 ft.)
8" PVC DR18	AWWA C900	23,300
8" HDPE 4710 DR9	AWWA C906	42,600
8" DI CL51	AWWA C151	50,900
8" PVC DR25	AWWA C900	15,900
8" HDPE 4710 DR13.5	AWWA C906	29,600
8" DI CL51	AWWA C151	50,900
24" PVC DR25	AWWA C905	137,900
24" HDPE 4710 DR13.5	AWWA C906	240,800
24" DI CL51	AWWA C151 AWWA C104	206,600
24" PCCP PC200	AWWA C301	53,500

Key: DI – Ductile iron. PCCP - Prestressed concrete cylinder *pipe*. PP - Polypropylene pipes.
Source (SSC 2017)

These results indicate that for the cradle-to-gate order of ranking of the lowest embodied energy (least GHG) for either 8-inch category pipe is shown below:

1. PVC
2. HDPE
3. Ductile iron

For 24-inch pipe, the cradle-to-gate order of ranking of the lowest embodied energy (least GHG) is listed below.

1. PCCP
2. PVC
3. Ductile iron
4. HDPE

Note that in the study referenced below, steel pipe material was not included or evaluated. Thus, PVC has the lowest embodied energy at the 8-inch-diameter size. PCCP is the lowest at the 24-inch-diameter size.

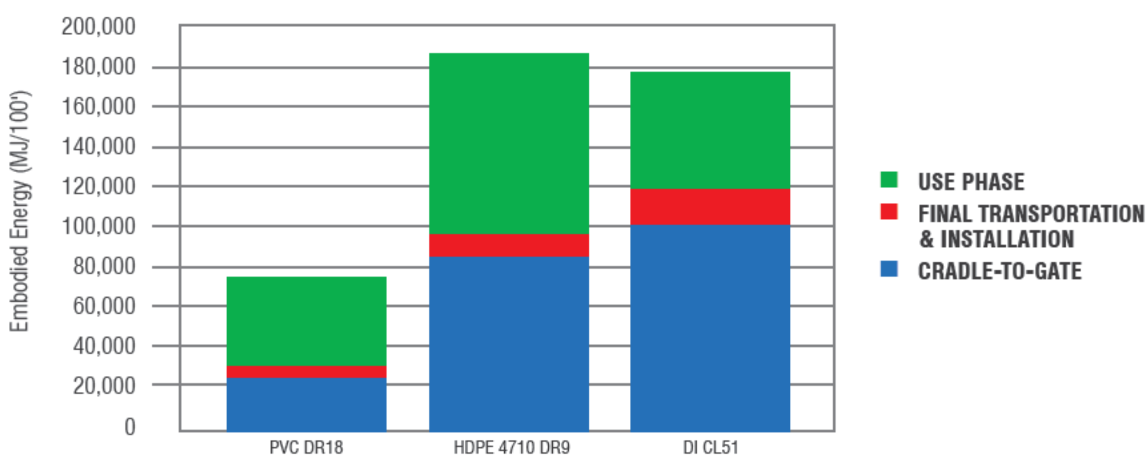

Figure 3. Total 100-year Embodied Energy for Equivalent 8″ Pressure Pipes (PVC DR18) (Source: SSC 2017)

Figure 4. Total 100-year Embodied Energy for Equivalent 8″ Pressure Pipes (PVC DR25) (Embodied Energy in MJ/100 ft of pipe) (Source: SSC 2017)

For the entire life cycle, the results are different. SSC's results indicate changes from the Cradle-To-Grave energy associated with transportation (weight) and frequency of pipe replacement. These SSC results also indicate that over the life cycle, from Cradle-To-Grave, PVC pipe material for 8-inch pipes (DR18) have the lowest embodied energy followed by ductile iron and HDPE iron. Over the life cycle PVC pipe material for 8-inch pipes (DR25) have the lowest embodied energy followed by HDPE and ductile iron. For 24-inch pipe material, the cradle-to-gate rank order of the embodied energy starting with the lowest, were prestressed concrete cylinder pipe (PCCP), PVC, ductile iron and HDPE. These results are summarized in Table 7 below.

Table 7. Cradle-to-Grave Ranking of Alternative Water Pipe Material (by Embodied Energy) (Source: SCC 2017)

Diameter Size/Product	Rank	Pipe Material
8-inch DR18	1	PVC
	2	Ductile Iron
	3	HDPE
8-inch DR25	1	PVC
	2	HDPE
	3	Ductile Iron
24-inch	1	PVC
	2	PCCP

	3	Ductile Iron
	4	HDPE

Recycled Content of Pipe Material and Recycling End of Life Pipe

Current studies of carbon intensity of pipe materials assume no recycled content in pipe material purchased and an assumption of standard practice for the percentage of pipe material recycled (from 20 to 80 percent, depending upon the type of pipe material). Two measures that could lower the net GHG during the life cycle of water supply pipes are: (1) purchasing pipe material with recycled material content, and (2) increasing recycling used pipe at the end of service life at the time of replacement. If these measures are adopted, monitoring and recording of annual data associated with each would be needed and could be included in annual GHG inventory accounting.

Chemicals

Of the five chemicals TW purchases on an annual basis, the largest quantities for CY 2018 in rank order are chlorine, sulfuric acid, hydrogen peroxide, ammonia and sodium bisulfate. After 2018, chlorine is no longer purchased and sodium hypochlorite is substituted.

There are LCA data gaps for all bulk chemicals commonly used in water treatment as these are not specifically included in existing LCA databases (WEF 2013) and have only recently been partially addressed. An LCA (Cradle-to-Gate) for eleven typical water treatment chemicals was completed by WEF; two of those chemicals used by TW, sulfuric acid and sodium hypochlorite, were included, as shown in the table below. Based on an analysis using the WESTweb tool, a factor for chlorine was identified and is included below (WESTweb 2018). Thus, climate LCA factors are available to compare for a total of three of the five water treatment chemicals purchased by TW in 2018, plus for sodium hypochlorite.

With the available data, below in rank order, is a numerical comparison of the relative LCA carbon intensity of alternative types of water treatment chemicals.

Table 8. Comparison of Global Warming Factors for Water Treatment Chemicals

Water Treatment Chemical	Global Warming Factor ($g\ CO_2eq$ / kg)
Ammonium sulfate	2370
Chlorine (from WESTweb)*	1,357
Phosphoric acid, 85% in H_2O	1,210
Hydrochloric acid	1,170
Sodium hydroxide, 50% in H_2O	1,010
Quicklime, milled, packed	982

Sodium hypochlorite, 15% in H_2O	763
Hydrochloric acid, 30% in H_2O	735
Iron (III) chloride, 40% in H_2O	617
Aluminum sulfate, powder (Alum)	458
Sulfuric acid, liquid	86

*included for comparison

Source: WEF 2013. WESTweb 2018.

Chlorine's Global Warming Factor is almost twice as carbon intense as sodium hypochlorite. Sulfuric acid is low in carbon intensity; however, a comparison to other TW chemical purchases of hydrogen peroxide, ammonia and sodium bisulfate is not possible without additional LCA factors. These chemicals perform differing functions during water treatment and the substitution of alternatives would be subject to the process in use at each treatment stage.

8 Exclusions

Data availability limits TW from being able to measure and estimate all GHG emissions associated with the operation of the utility. The emissions sources described below are excluded.

8.1 Scope 1 Exclusions

- *Fugitive Emissions from TW owned vehicle fleet* – Leaking refrigerants from the TW fleet could not be determined for the CY 2018 due to a lack of data availability.

8.2 Relevant Scope 3 Exclusions

- *Emissions from Purchased (Contracted) Services* – Emissions from purchased services because of TW capital projects or operations could not be determined due to limitations in available information. ICELI recommends reporting this emissions category if data are available (ICELI 2010). In the future, TW could begin gathering this information by tracking overall construction expense completed by third party contractors or, more specifically, having contractors estimate emissions through tracking fuel use and materials purchased for construction or maintenance of TW projects and equipment.
- *Upstream production of emissions of purchased fuels* – Upstream emissions of purchased fuels were outside the scope of this inventory. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol.
- *Employee Commute* – Emissions from this category were excluded since employee commute data associated with TW employees could not be disaggregated from data

for all City staff (PAG 2020). This is a required Scope 3 emissions source for reporting per the ICELI (2010) protocol. It is recommended to review the current PAG methodology for *quantifying* the City's employee commute emissions and that TW arrange for future data collection to allow for disaggregation for TW to enable incorporating this information by category into future TW and City-wide inventories.

- *Processing, Use, and End-of-Life Treatment of Sold Products* – Emissions associated with the energy used by potable water consumers were not estimated for this inventory. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol. To estimate these emissions TW could create a tracking inventory of all purchased materials for utility operations on an annual basis.
- *Investments* – Emissions related to TW investments were not quantified for this inventory. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol. If TW has investments in securities quantifying and categorizing these investments by industry or sector and the amount invested could help estimate emissions associated with TW holdings.
- *Employee Business Travel* – Employee business travel is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol. TW does track travel through travel orders and purchasing. These data were not able to be included for CY 2018, and in the future, could be collected, compiled, and included per the guidance in the ICLEI protocol and input requirements of their ClearPath tool. Emissions from travel in personal vehicles for work and air travel can be investigated for incorporation in future TW inventories.

8.3 Non - Relevant Scope 3 Exclusions

- *Leased assets* – TW does not have a significant amount of leased assets. This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol.
- *Franchises* – Not relevant for a public water utility This is an optional Scope 3 emissions source for reporting per the ICELI (2010) protocol.

9 References

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Appendix C
ONE WATER 2100 SCENARIO PLANNING

One Water 2100
Master Plan

Technical Memorandum
ONE WATER VISION AND SCENARIO PLANNING

JANUARY 2022

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Executive Summary

Throughout history, water supply has been a challenge to all who live in the area that is currently called Tucson. Currently, the Central Arizona Project (CAP) provides a renewable source of water for a regional population of more than one million residents. However, this supply is increasingly uncertain due to long term drought and climate change. To address the challenge of providing water to a large city in the desert with limited water supply options, the City of Tucson has taken a proactive approach to water management.

The previous water master planning effort was written in 2004 and was titled “Water Plan: 2000-2050”. Since Water Plan: 2000-2050 was completed, there have been many changes in development patterns, water supplies, water demand, and water quality issues. Updates to were made to the plan in 2008 and 2012.

Water Plan 2000 - 2050 led to a change in water supply: Tucson reduced its reliance on pumping non-renewable groundwater and expanded beneficial use of renewable sources such as CAP water and reclaimed water. The Plan included the City’s first formal stakeholder engagement and scenario planning exercises. The commitment to stakeholder engagement continues with the One Water 2100 (1W2100) plan.

To ensure that the water supply remains secure through the year 2100 and beyond, Tucson has adopted a One Water approach to planning. One Water is an integrated approach to managing finite resources for long-term resilience and reliability. A distinguishing feature of this approach is the engagement of stakeholders and partners, particularly in visioning and scenario planning. The results from a One Water planning approach are unique to each individual community and can be applied at many different scales (e.g., regional or local) depending on the specific needs of the entity.

With guidance and support from Brown and Caldwell (BC), Tucson Water developed a One Water framework for 1W2100. This tailored approach for Tucson Water included vision and goal setting work with Mayor and Council and Tucson Water staff as well as a scenario planning effort with community stakeholders.

One Water Vision and Guiding Principles

Workshops, surveys, and one-on-one interviews with Tucson Water staff, City of Tucson staff and Mayor and Council led to creation of the following vision statement and guiding principles for Tucson Water.

Vision Statement:

One Water is Tucson’s commitment to:

- Resilience
- Equity
- Stewardship

- Quality of life

Guiding Principles:

1. Deliver water reliability through water supply diversification, conservation, and innovative improvements to infrastructure.
2. Build resilience by planning for climate change, leading mitigation efforts, and implementing collaborative and adaptive strategies that harness the water-energy nexus.
3. Enhance the community's quality of life by preserving and restoring riparian areas, increasing urban tree canopy, and supporting economic growth.
4. Achieve affordability, accessibility, and social justice by committing to fiscal responsibility and prioritizing equitable projects and programs.
5. Ensure public confidence with safe, high-quality water supplies and exceptional customer service that includes transparency and responsiveness.

Scenario Planning

Building on the vision statement and guiding principles, the project team consisting of BC and Tucson Water led a stakeholder group through a scenario planning process. These stakeholders represented various business, environmental, and other community groups within Tucson. From this exercise, the scenario planning stakeholders developed the following four strategies to protect against a variety of future scenarios involving changes in supply or demand:

- Reduce use of CAP water
- Increase reliance on reclaimed water to help offset reduced use of CAP water
- Do not abandon remediated groundwater, and even consider expanding it
- Incorporate rainwater/stormwater harvesting and onsite reuse into the long-term water plan

Generally, the above themes can be summarized as a recommendation to rebalance the supply portfolio through more use of locally controlled and distributed sources and deliberately less reliance on CAP water.

In addition to these direct actions related to the future portfolio of water supplies, the stakeholders recommended the following policies to guide Tucson Water:

- Develop and implement a consistent and effective public outreach and education campaign to disseminate messaging on water conservation and local water management strategies.
- Promote awareness of equity in the community to help avoid future conditions in which the economics of water in Tucson are unreasonably stratified and decisions difficult to implement.
- Remain involved in state and federal policy and regulatory discussions, both to help advocate and influence and to stay aware of pending changes.

- Consider the water-energy nexus as a key element of a sustainable water plan, with energy requirements and opportunities to reduce emissions through siting and renewable energy serving as important decision drivers.

This technical memorandum details the process and key conclusions of the One Water visioning and scenario planning efforts.

1 Introduction

1.1 Background

In 2004, Water Plan: 2000-2050 was published with a stated purpose "to initiate a dialog between Tucson Water and the community about the water resources challenges that must be addressed in the coming years." In making this statement, Tucson Water reaffirmed its commitment to hearing the voice of the community on water issues. This commitment continues today through One Water 2100 (1W2100).

Since Water Plan: 2000-2050 was written in 2004, there have been many changes in development patterns, water supplies, water demand, and water quality issues. One noteworthy event was the economic recession of 2007-2009. During this period, development slowed and real estate values fell. This changed the trajectory of projected water demands throughout the Tucson Water service area. Updates to were made to the plan in 2008 and 2012.

Water Plan 2000 - 2050 led to an inflection point in Tucson water usage. Actions resulting from the plan shaped both the source of, and how, Tucson uses water. It also presented the results of the City's first formal stakeholder engagement and scenario planning exercises. Not surprisingly, stakeholders identified drivers that, while different from today's drivers in their details, share common themes.

For example, in 2004, a fundamental question existed regarding how to make use of Central Arizona Project (CAP) Water. While memories of the unsuccessful direct introduction of CAP water to the distribution system were fresh at the time, the dialog was fundamentally related to water quality, aesthetics, and sustainability – themes also identified in 1W2100 work.

A second key theme was related to renewable water. Between 1940 and 2000, water levels in Tucson's central wellfield dropped nearly 200 feet. The planning and foresight of Water Plan 2004 reversed this trend (Figure 1-1) and changed the trajectory of groundwater use. Further, decisions made because of the 2004 plan led to the highly successful CAP recharge program that remains the cornerstone of Tucson's sustainable water supply. The paths identified concerning renewable water were threefold: convert to pumping renewable groundwater (versus mining fossil groundwater), use wastewater effluent for potable purposes, and recharge the full allocation of CAP supply to the aquifer. The pathways established have been successful: data shows a rise in the central wellfield's aquifer levels through 2020 (Figure 1-1), and the transition from fossil groundwater to renewable CAP supplies began following the publication of Water Plan 2004 (Figure 1-2). Groundwater recovered from CAP recharge areas (i.e., groundwater from renewable supplies) makes up the majority of the water supplied by Tucson Water. In addition, recognizing the interconnected nature of water, Tucson has invested in numerous projects that ensure a sustainable supply while improving the quality of life for area residents. For example, the Southeast Houghton Area Recharge Project (SHARP), which opened in 2020, provides 40 acres of desert landscape for walking and recreating while recharging more than 1 billion gallons of recycled water per year to the aquifer.

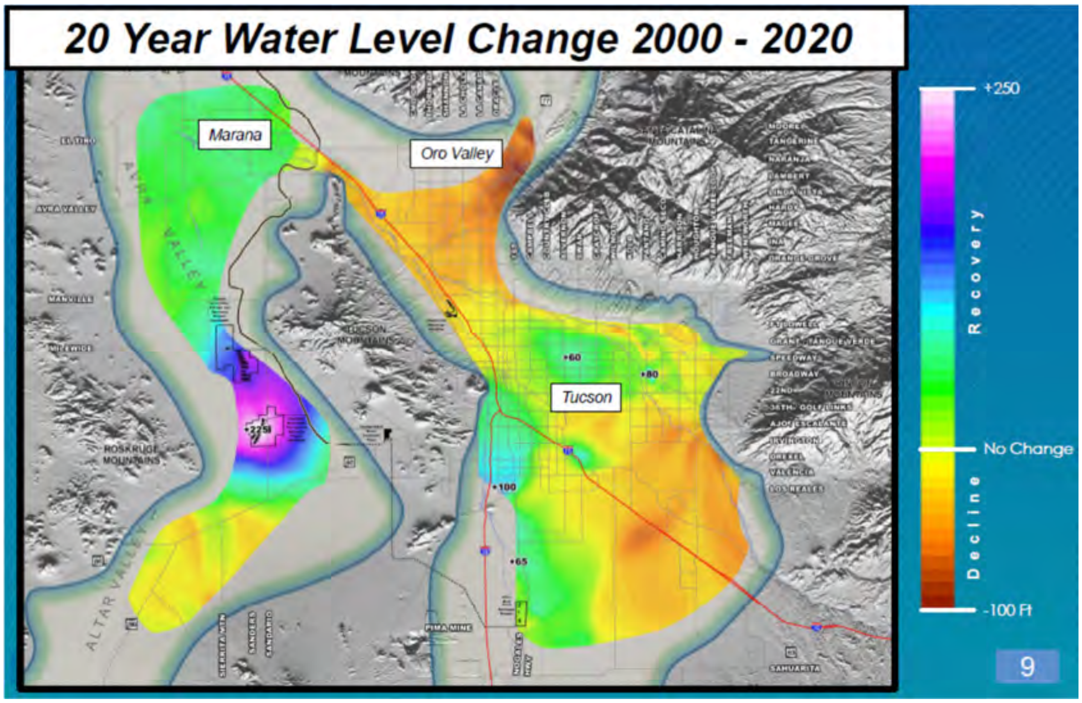


Figure 1-1. Illustration showing the increase in water levels in Tucson's central wellfield and in recharge areas to the west of the city (Central Avra Valley Storage and Recovery Project [CAVSARP] and Southern Avra Valley Storage and Recovery Project [SAVSARP]) between 2000 and 2020.

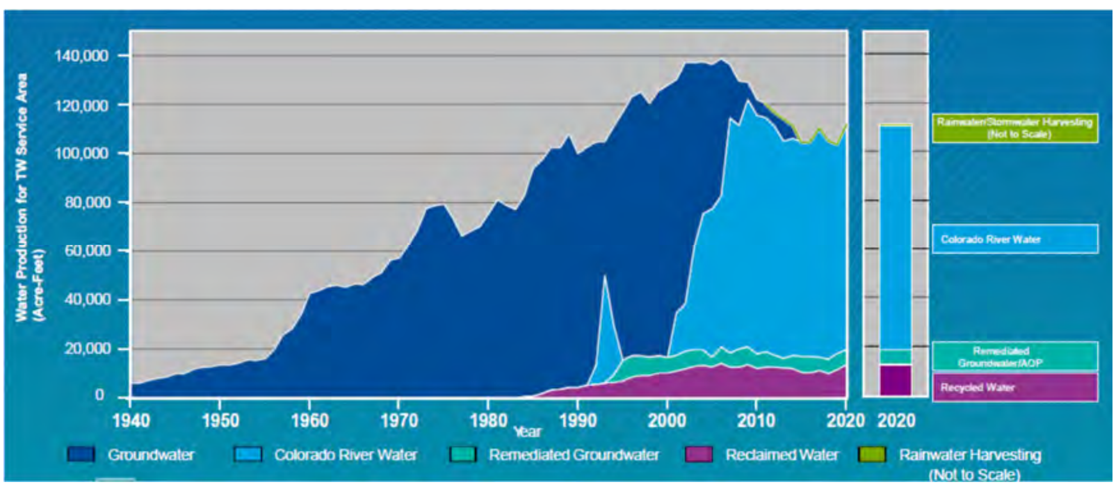


Figure 1-2. The arrival of CAP water in the late 1990s allowed the transition from non-renewable to renewable water sources – a key pathway identified in the Water Plan: 2000-2050.

Another concern identified in 2004 was land subsidence due to over-pumping of groundwater. While this issue is largely resolved in the central basin and in the Tucson Active Management Area, fissures resulting from over-pumping in rural areas surrounding Tucson have closed roads and damaged infrastructure. For this reason, the issue of land subsidence remains at the forefront of stakeholders' minds today.

The issues identified by stakeholders through the 1W2100 visioning exercise have common roots to those identified in 2004, but with contemporary twists. For example, the 1W2100 visioning and scenario planning work was conducted during some of the driest and hottest years in Tucson's history. A total of only 4.17 inches of rain fell throughout 2020, and the monsoon season was the driest on record. With this backdrop, risks to continuous high-quality water supply and uncertainty in demand trends were identified as key issues. Though the scenario planning work was conducted in 2021, a much wetter year on record, climate change and its impacts on the Colorado River and CAP allocations continued to be a primary concern. Climate change, underpinned by data showing that Tucson is the third fastest-warming city in the United States (Climate Central, 2019), together with recognition of the water-energy nexus, drove concern regarding climate from staff and the stakeholder groups. In addition, rather than a decision of how to use CAP water supplies, today's concerns relate to whether these supplies will remain viable in the long term with the watershed under a first-ever shortage declaration. Other top-of-mind issues include public education and equity awareness, conservation, water quality (particularly related to perfluoroalkyl substances [PFAS]), system resiliency, and governmental instability.

The following activities have all contributed to a positive water future for Tucson:

- Programs such as tiered water rates and education programs that encourage conservation
- Investment in stormwater and rainwater usage
- Regional collaborations and water-sharing agreements
- Maintain full CAP allocation through long-term storage buildup while reducing overall annual consumption

However, risks abound. Events that occurred during the 1W2100 scenario planning work and that influence key drivers and possible pathways include the declaration of shortage on the Colorado River, the shutdown of the Tucson Airport Remediation Project (TARP), and a global pandemic. Each of these events highlight uncertainty and the need for reliable, safe water.

Lake Mead was nearly full when Water Plan was released in 2004. Now, nearly 20 years later, significantly declining levels in Lake Mead are driving allocation changes and decisions. Figure 1-3 shows the projected level of Lake Mead, the sentinel reservoir, through 2023. The tiered Drought Contingency Plan, negotiated in 2019, places the burden of the initial reduction resulting from a shortage declaration on the agricultural industry. Tucson Water's allocation of water supplies are not reduced in their first two tiers, and the recharge of CAP at SAVSARP and CAVSARP will continue. Table 1-1 shows the trigger levels for Tucson Water. If drought persists and water levels reach tier

3, there will be a 14 percent reduction in Tucson's water supply. Further, the management guidelines that govern water releases among basin states is set to expire in 2026. To prepare, Arizona is forming the Arizona Reconsultation Committee (ARC) to develop an Arizona perspective for reconsultation of the Colorado River Interim Guidelines. Renegotiation may result in a change to Tucson's allocation even if drought eases. These events influence the scenario planning described herein.

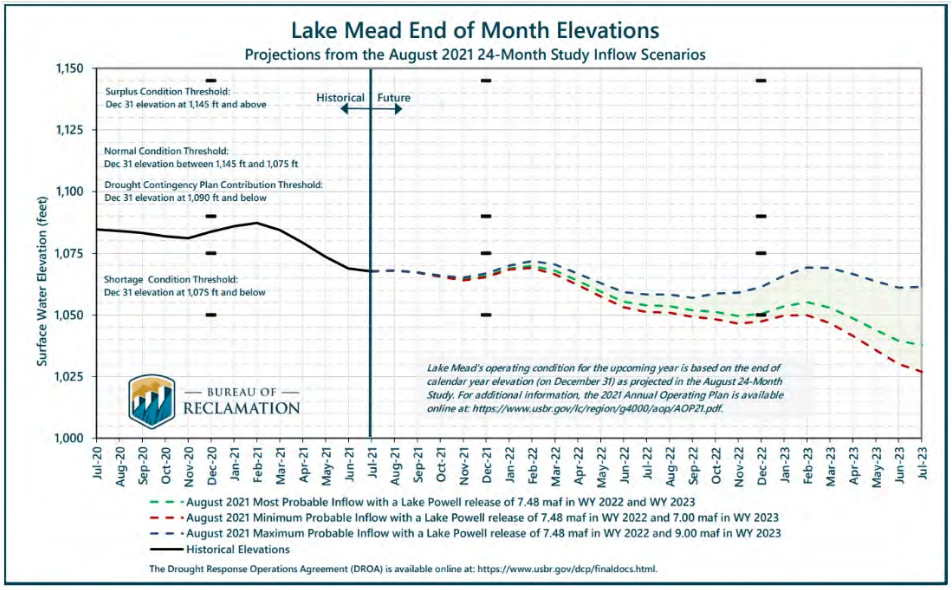


Figure 1-3. Projected Lake Mead water levels through July 2023.

Table 1-1. Summary of Colorado River shortage predictions and impacts to Tucson.

Shortage Tier	Lake Mead Level	Probability estimate (summarized)	Cuts to Tucson	Net CAP water available to Tucson (acre-feet)	2020 potable demand (acre-feet)	Amount CAP water stored based on 2020 demand (acre-feet)
1	< 1075'	>99% in 2022	0	144,191	96,179	48,012
2	< 1045'	~25-55% in 2023-2024	0	144,191	96,179	48,012
3	< 1025'	~20% in 2025	~14%	124,004	96,179	27,825

Generated by Tucson Water, source of predictions Bureau of Reclamation: https://www.usbr.gov/lc/region/g4000/riverops/crss-5year-projections.html

In the second key event that occurred during the scenario planning work, Tucson stopped supplying TARP-treated water to the public due to increasing PFAS concentrations. This water supply, shown on Figure 1-2 as the teal “Remediated Water/AOP,” represented less than 10 percent of the overall supply; however, this water has now been removed from the potable supply. While the water will be diverted for discharge to the Santa Cruz River or for use in the reclaimed system, reliance on CAP or use of nonrenewable fossil groundwater will likely increase because of this event. For these and other reasons, uncertainties associated with water supply are key issues driving the development of 1W2100 and the scenario planning exercises described below.

The following sections summarize the results of the tasks, as well as foundational elements, planning approach, and visioning and scenario planning efforts to establish the framework for 1W2100.

1.2 One Water Overview

The One Water planning approach, originally documented in the Blueprint for One Water (WRF, 2017), involves first developing vision and guiding principles with key staff to establish direction for a comprehensive water plan. These principles are then used to engage public and community stakeholders to collect input to the process from their perspectives. To achieve these objectives, a One Water approach will include these elements:

- The mindset that all water has value
- A focus on multiple benefits
- Watershed-scale thinking and action
- Right-sized solutions
- Partnership for progress
- Inclusion and engagement of all

In short, One Water is an integrated planning and implementation approach to managing finite resources for long-term resilience and reliability. A distinguishing feature of the approach is the engagement of stakeholders and partners. The results from a One Water approach can take the form of a guiding framework, a document describing how to leverage existing plans, a scope defining prioritized water resource initiatives, or a combination thereof. The results are unique to each individual community and can be applied at many different scales (e.g., regional or local) depending on the specific needs of the entity. With guidance and support from Brown and Caldwell (BC), Tucson Water developed a unique One Water framework for 1W2100. The One Water planning approach, originally documented in the Blueprint for One Water (WRF, 2017), involves developing a One Water vision and guiding principles with key staff to establish direction for the plan, and engaging public and community stakeholders to provide valuable input and guidance to the process.

The City of Tucson's overall planning effort, currently in progress, includes multiple components united under the umbrella of Plan Tucson. Other city-wide planning documents include the Climate Action and Adaptation Plan (2022), People, Communities, and Homes Investment Plan (P-CHIP, 2021), Move Tucson (2021), and 1W2100 (2021) will provide the basis for the general plan update. Mayor Romero's office, Housing and Community Development, and the Department of Transportation and Mobility are using community wide stakeholder engagement practices to inform these plans. The 1W2100 Master Plan intends to provide a "comprehensive long-range plan to ensure the viability and quality of Tucson's water supply for the next 80 years." It is Tucson's vision to incorporate environmental sustainability, social equity, and economic vitality through water in a way that is atypical of previous water plans. Community engagement is critical to the success of 1W2100.

1.3 Project Overview

The approach included two major tasks led by Brown and Caldwell with support from Tucson Water:

- Task 1: One Water Planning and Visioning (June 2019 - March 2020). The One Water approach starts with the collection of ideas from key internal stakeholders and process. Also, as part of Task 1, Tucson Water engaged city leadership including Mayor and Council and Tucson Water's Director's Office, and the Citizens' Water Advisory Committee (CWAC). The approach benefits from developing internal champions through collaborative engagement of staff across all relevant departments within the organization. To accomplish this, Tucson Water identified staff throughout various City departments to participate in the One Water visioning process, including planning, engineering, conservation, environmental compliance, and hydrology. This team was engaged with a series of workshops, surveys, and one-on-one interviews. City leadership including Mayor and Council and Tucson Water's Director's Office, and the CWAC, were also engaged in workshops, surveys, and one-on-one interviews. Information collected from these two groups, leadership, and staff, was used in planning for the engagement of a broader community stakeholder group.
- Task 2: Scenario Planning (March 2020 – June 2021). In this task, the project team led the group of community-based stakeholders through a series of workshops and surveys to understand current supply and water system dynamics, then uncover system vulnerabilities, and finally identify robust solutions to achieve broad benefits over a range of potential future scenarios. Given the onset of the global pandemic caused by Covid-19, the original scenario planning process was paused for the remainder of 2020 and was re-envisioned as a virtual process in early 2021.

In all, these various participants provided feedback and guidance on the objectives, vision, and strategies for the 1W2100 integrated plan described herein.

To complete Task 2, BC and Tucson Water invited a diverse team of community representatives, business stakeholders, and local academics. Every effort was made to incorporate viewpoints from various socio-economic groups. Table 1-2 is a list of the various organizations that were invited to participate in the 1W2100 scenario planning efforts. These organization cover a range of missions such as preserving the environment, promoting sustainable farming practices, enacting improvements in the neighborhood on issues, protecting and restoring watershed health, protecting public health, and many other beneficial causes. A single representative of each organization provided insight specific to their concerns and priorities.

Table 1-2. Organizations invited to participate in the stakeholder team. The stakeholders participated in a series of workshops in Task 2 to work through the scenario planning process.

Tucson Local Organizations
BKW Farms
Chicanos Por La Causa
Citizens' Water Advisory Council (CWAC)
Community Water Coalition
Menlo Park Neighborhood Association
Merchant's Garden/Pima County Food Alliance/AZ Farm Bureau
Metropolitan Pima Alliance
Pima Council on Aging
Pima County Consumer Health and Food Safety
Pima County Emergency Management
Pima County Office of Sustainability
Primer Pools and Spas
Sonoran Institute - Resilient Communities and Watersheds
Southern Arizona Homebuilders Association
Sunnyside School District
Sustainable Tucson
Tucson Electric Power
Tucson Residents for Responsive Government
UA - Public Health
Unified Community Advisory Board (UCAB) - AZ Dept of Environmental Quality
University of Arizona (UA) School of Architecture
Visit Tucson

2 Vision and Guiding Principles

As described above, One Water planning begins with the collection of key themes and values for developing the One Water vision and guiding principles (Task 1). During the workshops, surveys, and interviews, information and insight was collected on the current state of water in Tucson. This information assisted the project team in forming focus statements for the scenario planning exercises in Task 2.

2.1 Mayor and Council and CWAC Outcomes

The project team developed a survey for city leadership. Those surveyed included representatives from the Citizens' Water Advisory Committee (CWAC), the mayor's and City council offices. The objective of the survey was to understand, from the perspective of leadership, what are the top challenges the City of Tucson faces over the next 80 years. The questions in the survey began with broader questions on challenges the city faces (i.e., "what are the biggest challenges that Tucson is facing over the next 80 years?") then continued with focused on water-related challenges (i.e., "what are the top three challenges, related to water, that the city faces?" Responses to these two questions are summarized in Figures 2-1 and 2-2. Interestingly, while the first question was not specific to water, the top concern identified affects water supply: extreme weather and climate change. Further, other top issues raised including social inequality and education, also can be related to water. In the second question, the clear top three water challenges were demand management, water quality and water supply. These initial responses, paired with one-on-one interviews to further investigate the survey responses, revealed that Tucson leadership recognizes the challenges associated with an uncertain future particularly with threats to water supply, climate and changes in demand.

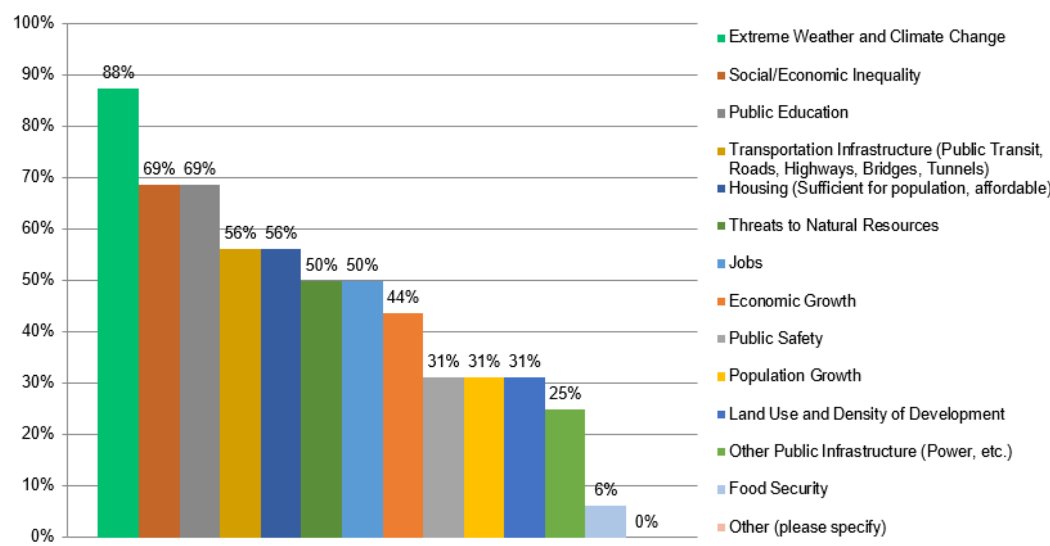


Figure 2-1. Survey responses to the question: what are the biggest challenges that Tucson is facing over the next 80 years?

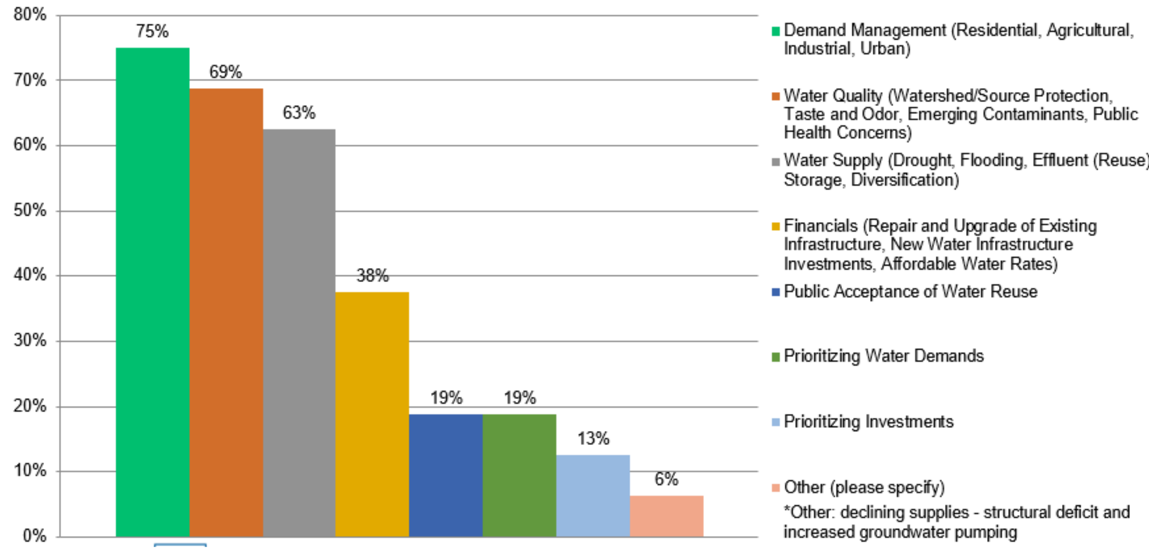


Figure 2-2. Survey responses to the question: what are the top three challenges that Tucson is facing related to water over the next 80 years?

BC's one-on-one interviews with individual members from CWAC, City Council, and the mayor's office helped decipher survey responses and dive deeper into specific concerns and key themes they would like considered in the One Water plan, vision, and guiding principles. These interviews were conducted over a two-day period from September 23-24, 2019 and included a total of 10 individual interviews. The interviews confirmed key themes identified by Tucson Water staff, including protecting quality of life, taking a One Water approach to resource management, equity, stormwater management, and climate change adaptation – elements that were echoed by community stakeholder participants and carried throughout the planning process. Notably, when asked how critical water is to sustaining Tucson's vitality, 100 percent of participants responded with "Very Important." The interviews also provided an opportunity to uncover issues specific to Tucson, including stormwater management, equity and water quality, which were presented as historic issues observed in the community. The interviewees listed specific outcomes they wanted to see out of 1W2100, which included climate resilience planning, adaptive planning, stakeholder involvement, the addressing of emerging contaminants, quality of life, and supply reliability.

The findings from the one-on-one interviews and surveys served as the foundation for establishing the One Water vision and guiding principles specific to Tucson Water and provided key issues to mitigate in 1W2100 and through the scenario planning process.

2.2 Tucson Water Staff Outcomes

In the first workshop, conducted in June 2019, roughly 30 staff members voted on the most important issues for One Water planning. Results from this exercise are provided in

Figure 2-3 below. The top issue concerning Tucson Water staff was quality of life, indicative of Tucson Water's commitment to its community. Climate change adaptation, infrastructure, and water quality followed as top priorities.

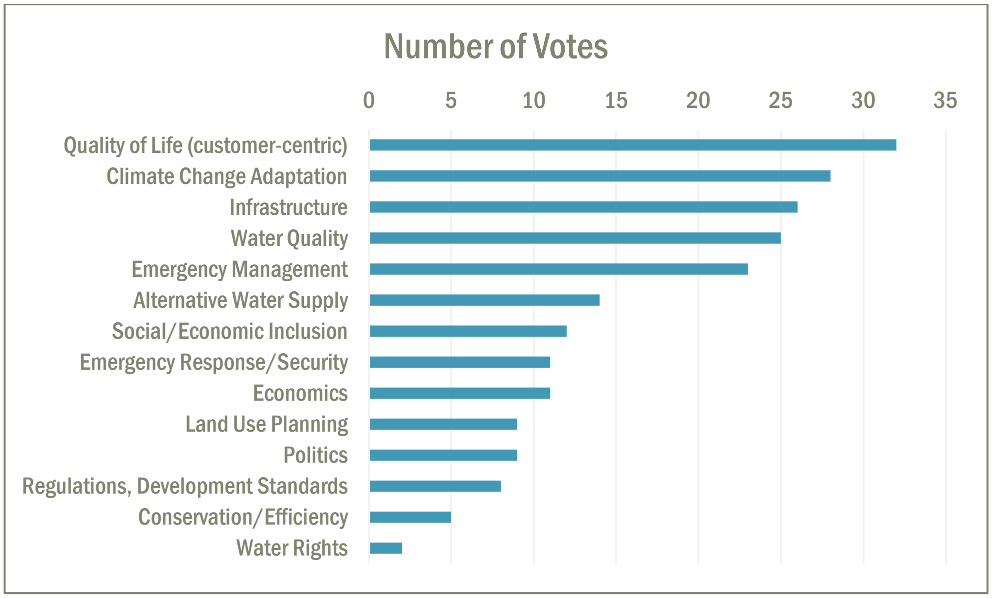


Figure 2-3. Results of City of Tucson Staff's prioritization exercise regarding the relative importance of various issues as related to One Water planning

With the top four priorities – quality of life, climate change adaptation, infrastructure, and water quality—identified, staff broke into smaller groups to determine foundational or organizational issues, obstacles or opportunities for improvement, drivers behind the priorities, and associated stakeholders effected by the priorities.

In the second workshop, conducted in October 2019, participants were briefed on feedback received from Tucson water leadership, asked to review draft vision statements and guiding principles, and were introduced to the upcoming scenario planning effort. Tucson staff was in alignment with the responses received from city leadership on Tucson's water challenges over the next 80 years which included demand management, water quality, water supply, financials. The group reviewed the draft One Water vision developed by BC and engaged in activity to customize their unique vision statement. Key words and phrases for the vision statement that resonated with staff included: collaboration, integrated, quality of life, resilience, adaptive, equity, stewardship and multi-beneficial. Regarding guiding principles, Staff participated in another activity to customize their One Water Guiding Principles. Six guiding-principle statements were written on posters and placed around the room. Staff broke into groups of three to four to circulate the room and review and comment on each guiding principle. Staff requested that words such as reinforce, enhance, and improve be removed from all statements as they imply a deficiency. Action words such as continue, commit, and provide were preferred. The results of workshop 2 provided the project team information from which to draft the vision statement and guiding principles.

One key takeaway from staff was the belief that, given actions taken over the previous 20 years and the fact that a significant amount of water has been banked in the aquifer, the future of water in Tucson is secure. This was a key result given that this group is intimately familiar with the current water scenario. This sentiment indicates that prior long-range plans and subsequent projects have created a sense of security around supply reliability despite mounting pressures and uncertainty. Additionally, some staff members acknowledged the bold leadership and vision from senior leadership within the organization who have clearly communicated the vision, priorities, and strategy. The purpose of 1W2100 is to ensure that water supply remains secure for the next 80 years and beyond.

2.3 Tucson Water Vision and Guiding Principles Development

With input from all the stakeholders in the planning process, the project team developed the following vision statement:

One Water is Tucson's commitment to:

- Resilience
- Equity
- Stewardship
- Quality of life

This statement encompasses many of the key themes uncovered through interviews with Mayor and Council. Tucson Water staff also developed the following guiding principles:

1. Deliver water reliability through water supply diversification, conservation, and innovative improvements to infrastructure.
2. Reinforce resiliency by planning for climate change, leading mitigation efforts, and implementing collaborative and adaptive strategies.
3. Enhance the community's quality of life by preserving and restoring riparian areas, increasing urban tree canopy, and supporting economic growth.
4. Achieve affordability, accessibility, and social justice by committing to fiscal responsibility and prioritizing equitable projects and programs.
5. Ensure public confidence with safe, high-quality water supplies and exceptional customer service that includes transparency and responsiveness.

The vision statement and guiding principles serve as the foundation of, and direction for, the 1W2100 plan and establishes Tucson Water's commitment to incorporating these themes throughout the planning process. Furthermore, these guiding principles may be used to inform Tucson Water's approach to water management going forward. They provide a foundation to reference as Tucson heads into an uncertain future and orients them to their core principles while they develop strategies to adapt to future issues. The One Water planning and visioning process also served as the launching point for the next phase of the One Water work with community stakeholders. A list of driving factors and uncertainties was developed as identified by key staff through the workshops, surveys, and interviews. The list of driving factors was the first introduction to the community stakeholders to review, provide feedback, and begin their process of develop management strategies through scenario planning visioning as discussed in Section 3.

3 1W2100 Scenario Planning

3.1 Introduction

Scenario planning has been used by organizations for decades to help prepare for uncertain futures. It offers insight into plausible combinations of risk (uncertain factors and the significance of their potential impacts) that could emerge as future realities. Scenario planning provides a structured framework for organizations to identify factors that could influence their future, characterize the uncertainties associated with each factor, and determine how impactful each range of uncertainty could be. Within this framework, today's decisions can be tested to see how resilient they may be to various combinations of the most impactful future uncertainties.

Figure 3-1 begins to illustrate the concept. The scenario planning effort takes a qualitative approach based on quantitative findings traditionally determined through modeling and/or planning studies. The qualitative approach in scenario planning includes developing scenarios to describe impactful uncertainties that create a structured space for planning, i.e., a framework of plausible future scenarios against which to test decisions. In this effort, the quantitative findings from the work completed by Jacobs Engineering, which included water use projection data, supported the qualitative scenario planning approach in which the summary from the work conducted was used to inform the stakeholders about the range of future outcomes to develop future narratives and risk mitigation strategies. The scenario planning approach taken in this work focuses on preparing for the most impactful plausible future.

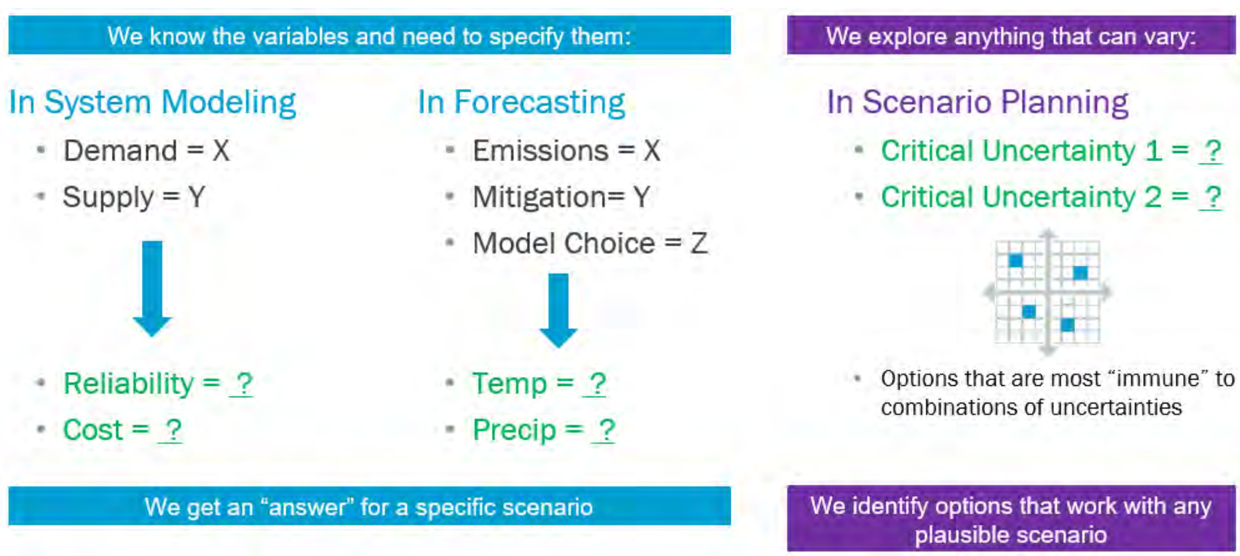


Figure 3-1. Traditional Planning and Scenario Planning

One useful way to visualize the philosophy of scenario planning is shown on Figure 3-2. Many traditional planning methods attempt to forecast future conditions either deterministically or probabilistically, and base decisions on the "most likely" future. Scenario planning acknowledges that beyond any probable future are a wide range of plausible futures, none considered any more probable than any other. In this context, the resilience of decisions made today can be tested against a range of plausible future condition to determine how durable they can be shown to be against the most critical uncertainties.

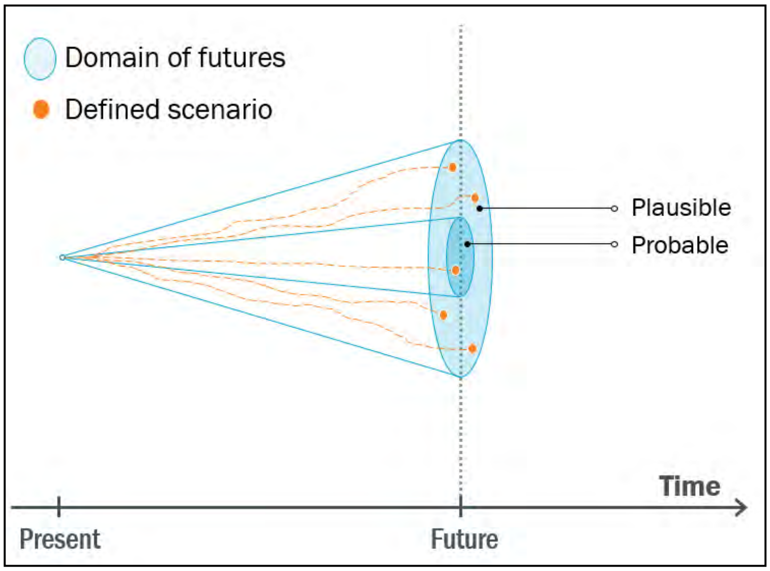


Figure 3-2. Plausible Future Scenarios Emphasized Over Probable

More specifically, scenario planning combines the most uncertain and most impactful future conditions (perhaps climate, economics, politics or institutional leadership, public health, demographics, etc.) and combines them across their full spectrum of possibilities in the form of 2 x 2 matrices to create four quadrants that describe plausible future conditions. Resource management or institutional strategy decisions are then formulated and tested in all four quadrants of uncertainty (all four "scenarios"), so that organizations are well-equipped to manage the most potentially impactful future conditions.

A useful analogy is asset management, where facilities are renewed based on the combined influence of likelihood and consequence of failure. The facilities that have the greatest probability of failure and the greatest impact in the event of a failure receive the greatest allocation of resources for improvements. In the scenario planning realm, we look at uncertainty and potential impacts of that uncertainty in much the same way to guide institutional decisions.

Figure 3-3 illustrates a typical process for scenario planning, in general terms. The remaining figures in this section illustrate the process in more detail. Tucson Water's results for this same framework are included in Sections 3.3 - 3.4.

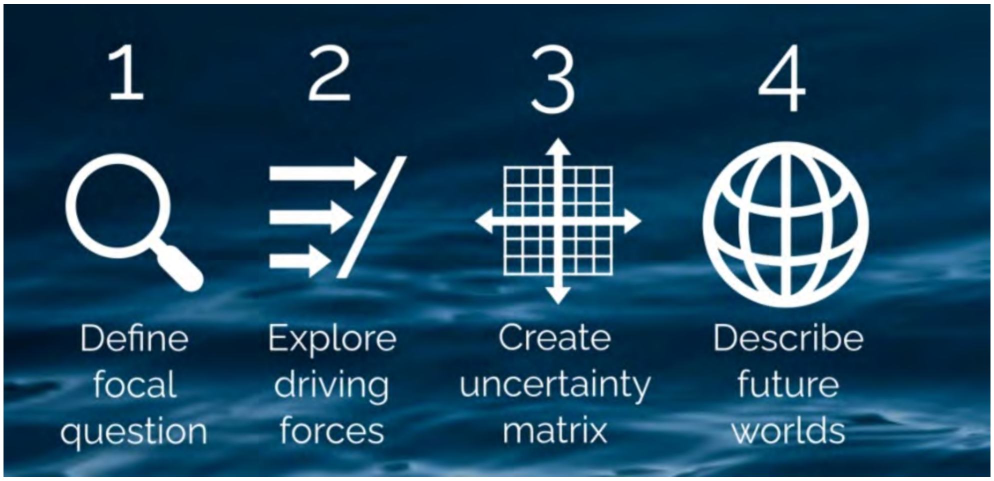


Figure 3-3. Standard Scenario Planning Process

The specific steps in scenario planning (generic):

- **Step 1:** Define the Focal Question: articulate the driving question that must be addressed.
- **Step 2:** Define factors, uncertainty, and criticality.
- **Step 2a:** Brainstorm factors that could influence future conditions (drivers).
- **Step 2b:** Group the factors by theme and rank based on uncertainty. "Uncertainty" is defined here as either a broad or narrow range of possible outcomes, without yet considering the consequences of each range.
- **Step 2c:** Rank each group of factors by the criticality/impactfulness of its uncertainty. "Impactfulness" is defined as the potential consequences of experiencing either end of the spectrum of uncertainty.
- **Step 3:** Define plausible future conditions.
- **Step 3a:** Combine the Factors with Highest Critical Uncertainty (Greatest Risks) into 2 X 2 Grids. The axes of each grid are defined as the extreme ranges of uncertainty, and do not necessarily need to be positive/negative.
- **Step 3b:** Identify the most useful grid (or grids) for future planning. Note that this is an example only and does not reflect the specific drivers or axes defined by Tucson Water – See Section 3.3 – 3.4.
- **Step 4a:** In narrative form, describe the 4 quadrants as equally plausible future scenarios. This is an example of a quadrant description from Tucson Water's Scenario Planning Exercise:
    - Quadrant A: In a managed water use reality, we observe a decrease in demand resulting from intentional education, policies driving stewardship, and social equity programs. However, water use is tightly managed because

our reliance on limited water resources could or has resulted in a decrease in available supply, or unreliable quantities of water year to year.

The steps described above are illustrated in Appendix A Scenario Planning Process.

3.2 The Focal Question

The focal question for Tucson Water (step 1 in the process outlined above) is best expressed as the transition between a current state assessment and an outlook into the future:

"Through a diverse water supply portfolio and prudent storage of surplus CAP water, Tucson Water is well prepared for a severe drought in the Colorado River Basin in the near term. What adjustments to the supply portfolio and water management policies, both now and in the future, could help us provide the same confident assurance to all people of Tucson throughout the 21st Century?"

3.3 Critical Drivers and Uncertainties

The scenario planning stakeholder group met virtually on March 15, 2021 for the first of three workshops. During the first workshop they developed a list of uncertainties that could affect Tucson Water. The BC and Tucson Water staff team then developed categories to group the uncertainties listed into eight major driving factors. Table 3-1 summarizes the driving factors, and the specific uncertainties that comprise the categories, as developed with the stakeholders. This table represents the results of Steps 2a and a portion of 2b outlined above.

Table 3-1. Tucson Water Driving Factors and Uncertainty

Major Driving Factors	Uncertainties Identified by Stakeholders
Water Supply Changes	Threats to natural resources: CAP, water rights, water quality, the watershed and the Colorado River (induced by climate, political, or other human factors). Opportunities for green infrastructure (rainwater harvesting). Premise plumbing and effects on water quality. Environmental risks to riparian areas and stream recharge and how those affect the overall water system. Groundwater quality (contaminants of emerging concern and perfluorinated compounds).

Major Driving Factors	Uncertainties Identified by Stakeholders
Water Demand Changes	Land use changes due to climate or zoning changes. Economic factors, such as availability/lack of availability of incentives for business and housing affordability. Population trends (significant and/or unplanned increase or decrease). Forms of transportation and incorporating green infrastructure opportunities to offset demand. Effects from water conservation. Potential for Tucson Water to acquire other service areas or remove service areas outside core area.
System Resilience	Water system reliability. Smart technologies. • Cyber security threats • Possible efficiency improvements Climate effects on infrastructure. Emergency planning and response.
Community/Educational Factors	Potential for public misinformation. Potential for widespread community engagement. Public acceptance and support (reclaimed water, resource dependency, etc.).
Equity and Affordability	Cost of service, affordability for all demographics. Realization of equity – understanding what it looks like and how it could be achieved. Stormwater and flooding impacts specifically observed in lower income areas.
Government/ Policy/ Regulations	Policy making on regional, state, and federal levels. Regulatory trends on all levels (local, state, and federal). State politics and decisions. Government instability.
Water-Energy Nexus	Ability to provide energy security, recognizing the energy future might be out of Tucson Water's control. Incorporating redundancy for resilience. Ability to reduce carbon footprint.
Economic Variability	Change in workforce. Potential for youth flight due to climate effects. Changes in business connections to water service/ inability to incentivize business connections. Aging workforce and whether that leads to population increase or decrease.

These eight prevailing factors were then ranked by stakeholders (on relative scales) based on their inherent uncertainty, and again on the impacts of that uncertainty, using the following guiding definitions:

- **Uncertainty:** The unknown range of affects a driver may have, whether positive or negative.
- **Potential Impact:** The criticality of uncertainty on the efficacy of decisions: Sometimes uncertainty matters and other times it may not.

Throughout the process, the analogy of a wedding plan was used to help clarify these definitions. If a wedding is planned for a Saturday, one might say that the weather for the Friday before the wedding and the Saturday of the wedding is equally uncertain, but only one of these uncertainties could impact the wedding. BC also used the analogy of asset management, in which total risk is a combined function of both the likelihood of failure (uncertainty) and the consequence of failure (potential impact). Together, uncertainty and potential impact of the uncertainty offer a profile on the risks posed by each driving factor.

Figures 3-4 and 3-5 illustrate how the stakeholders ranked the eight factors based on their relative uncertainty and potential impact (shown separately). Figure 3-6 combines the results using the average placement of each driver in the individual stakeholder lists and illustrates that the drivers identified range from high uncertainty with high impact to moderate uncertainty with low impact. These results completed steps 2b and 2c of the process outlined above and prepared the stakeholders for Step 3, in which they identified the most important drivers for the 1W2100 Plan and redefined them using some of the less-impactful drivers, as discussed in the following sections.

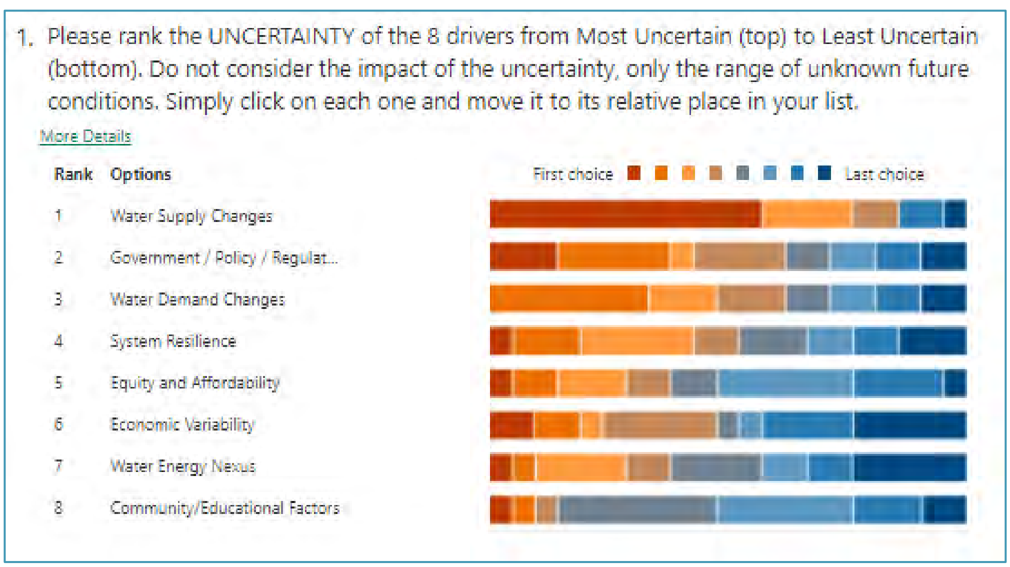


Figure 3-4. Stakeholder Survey Question and Results for Relative Uncertainty of Driving Factors

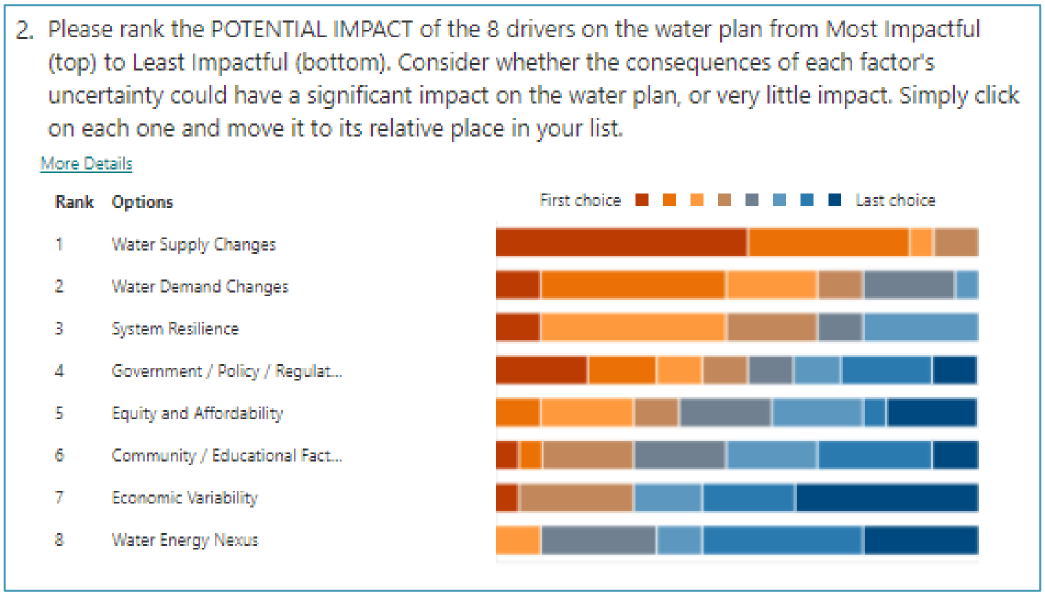


Figure 3-5. Stakeholder Survey Question and Results for Relative Potential Impact of Driving Factors

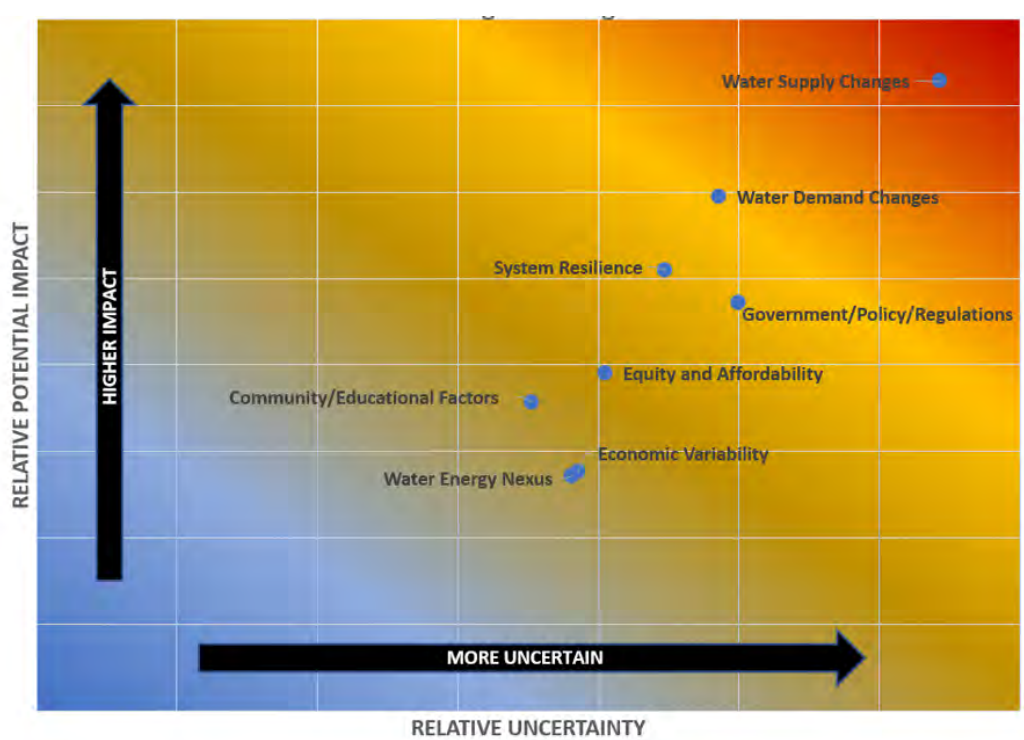


Figure 3-6. Average Stakeholder Results for Uncertainty and Impact of Driving Factors

3.4 Future Scenarios

As illustrated on Figure 3-7, stakeholders identified four of the eight driving factors as High Uncertainty / High Impact:

- Water supply changes
- Water demand changes
- System resilience
- Government/Policy/Regulations

In Step 3a outlined above, the group experimented with various combinations of these four drivers in the form of a 2 x 2 grid, in which each axis represented the full spectrum of uncertain outcomes for one of the two factors, and each quadrant, therefore, represented a future "scenario" based on the combinations of the two. Tucson Water's stakeholders felt that it was important to also include some of the driving factors with less uncertainty or impact to help ensure that the future conditions explored in this exercise were broadly representative of their interests and concerns. Ultimately, four subgroups of the stakeholder committee were formed to explore four combinations of drivers, as outlined in Table 3-2, and highlighted in the left columns of Figure 3-7.

Pair ID	Driver 1	Driver 2
A	Supply	Demand
B	Supply	Resilience
C	Supply	Govt/Policy/ Regs
D	Demand	Resilience
E	Demand	Govt/Policy/ Regs
F	Resilience	Govt/Policy/ Regs
G	Equity/ Affordability	Supply or Demand
H	Community/ Ed. Factors	Supply or Demand
I	Water-Energy Nexus	Supply or Demand
J	Economic Variability	Supply or Demand

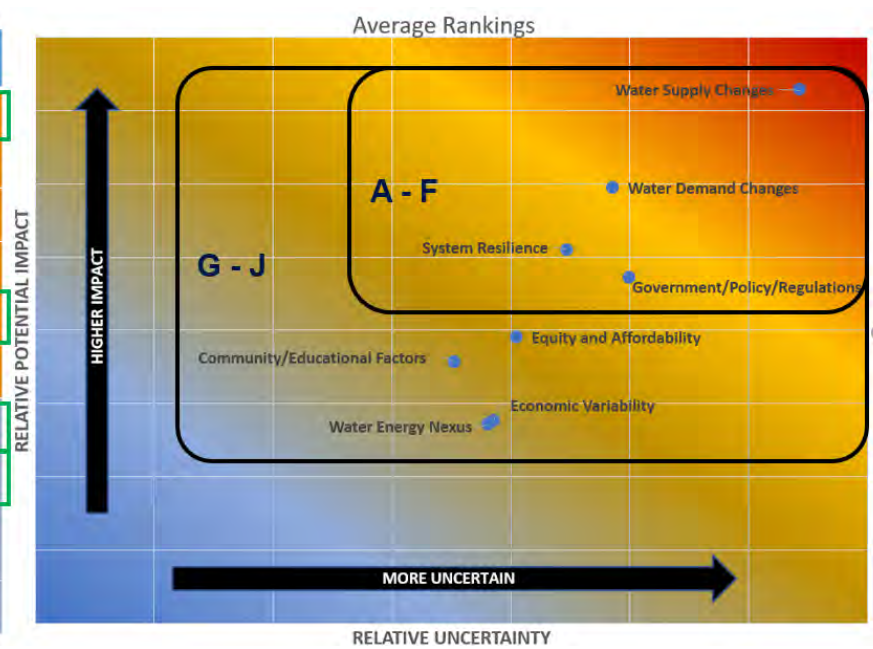


Figure 3-7. Groupings of Factors for Future Scenarios

Table 3-2. Selected Pairings of Driving Factors for Exploratory Scenario Definition

DRIVER 1	DRIVER 2
Water Supply Changes	Water Demand Changes
Water Demand Changes	Government/Policy/Regulations
Equity/Affordability	Supply or Demand (and/or)
Community/Education Factors	Supply or Demand

Each group created a 2 x 2 matrix as part of Step 3a and deliberated on combinations of their chosen drivers that create future conditions, or scenarios. Some instructive observations from these deliberations included:

- Each of the groups focused in some way on either water supply or water demand uncertainties, or both.
- Through discussion, the groups recognized that uncertainties in equity, affordability, education, and government/regulatory decisions were a "means" to arriving at future conditions in which supply and/or demand had experienced significant changes. As such, these driving factors were incorporated into the definition of the principal uncertainties of supply and demand and their associated scenarios in Step 4, to be discussed below.
- The groups recognized that the most common, most uncertain, and most potentially impactful uncertainties were those associated directly with future supply and future demand. Hence, as Step 3b, these two uncertainties were combined into the overarching matrix of four future scenarios around which alternative water management strategies were developed in Step 4, to be discussed below.

Figure 3-8 presents the governing matrix for the formulation of alternative water management strategies in Step 4. The first action in Step 4 was to develop narrative descriptions of each future scenario based on the plausible combination of supply and demand trends in each quadrant. Figure 3-8 illustrates the definition of the supply and demand axes, which incorporate previously identified and explored driving factors as key reasons why future conditions may develop. Figure 3-8 also includes the narrative description of each combination of supply and demand uncertainties, as developed by stakeholders who were asked to "imagine living in this quadrant in 50 years and explain what you observe."

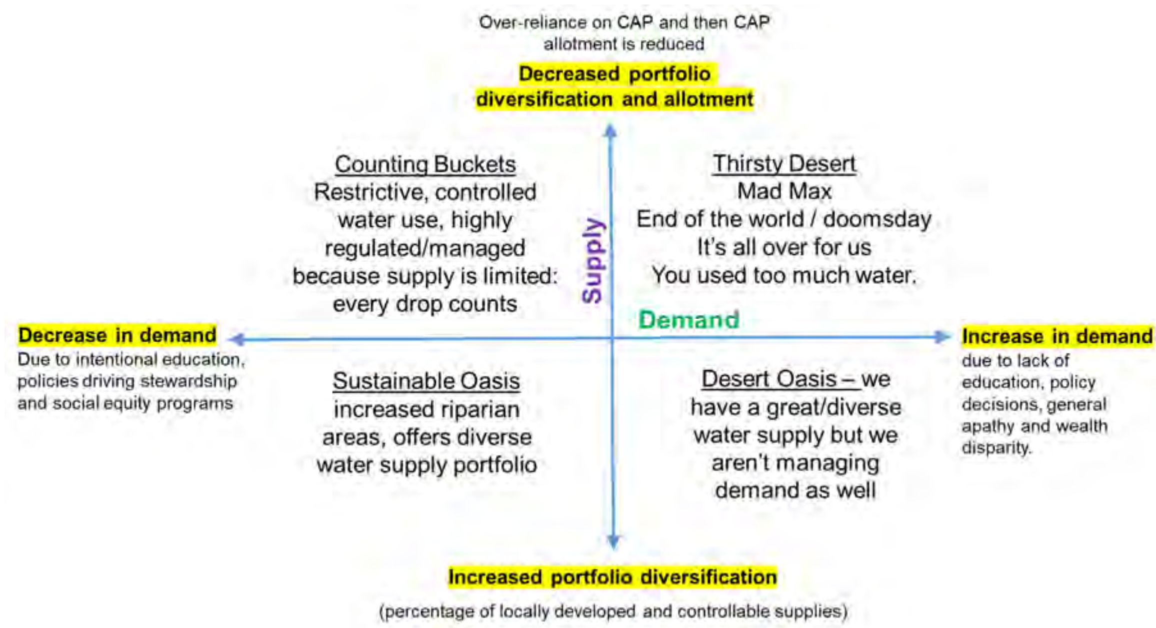


Figure 3-8. Plausible Future Scenarios

3.5 Conclusions: Stakeholder Findings and Recommended Water Management Strategies

As a final exercise (Step 4b), the stakeholders were asked to formulate approaches to either mitigate imagined circumstances associated with future scenarios, or to help avoid the circumstances from developing. Figure 3-9 illustrates how each of the four groups (each associated with one of the four scenario quadrants in Figure 3-8), approached this by discussing relative changes to current water supply portfolio allocations. Figure 3-9 illustrates the results of this discussion. The relative height of bars and the allocations within them do not represent numerical values. They are illustrations of the relative importance that different water supply types were given during each group's discussion. The first bar on the left represents Tucson Water's current, relative allocation of water supply sources. Each of the bars to the right present recommendations from the individual groups focused on specific future supply and demand scenarios.

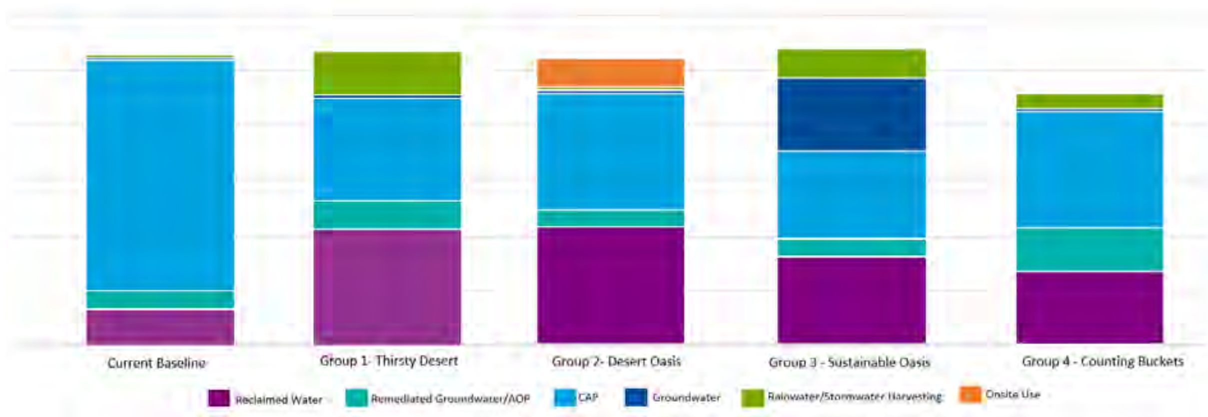


Figure 3-9. Testing Alternatives or Decisions Against Plausible Futures (RELATIVE CHANGES ONLY – Nonquantitative.)

All groups agreed on many recommendations, suggesting that certain decisions could be beneficial regardless of which supply and demand conditions emerge in the future. These universal recommendations build "immunity" to future uncertainty because they address uncertainties in each of the four scenario quadrants. The concluding recommendations from the stakeholder-driven scenario planning process are as follows:

- Tucson should plan on reducing reliance on CAP water through increased efficiency and conservation
- Increase on the use of reclaimed water to help offset reliance on CAP water, either moderately or significantly.
- Continue to treat or remediate groundwater
- Expand rainwater and stormwater harvesting
- Develop onsite reuse strategies

In general, these recommendations seek to increase the use of locally controlled and distributed water resources and decrease reliance on CAP water.

The stakeholders also recommended the following practices to be upheld in 1W2100:

- Develop and implement a consistent and effective public outreach and education campaign on water conservation and local water management strategies – this can help manage future uncertainty.
- Promote awareness of equity in the community to help avoid future conditions in which the economics of water in Tucson are unreasonably stratified and decisions difficult to implement, including policy and other water related decisions.
- Remain involved in state and federal policy and regulatory discussions
- Consider opportunities to reduce emissions in light of the water-energy nexus

4 References

Water Research Foundation (WRF). 2017. Blueprint for One Water. Denver, Colorado. Project 4660.

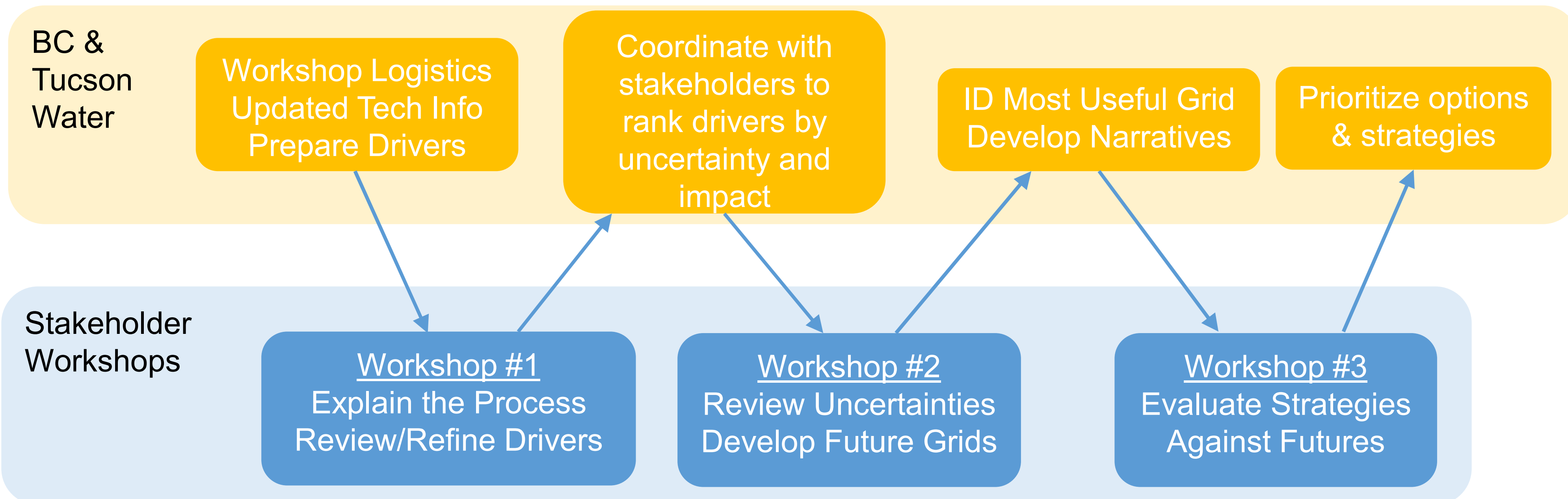
Climate Central. 2019. American Warming: The Fastest-Warming Cities and States in the U.S. Research Brief. April 17, 2019.

Appendix A. Scenario Planning Process

Scenario Planning

Putting it into action for Tucson Water

Your Role in Tucson Water's One Water Process:
Scenario Planning to Identify and Mitigate Uncertainties



DRIVERS

Tucson Water brainstorms driving factors that are causing them to take action, and whose uncertainty could affect the efficacy of the plan

xxxx

xxxx xxxx xxxx xxxx

xxxx xxxx xxxx

xxxx xxxx xxxx xxxx

xxxx xxxx xxxx xxxx

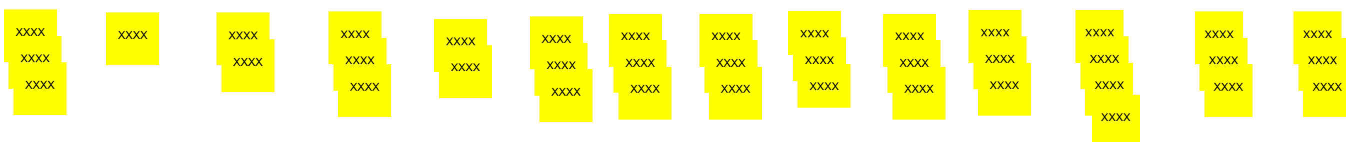
xxxx xxxx xxxxv xxxx xxxx

xxxx xxxx xxxx

xxxx

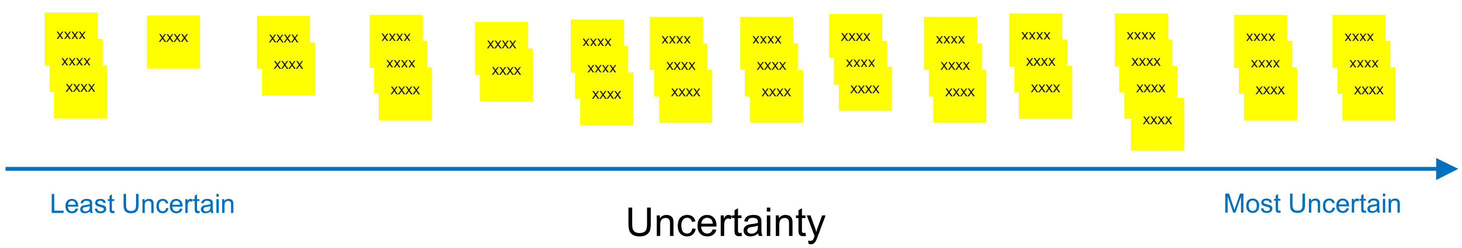
RELATED THEMES

We will help group the drivers into related themes



RELATIVE UNCERTAINTY OF THE DRIVERS

Stakeholders will refine the drivers and help rank them on their uncertainty

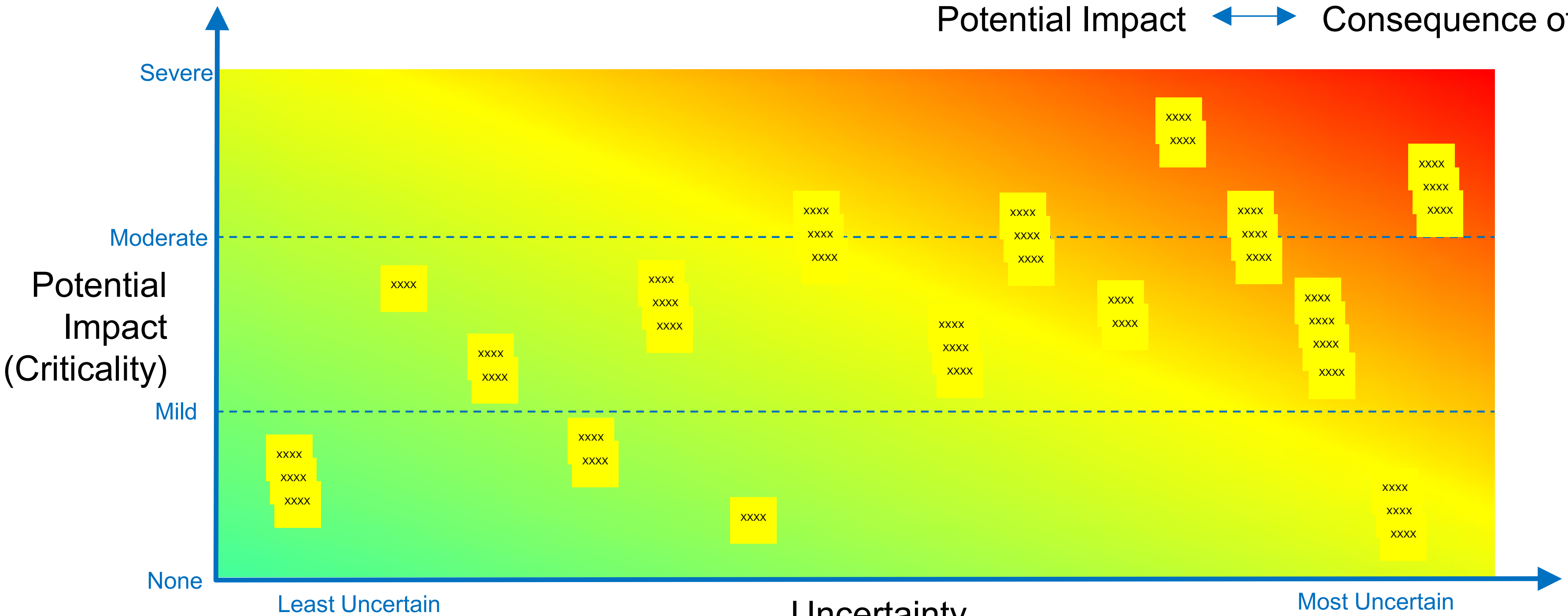


RELATIVE IMPACT OF THE UNCERTAINTY

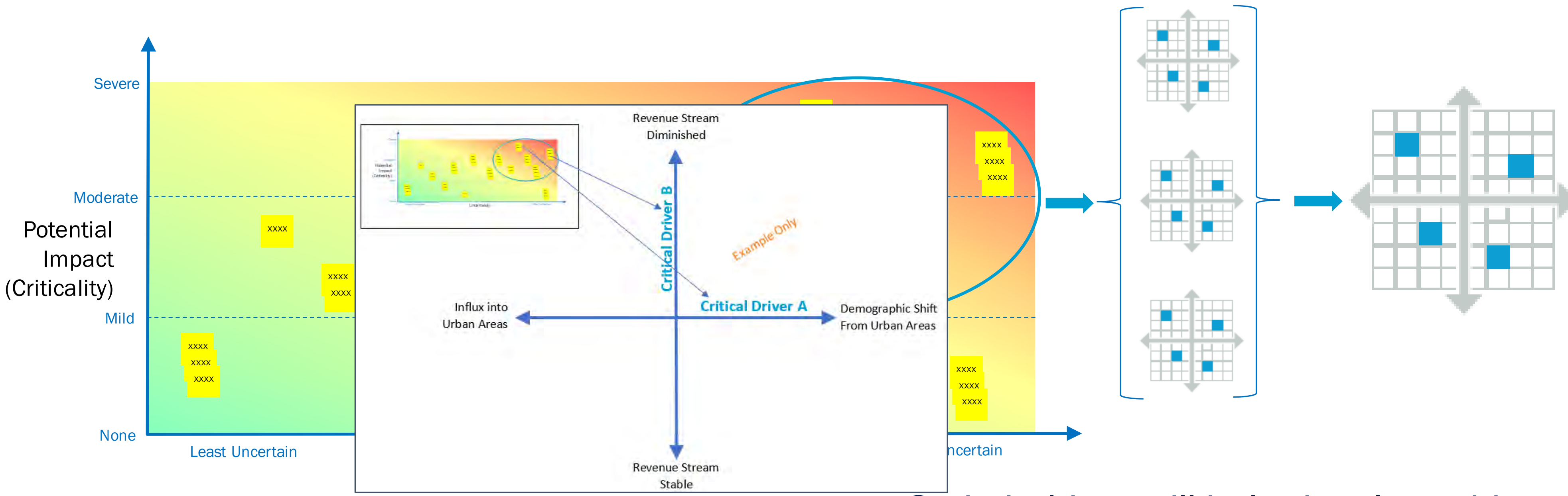
Stakeholders will help rank the drivers on their impact

We will borrow some philosophy from Asset Management:

Uncertainty ↔ Likelihood of Failure
Potential Impact ↔ Consequence of Failure

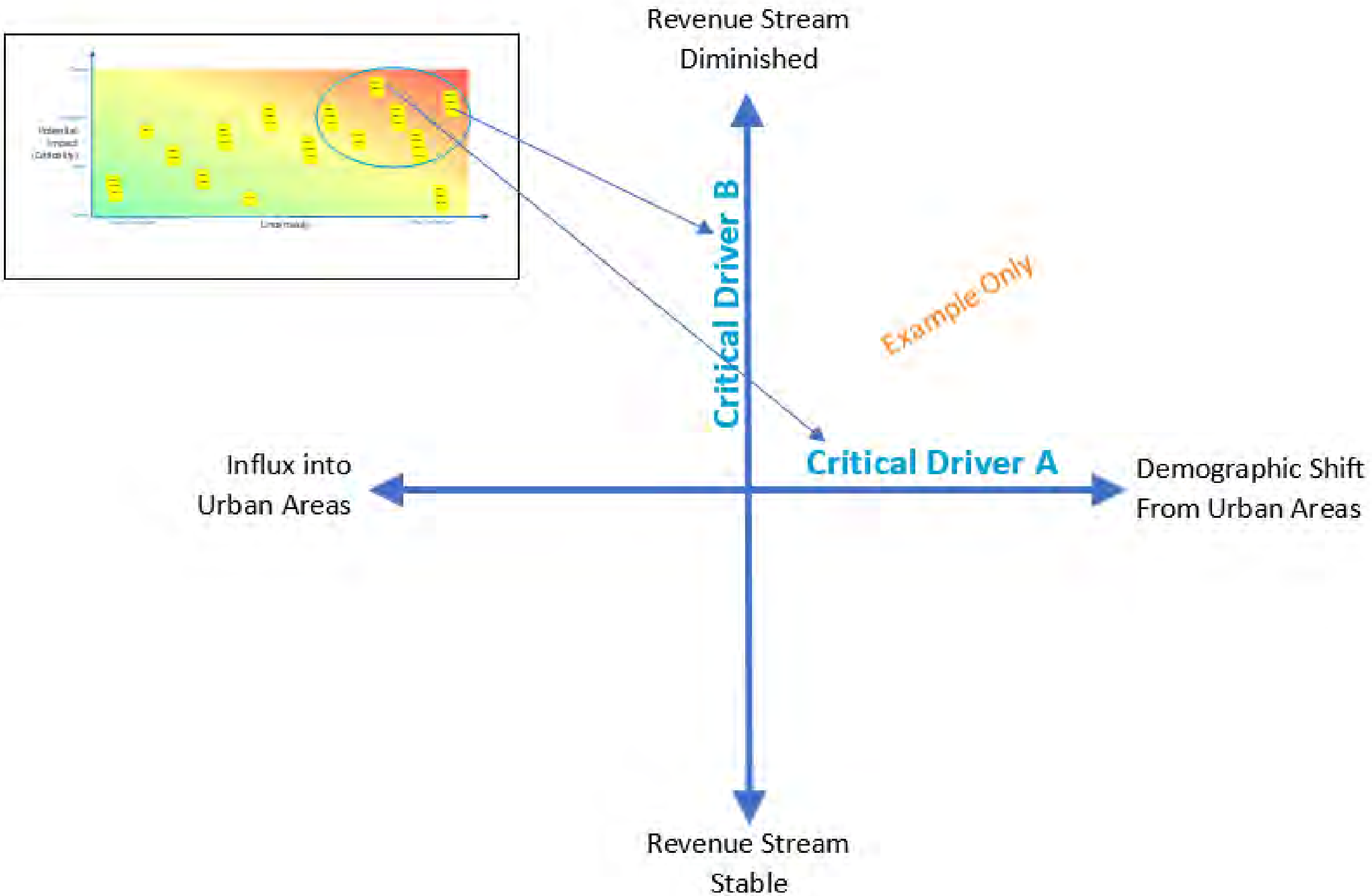


COMBINING THE MOST IMPACTFUL UNCERTAINTIES



Stakeholders will help develop grids of future risk and evaluate strategies to mitigate risk

Defining Plausible, High-Risk Futures



Testing Alternatives Against Plausible Futures

Alternatives	Quadrant A	Quadrant B	Quadrant C	Quadrant D
Alternative A	Extremely Satisfied	Dissatisfied	Dissatisfied	Extremely Dissatisfied
Alternative B	Extremely Satisfied	Satisfied	Dissatisfied	Dissatisfied
Alternative C	Extremely Satisfied	Satisfied	Dissatisfied	Extremely Dissatisfied
Alternative D	Satisfied	Satisfied	Satisfied	Satisfied

- Extremely Satisfied
- Satisfied
- Dissatisfied
- Extremely Dissatisfied

Appendix D
ONE WATER 2100 STAKEHOLDER PARTICIPATION

Organizations
Arts Foundation for Tucson and Southern Arizona
AZ Lodging & Tourism Association
BKW Farms
Building Owners & Managers Association
Chicanos Por La Causa
Coalition for Sonoran Desert Protection
Community Food Bank
Community Home Repair Projects of AZ
Community Water Coalition
CWAC
EcoBlue
EEE
Fourth Avenue Merchants Association
Local First Arizona
Merchant's Garden/Pima County Food Alliance/AZ Farm Bureau
Metropolitan Pima Alliance
Paul Ash Management for the Meadows Townhouses
Pima Council on Aging
Pima County Consumer Health and Food Safety
Pima County Emergency Management
Pima County Office of Sustainability, Water
Pima County Wastewater
Primer Pools and Spas
Raytheon Sustainability Manager
So. AZ Chapter of the National Assn. of Residential Property Managers
Sonoran Institute - Resilient Communities and Watersheds
Sonoran Oasis Landscaping
Southern Arizona Leadership Council
Startup Tucson
Sunnyside School District
Sustainable Tucson
Technicians for Sustainability
Trees for Tucson
Tucson Electric Power
Tucson Metropolitan Chamber of Commerce
Tucson Residents for Responsive Government
Tucson Young Professionals
UA - Public Health
UA AIRES
UA AVP, Facilities Management
UA Energy Manager
UA School of Architecture
UA Technology Park
UA Utility Services
UCAB-AZ Dept of Environmental Quality
Visit Tucson
Watershed Management Group

Appendix E

ONE WATER 2100 WATER QUALITY MANAGEMENT

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
WATER QUALITY MANAGEMENT

FINAL | March 2022

Tucson Water

One Water 2100 Master Plan

Technical Memorandum

WATER QUALITY MANAGEMENT

FINAL | March 2022

Registered Professional Engineer (Environmental)
CERTIFICATE NO.
60041
CORIN A.
MARRON
DATE SIGNED
ARIZONA, U.S.A.

Digitally signed by Corin A. Marron
Contact Info: Carollo Engineers, Inc.
Date: 2022.03.07 18:09:44-07'00'

Contents

Appendices

Tables

Figures

Abbreviations

µm	micrometer(s)
µmg/L	micrograms per liter
A.A.C.	Arizona Administrative Code
ac-ft	acre-foot
ADEQ	Arizona Department of Environmental Quality
AFFF	aqueous film-forming foam
AL	action level
ALE	action level exceedance
APP	Aquifer Protection Permit
AZPDES	Arizona Pollutant Discharge Elimination System
CAP	Central Arizona Project
Carollo	Carollo Engineers, Inc.
CAVSARP	Central Avra Valley Storage and Recovery Project
CCL	Contaminant Candidate List
CCPP	calcium carbonate precipitation potential
CCR	Consumer Confidence Report
CCT	corrosion control treatment
CEC	contaminant of emerging concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CFU	colony forming units
CT	concentration times time
CTPP	Central Tucson PFAS Project
cVOC	carcinogenic volatile organic compound
D/DBPR	Disinfectants and Disinfection Byproducts Rule
DBCP	1,2-Dibromo-3-chloropropane
DBP	disinfection byproducts
DBPR	Disinfection Byproducts Rule
DMAFB	Davis Monthan Air Force Base
EDB	ethylene dibromide
EDC	endocrine disrupting compound
EPA	United States Environmental Protection Agency
FBRR	Filter Backwash Recycling Rule
FR	Federal Register
GAC	granular activated carbon
GRR	galvanized requiring replacement
GTLO	Get the Lead Out
GWR	Ground Water Rule
GWS	groundwater system

HAA5	haloacetic acids (total of concentrations of 5 selected compounds)
HAB	harmful algal blooms
HAL	Health Advisory Level
HAN	haloacetonitriles
HCFC	hydrochlorofluorocarbon
HK	haloketones
HNM	halonitromethanes
HPC	heterotrophic plate count
IESWTR	Interim Enhanced Surface Water Treatment Rule
IOC	inorganic contaminant
IRIS	Integrated Risk Information System
IX	ion exchange
LCR	Lead and Copper Rule
LCRMR	Lead and Copper Rule Minor Revisions
LCRR	Lead and Copper Rule Revisions
LRAA	locational running annual average
LSI	Langelier Saturation Index
LSL	lead service line
LT1ESWTR	Long-Term 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MDBP	Microbials and Disinfection Byproducts
mg/L	milligrams per liter
mgd	million gallons per day
mL	milliliter(s)
MPN	most probable number
MRDL	maximum residual disinfectant level
MRDLG	maximum residual disinfectant level goal
mrem	millirem (milli-roentgen equivalent man)
MRL	minimum reporting limit
NA	not applicable
NCOD	National Drinking Water Contaminant Occurrence Database
NDBA	nitrosodibutylamine
NDEA	N-nitrosodiethylamine
NDMA	N-nitrosodimethylamine
NDPA	N-nitrosodi-n-propylamine
NDPhA	N-nitrosodiphenylamine
NOM	natural organic matter

NPDES	National Pollution Discharge Elimination System
NPDWR	National Primary Drinking Water Regulations
NPYR	nitrosopyrrolidine
NSDWR	National Secondary Drinking Water Regulations
NTU	nephelometric turbidity unit
PAG	Pima Association of Governments
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi/L	picocuries per liter
PFAS	per- and poly-fluoroalkyl substances
PFBS	perfluorobutane sulfonic acid
PFHpA	perfluoroheptanoic acid
PFHxA	perfluorohexanoic acid
PFHxS	perfluorohexane sulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PFU	plaque-forming unit
PHA	provisional health advisory
ppb	parts per billion (micrograms per liter)
PPCP	pharmaceuticals and personal care products
ppm	parts per million (milligrams per liter)
ppt	parts per trillion (nanograms per liter)
PQL	practical quantitation limit
RAA	running annual average
RDX	Research Department eXplosive
RTCR	Revised Total Coliform Rule
RWS	recycled water system
S.U.	standard units
SCP	Salinity Control Program
SDWA	Safe Drinking Water Act
SHARP	South Houghton Area Recharge Project
SHPS	Snyder Hill Pump Station
SMCL	secondary maximum contaminant level
SOC	synthetic organic compounds
SVOC	semi-volatile organic compounds
SWTR	Surface Water Treatment Rule
TAMA	Tucson Active Management Area
TARP	Tucson Airport Remediation Project
TCE	trichloroethene

TCR	Total Coliform Rule
TDS	total dissolved solids
TKN	Total Kjeldahl nitrogen
TL	trigger level
TOC	total organic carbon
TON	threshold order number
TT	treatment technique
TTHM	total trihalomethanes
TUc	chronic toxic unit
UCMR	Unregulated Contaminant Monitoring Rule
USBR	United States Bureau of Reclamation
UV AOP	ultraviolet light-hydrogen peroxide advanced oxidation process
VOC	volatile organic compound
WET	whole effluent toxicity
WQARF	Water Quality Assurance Revolving Fund
WQP	water quality parameter
WQZ	water quality zone
WRF	water reclamation facility
WTP	water treatment plant

Technical Memorandum

WATER QUALITY MANAGEMENT

Executive Summary

Introduction

Tucson Water, the water department of the City of Tucson, serves 722,000 customers over a 390-square-mile service area. The potable water distribution system includes over 200 production or standby groundwater wells; approximately 300 million gallons of water storage; and over 4,600 miles of pipelines. The recycled water system includes another 15 million gallons of storage and 160 miles of pipelines supplying irrigation water to golf courses, parks, schools, and select residences around the city; providing water for surface flow in a normally-dry riverbed to reinvigorate desert habitat through the Santa Cruz River Heritage I project; and replenishing groundwater through aquifer recharge projects.

"One Water" conveys the concept that all water is a valuable resource and can be considered part of a community's water portfolio. While surface water and groundwater can supply drinking water to communities, after the water is used and treated, it can replenish surface waters, be recharged to groundwater, be used as recycled water for landscape irrigation and other non-potable uses, or be purified for drinking water. Stormwater can also be collected and used for groundwater replenishment or landscape irrigation. In all uses of water, the quality must be adequate for the desired use. This technical memorandum presents water quality data for Tucson Water's current resources and relates that data to current and projected regulations for different water types and uses. Tucson Water conducts over 14,000 water quality tests each year (see Figure ES.1). This memorandum will help guide the water quality monitoring program so Tucson Water continues to supply high quality water to Tucson Water customers into the next century and beyond.

Water Quality Challenges

The foremost challenges to Tucson's water quality are related to evolving regulations and to potential and future changes to Central Arizona Project (CAP) water deliveries and Tucson Water's operations. Tucson Water is meeting all existing Federal and State regulations, but new regulations for emerging contaminants could add monitoring and/or treatment requirements or restrict the use of some water supplies. The U.S. Environmental Protection Agency's Lead and Copper Rule Revisions, which go into effect by 2024, will add monitoring and communication requirements beyond existing lead and copper compliance activities. Water received from the CAP could continue to increase in salinity, increasing basin-wide salt loading and affecting the quality of water delivered to customers. Introducing remediated groundwater into the recycled water system will alter the water quality characteristics of supplies distributed by that system.

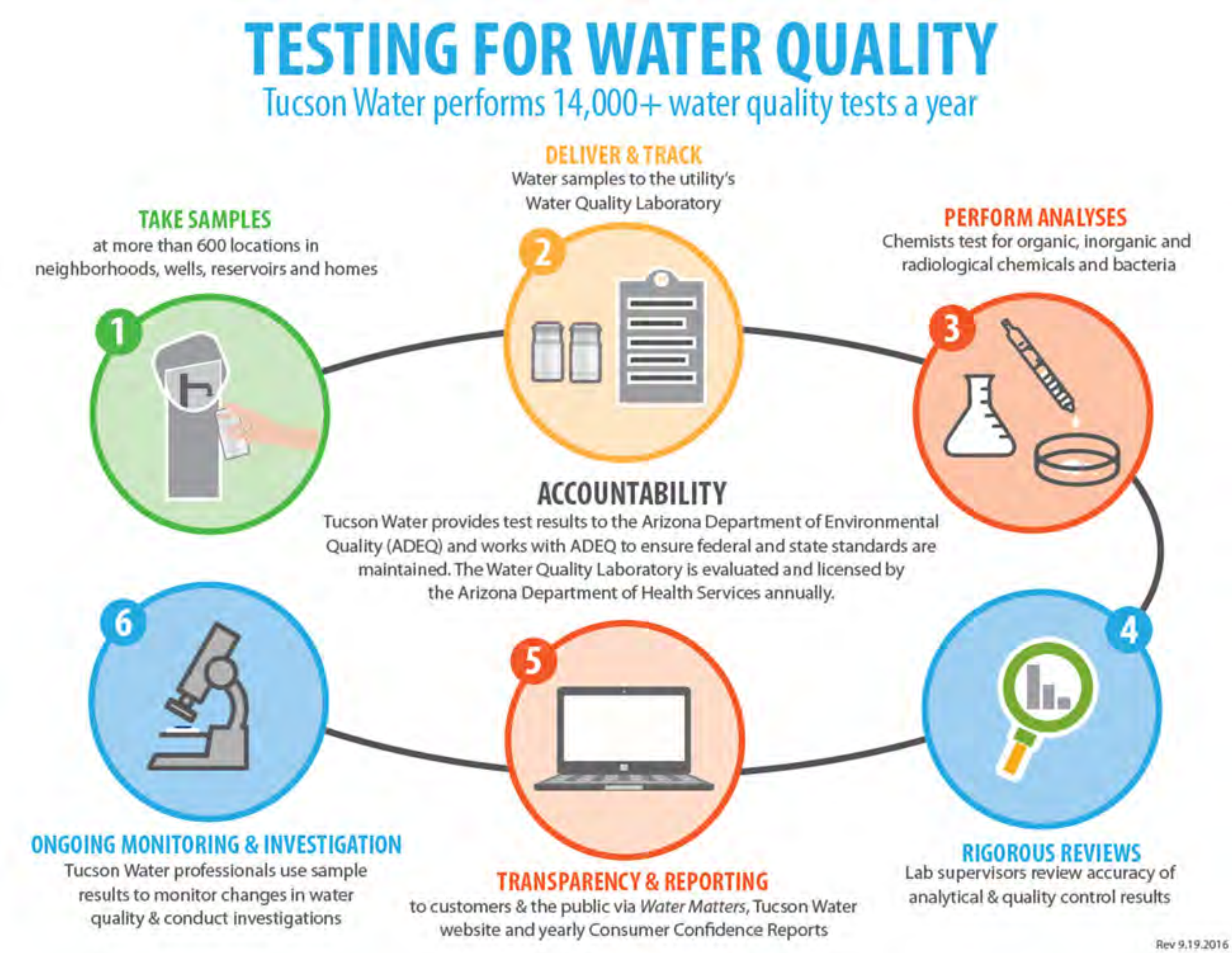


Figure ES.1 Tucson Water Quality Monitoring Facts

Meeting the Challenges

Due to effective planning, diligent water quality monitoring, and strategic infrastructure investments, Tucson Water is well-positioned to meet the water quality challenges the utility faces. The Sentry Program has monitored contaminants of emerging concern (CECs) for over 14 years and helps Tucson Water track and proactively manage contaminants that may be regulated in the future. Lead and copper concentrations in the drinking water distribution system are already very low, a testament to the success of Tucson Water's "Get the Lead Out" program and mitigation of corrosion concerns in the distribution system. Recharge and recovery of CAP water has ensured that salinity of the recovered water has climbed only gradually over time. By sending remediated groundwater from the Tucson Airport Remediation Project (TARP) into the recycled water system, the average quality of water distributed by that system should improve for several key parameters, including salinity and emerging contaminants. Tucson Water is committed to ensuring the quality of water for all of the various uses of Tucson's water resources and is taking the steps now to maintain that quality.

1.0 Introduction

"One Water" conveys the concept that all water is a valuable resource and can be considered part of a region's or utility's water portfolio (see Figure 1). While surface water and groundwater can supply drinking water to communities, after the used water is treated, it can replenish surface waters, be recharged back to groundwater, be used as recycled water for landscape irrigation and other non-potable uses, or be purified for drinking water. Stormwater can also be collected and used for groundwater replenishment or landscape irrigation. In all uses of water, the quality must be adequate to the desired use. This technical memorandum presents water quality data for Tucson Water's current resources and relates that data to current and projected regulations for different water types and uses. The focus is primarily on potable water and recycled water. While stormwater is also a valuable resource, its high volume over relatively brief and infrequent periods in the desert and wide variations in quality have historically made it a more difficult resource to capture and use. Innovations in stormwater management and increasing pressure on water resources mean that use of stormwater is projected to increase, but existing data is minimal and thus is not examined in detail here.

Figure 1 Tucson Water's One Water Resource Portfolio

The first section provides an overview of Tucson Water's resource portfolio and distribution system. In Section 2, potable water quality is examined. Existing federal and state regulations for chemical and microbial contaminants are summarized, as are potential future regulations and requirements for monitoring unregulated contaminants. Colorado River water conveyed through the Central Arizona Project (CAP) aqueduct and recharged in Avra Valley is a major water supply for Tucson Water and differs significantly from the native groundwater. When it is recharged, the CAP water blends with the native groundwater; the recovered CAP water quality is summarized in the section. Tucson Water's compliance with existing drinking water regulations is presented next, and potential implications of future regulation of currently unregulated contaminants are also examined.

Section 3 presents data on water quality and regulations related to recycled water. A major component of improving the quality of water supplied through the recycled water system will be the introduction of treated water from the Tucson Airport Remediation Project (TARP) groundwater remediation facility. While this treated water was supplied to the potable system for nearly three decades, changing water quality in that portion of the aquifer led to the decision to discontinue serving the treated water as drinking water and instead route the water to the recycled water distribution system and to the Santa Cruz River, the latter of which commenced on November 2, 2021. Water quality requirements at other points of compliance for the recycled water system are also considered.

Finally, Section 4 summarizes conclusions and recommendations related to water quality.

1.1 System Description

Tucson Water relied on groundwater as the only source of drinking water delivered to customers up to the 1990s when Colorado River water became available with the construction of the CAP. After water quality challenges during direct treatment and delivery of CAP water in 1992-1994, which are well documented, Tucson Water returned to serving only groundwater as drinking water for several years. In 1997, the utility began recharging CAP water into the aquifer in Avra Valley. By 2001, Tucson Water also commenced recovery of a blend of recharged CAP water and native groundwater to begin serving renewable water supplies. Related to the One Water concept shown in Figure 1, when CAP water, which is surface water from the Colorado River, is recharged in large basins west and south of Tucson, it becomes groundwater in a physical and regulatory sense. At the recharge facilities, CAP water blends with native groundwater and is then recovered. As more and more CAP water is recharged to the ground, the native groundwater makes up a decreasing proportion of the recovered water. Section 2.3 discusses the water quality implications of this water management strategy. The vast majority of drinking water supplied to Tucson Water customers today is recharged and recovered CAP water. Tucson Water has also developed an extensive recycled water system that supplies non-potable water for irrigation to golf courses, schools, and some residences, in addition to other uses, such as groundwater recharge and environmental restoration projects. More detail on this system is given in Section 3, including the planned introduction of treated water from TARP to the recycled water system. Figure 2 shows Tucson Water's water supply portfolio for 2020, with nearly two-thirds of the total supply from recharged and recovered CAP water and the remainder from native groundwater, remediated groundwater (from TARP), and recycled water.

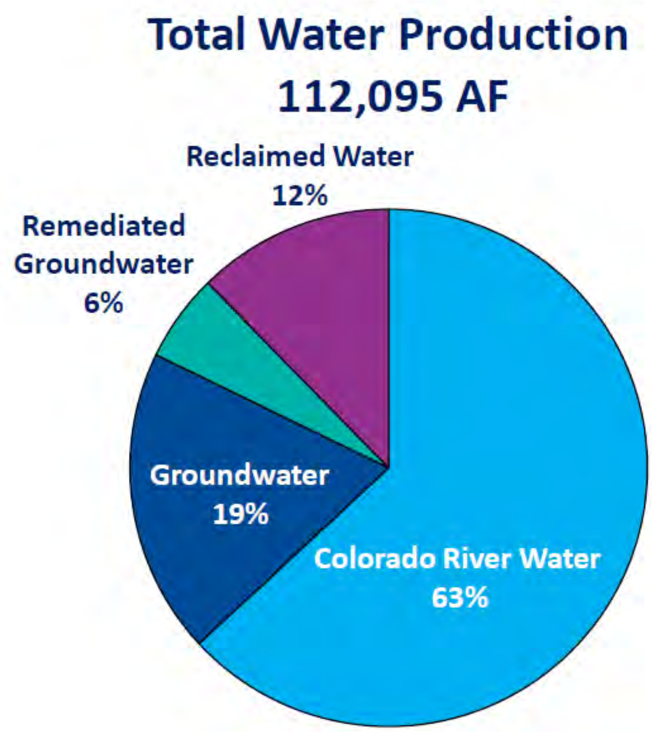


Figure 2 Water Production for the Tucson Water Service Area

2.0 Potable Water Quality

2.1 Drinking Water Regulations

Drinking water quality in the United States is governed by legislation enacted by the federal and state governments. Statutes, more commonly known as laws, direct the appropriate government agency to develop and publish regulations or rules to implement the requirements of the law. Standards specify the amount or concentration of a particular constituent that is legally allowed in drinking water. At the federal level, the United States Environmental Protection Agency (EPA) is primarily responsible for developing and enforcing drinking water regulations, whereas state health departments typically regulate drinking water quality at the state level.

Any drinking water regulations promulgated by a state are required to include standards that are at least as stringent as those imposed by comparable federal regulations; states may implement regulations in addition to those mandated by federal statutes or standards that are more restrictive than federal ones. In Arizona's case, however, state law prohibits state agencies making regulations stricter than those of the federal government unless approved by the state legislature. Federal regulations specify requirements and the process by which states may assume major responsibility, or primacy, for implementing and enforcing drinking water regulations. The Arizona Department of Environment Quality (ADEQ) has adopted federal drinking water regulations to maintain Arizona's primacy enforcement authority of the Safe Drinking Water Act. Although ADEQ has delegated authority for administration of the Safe Drinking Water Act Provisions and State drinking water rules to some county agencies, Tucson Water projects are not delegated and must be sent to ADEQ.

2.1.1 National Primary and Secondary Drinking Water Regulations

The Safe Drinking Water Act (SDWA) of 1974 and its amendments (1986 and 1996) provide a regulatory framework that specifies how National Primary Drinking Water Regulations (NPDWR) are developed, promulgated, and implemented. Elements of this regulatory framework require that EPA periodically review existing NPDWRs for continued protection of public health, evaluate potential risks associated with unregulated contaminants that are known to occur in drinking water supplies, and monitor the occurrence of contaminants in drinking water supplies.

The NPDWRs established by the EPA are legally enforceable primary standards applicable to all potable water systems and intended to protect the public from consuming water containing contaminants that present a risk to human health. The regulations set maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), and treatment technique requirements for a total of 94 contaminants. As shown in Figure 3, the number of contaminants regulated has increased dramatically from the original 22 listed in 1975 and 1976.

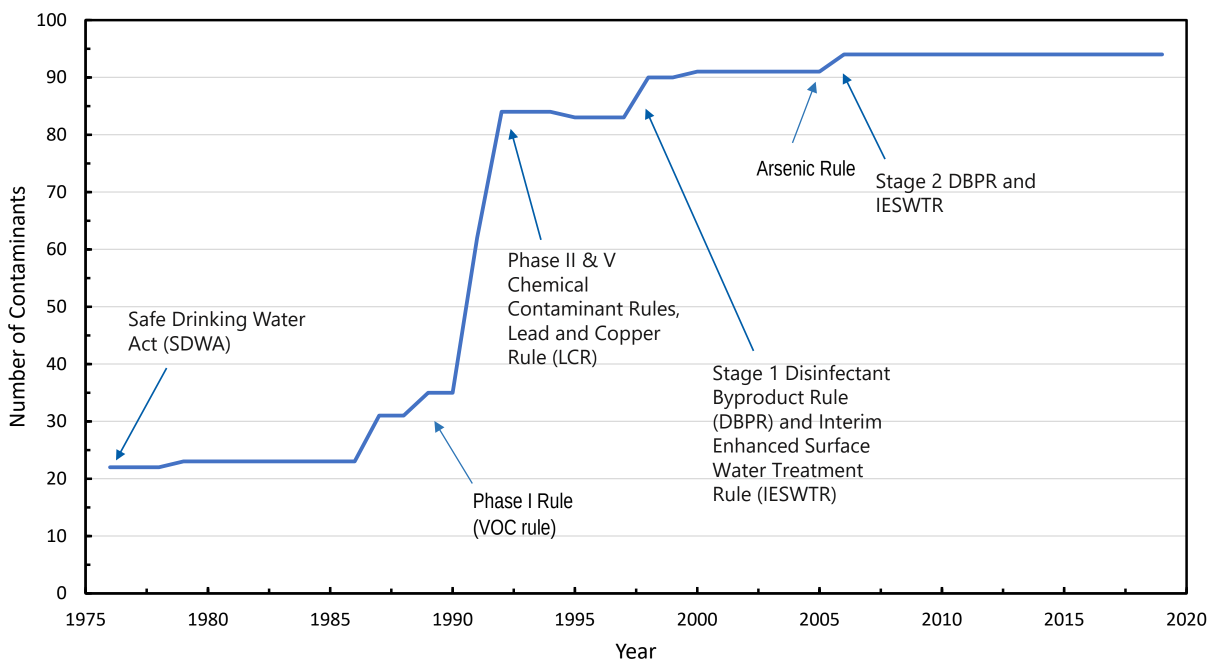


Figure 3 Water Quality Regulations and Drinking Water Standards

Secondary regulations are not legally enforceable and function as guidelines for water utilities to provide aesthetically pleasing drinking water and avoid cosmetic effects such as tooth discoloration. Taste and odor, for example, are aesthetic issues, as opposed to health issues, and secondary drinking water regulations are therefore applicable. The secondary standards set secondary MCLs for a total of 15 compounds that do not present a health risk at such levels.

The primary and secondary drinking water standards are presented in Table 1 and Table 2, respectively. All 94 contaminants regulated under the NPDWR are presented in Table 1, and the 15 contaminants regulated under the National Secondary Drinking Water Regulations (NSDWR) are presented in Table 2. Tucson Water's available data on the maximum detected concentrations of regulated organic chemicals, inorganic compounds, radionuclides, microorganisms, and disinfection byproducts is available in Appendix A for 2016-2018.

Table 1 National Primary Drinking Water Standards (as of 1/5/2021)

Contaminant	Regulation	MCL or TT(1) (ppm)(2)	MCLG (ppm)(2)
Organic Chemicals			
Acrylamide	Phase II	(TT)	Zero
Alachlor	Phase II	0.002	Zero
Atrazine	Phase II	0.003	0.003
Benzene	Phase I	0.005	Zero
Benzo(a)pyrene (PAHs)	Phase V	0.0002	Zero
Carbofuran	Phase II	0.04	0.04
Carbon tetrachloride	Phase I	0.005	Zero
Chlordane	Phase II	0.002	Zero
Chlorobenzene	Phase II	0.1	0.1
2,4-D	Phase II	0.07	0.07
Dalapon	Phase V	0.2	0.2
1,2-Dibromo-3-chloropropane (DBCP)	Phase II	0.0002	Zero
o-Dichlorobenzene	Phase II	0.6	0.6
p-Dichlorobenzene	Phase I	0.075	0.075
1,2-Dichloroethane	Phase I	0.005	Zero
1,1-Dichloroethylene	Phase I	0.007	0.007
cis-1,2-Dichloroethylene	Phase II	0.07	0.07
trans-1,2-Dichloroethylene	Phase II	0.1	0.1
Dichloromethane	Phase V	0.005	Zero
1,2-Dichloropropane	Phase II	0.005	Zero
Di(2-ethylhexyl) adipate	Phase V	0.4	0.4
Di(2-ethylhexyl) phthalate	Phase V	0.006	Zero
Dinoseb	Phase V	0.007	0.007
Dioxin (2,3,7,8-TCDD)	Phase V	0.00000003	Zero
Diquat	Phase V	0.02	0.02
Endothall	Phase V	0.1	0.1
Endrin	Phase V	0.002	0.002
Epichlorohydrin	Phase II	(TT)	Zero
Ethylbenzene	Phase II	0.7	0.7
Ethylene dibromide	Phase II	0.00005	Zero
Glyphosate	Phase V	0.7	0.7
Heptachlor	Phase II	0.0004	Zero
Heptachlor epoxide	Phase II	0.0002	Zero
Hexachlorobenzene	Phase V	0.001	Zero
Hexachlorocyclopentadiene	Phase V	0.05	0.05
Lindane	Phase II	0.0002	0.0002
Methoxychlor	Phase II	0.04	0.04
Oxamyl (Vydate)	Phase V	0.2	0.2
Pentachlorophenol	Phase II	0.001	Zero
Picloram	Phase V	0.5	0.5

Contaminant	Regulation	MCL or TT(1) (ppm)(2)	MCLG (ppm)(2)
Polychlorinated biphenyls (PCBs)	Phase II	0.0005	Zero
Simazine	Phase V	0.004	0.004
Styrene	Phase II	0.1	0.1
Tetrachloroethylene	Phase II	0.005	Zero
Toluene	Phase II	1	1
Toxaphene	Phase II	0.003	Zero
2,4,5-TP (Silvex)	Phase II	0.05	0.05
1,2,4-Trichlorobenzene	Phase V	0.07	0.07
1,1,1-Trichloroethane	Phase I	0.2	0.2
1,1,2-Trichloroethane	Phase V	0.005	0.003
Trichloroethene	Phase I	0.005	Zero
Vinyl chloride	Phase I	0.002	Zero
Xylenes (total)	Phase II	10	10
Inorganic Substances			
Antimony	Phase V	0.006	0.006
Arsenic	Arsenic Rule	0.010	Zero
Asbestos (fibers/L > 10 µm)	Phase II	7 million fibers/L	7 million fibers/L
Barium	Phase II	2	2
Beryllium	Phase V	0.004	0.004
Cadmium	Phase II	0.005	0.005
Chromium (total)	Phase II	0.1	0.1
Copper	LCR	(TT) AL=1.3	1.3
Cyanide	Phase V	0.2 (as free cyanide)	0.2
Fluoride	NPDWR	4	4
Lead	LCR	(TT) AL = 0.015	Zero
Mercury (inorganic)	Phase II	0.002	0.002
Nitrate (as N)	Phase II	10	10
Nitrite (as N)	Phase II	1	1
Selenium	Phase II	0.05	0.05
Thallium	Phase V	0.002	0.0005
Radionuclides			
Gross Alpha	Radionuclides Rule	15 pCi/L	Zero
Beta and photon radioactivity	Radionuclides Rule	4 mrem/yr	Zero
Radium-226 + Radium-228	Radionuclides Rule	5 pCi/L	Zero
Uranium	Radionuclides Rule	0.030	Zero

Contaminant	Regulation	MCL or TT[1] (ppm)[2]	MCLG (ppm)[2]
Microorganisms			
Cryptosporidium	LT2ESWTR	(TT) oocyst/100L	Zero
Fecal coliforms and *E. coli*	TCR	MCL[3]	Zero
Giardia lamblia	SWTR	(TT) cyst/100L	Zero
Heterotrophic plate count (HPC)	SWTR	(TT) CFU/mL	NA
Legionella	SWTR	(TT) #/mL	Zero
Total coliforms	TCR	5.0 percent[4] #/mL	Zero
Turbidity	SWTR	0.3 NTU[5]	NA
Viruses	SWTR	(TT) #/mL	Zero
Disinfectant Byproducts			
Bromate	Stage 1 DBPR	0.010	Zero
Chlorite	Stage 1 DBPR	1	0.8
Haloacetic Acids (HAA5[6])	Stage 2 DBPR	0.060[7]	NA[8]
Trihalomethanes (total)	Stage 2 DBPR	0.080[7]	NA[8]
Bromodichloromethane	Stage 1 DBPR	-	Zero
Bromoform	Stage 1 DBPR	-	Zero
Chloroform	Stage 2 DBPR	-	0.07
Dibromochloromethane	Stage 1 DBPR	-	0.06
Dichloroacetic acid	Stage 1 DBPR	-	Zero
Monochloroacetic acid	Stage 2 DBPR	-	0.07
Trichloroacetic acid	Stage 2 DBPR	-	0.02
Disinfectant Residuals			
Chloramines (as Cl_2)	Stage 1 DBPR	4[9]	4[10]
Chlorine (as Cl_2)	Stage 1 DBPR	4[9]	4[10]
Chlorine dioxide (as ClO_2)	Stage 1 DBPR	0.8[9]	0.8[10]

Notes:

(1) Treatment Technique (TT): A required process intended to reduce the level of a contaminant in drinking water.
(2) Units are ppm unless otherwise noted.
(3) Routine samples containing fecal coliform or *E. coli* triggers a repeat sampling event. If the repeat sample is fecal coliform-positive, an acute MCL violation occurs. If the repeat sample is negative, another repeat sampling is triggered. If the repeat sample is fecal coliform-positive, an acute MCL violation occurs.
(4) No more than 5 percent of samples total coliform-positive in a month. Every sample that is coliform-positive must be analyzed for fecal coliforms and *E. coli*. If two consecutive samples are total coliform-positive and one is fecal coliform-positive, an acute MCL violation occurs.
(5) Performance standard: no more than 5 percent of monthly samples may exceed 0.3 NTU.
(6) Sum of concentrations of five haloacetic acid species (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid).
(7) Measured as locational running annual average at each monitoring site.
(8) The group itself does not have an MCLG, but some individual contaminants have an MCLG as shown in the table (bromodichloromethane, bromoform, chloroform, dibromochloromethane, dichloroacetic acid, monochloroacetic acid, trichloroacetic acid).
(9) Maximum Residual Disinfectant Level.
(10) Maximum Residual Disinfectant Level Goal.

Abbreviations:
µm = micrometer(s); AL = action level; DBPR = Disinfection Byproducts Rule; CFU = colony forming units; LCR = lead and copper rule; LT2ESWTR = Long-Term 2 Enhanced Surface Water Treatment Rule; mL = milliliter(s); mrem = millirem (milli-roentgen equivalent man); NA = not applicable; NTU = nephelometric turbidity unit; PAH = polycyclic aromatic hydrocarbon; pCi/L = picocuries per liter; ppm = parts per million; SWTR = Surface Water Treatment Rule; TT = treatment technique; TCR = Total Coliform Rule;

Table 2 National Secondary Drinking Water Standards (as of 1/7/2021)

Contaminant	Secondary Maximum Contaminant Level (SMCL) (ppm)(1)
Aluminum	0.05 - 0.2
Chloride	250
Color	15 Color Units
Copper	1
Corrosivity	Non-corrosive
Fluoride	2
Foaming Agents	0.5
Iron	0.3
Manganese	0.05
Odor	3 Threshold Odor Units
pH	6.5 – 8.5 standard units
Silver	0.10
Sulfate	250
Total Dissolved Solids	500
Zinc	5

Notes:
(1) Units are parts per million (ppm) unless otherwise noted.

2.1.2 Chemical Contaminant Regulations

The EPA also issues a series of drinking water regulations intended to protect the public from chemical contaminants such as asbestos, arsenic, and lead that may be present in surface water supplies and from potential intrusion or leaching from buried pipes within the distribution system. These Chemical Contaminant Rules were promulgated in phases, with additional rules further limiting specific chemicals having been promulgated since. The family of regulations that focus on chemical contaminant control includes:

- Phase I, II, and V Rules (Phase II/V Rules, 1989, 1992/93 & 1994)
- Lead and Copper Rule (LCR, 1991)
  - Lead and Copper Rule Revisions (LCRR, 2021)
- Radionuclides Rule (Radionuclide Rule, 2000)
- Arsenic Rule (Arsenic Rule, 2001)

2.1.2.1 Phase II/V Rules

The Phase II/V Rules apply to all public potable water systems and regulate over 65 contaminants within three contaminant groups:

- Inorganic Contaminants (IOC)
- Volatile Organic Compounds (VOC)
- Synthetic Organic Contaminants (SOC)

The Phase II/V Rules establish MCLs, monitoring requirements, and the best available technologies for the removal of the 65 contaminants. Regulation through the Phase II/V Rules provide public health protection through the reduction of chronic risks of cancer, organ damage, circulatory system disorders, nervous system disorders, and reproductive system disorders posed by the 65 contaminants. Table 3 summarizes the contaminants regulated as part of the Phase II/V Rules.

Table 3 Phase II/V Rules Regulated Contaminants

Phase	VOC	SOC	IOC
Phase I, July 7, 1987 (52 FR 25690) Effective: 1989	Benzene Carbon tetrachloride p-dichlorobenzene Trichloroethylene Vinyl chloride 1,1,1-trichloroethane 1,1-dichloroethylene 1,2-dichloroethane		
Phase II, January 1991 (56 FR 3526) Effective: 1992	cis-1,2-dichloroethylene Ethylbenzene Monochlorobenzene (chlorobenzene) o-dichlorobenzene Styrene Tetrachloroethylene Toluene Trans-1,2-Dichloroethylene Xylenes 1,2-dichloropropane	Alachlor Atrazine Carbofuran Chlordane EDB (ethylene dibromide) DBCP (1,2-dibromo-3-chloropropane) Heptachlor Heptachlor epoxide Lindane Methoxychlor Toxaphene PCBs 2,4-D 2,4,5-TP	Asbestos Cadmium Chromium Fluoride Mercury Nitrate Nitrite Selenium
Phase IIB, July 1991 (56 FR 30266) Effective: 1993		Pentachlorophenol Aldicarb Aldicarb sulfone Aldicarb sulfoxide	Barium
Phase V, July 1992 (57 FR 31776) Effective: 1994	Dichloromethane 1,1,2-trichloroethane 1,2,4-trichlorobenzene	Benzo(a)pyrene Dalapon Di(ethylhexyl)-adipate Di(ethylhexyl)-phthalate Dinoseb Diquat Endothall Endrin Glyphosate Hexachlorobenzene Hexachlorocyclo-pentadiene Oxamyl Picloram Simazine 2,3,7,8-TCDD (dioxin)	Antimony Beryllium Cyanide Nickel Thallium

2.1.2.2 Lead and Copper Rule and the Lead and Copper Rule Revisions

The LCR was promulgated by the EPA on June 7, 1991. On January 15, 2021, the LCR was updated with the LCRR, with further actions occurring later in the year that postponed the effective date to December 16, 2021, and the compliance deadline to October 16, 2024. The LCRR varies from the LCR in six key focus areas which will be described in Section 2.4.2.

Under the provisions of the LCR, water systems serving greater than 100,000 people are required to sample household taps from 100 home sites for lead and copper with priority given to sites with higher lead potential such as those served by lead service lines (LSL). If the lead and copper concentrations in the 90th percentile of home tap samples are greater than the 0.015 ppm action level for lead or the 1.3 ppm action level for copper, then the utility must take follow up actions, including increasing monitoring frequency if the utility was on reduced monitoring, conducting a corrosion control treatment study, and conducting a public education program.

The rule also requires utilities to sample entry points and distribution system sample sites (25 sites in Tucson Water's case) for certain water quality parameters including pH, alkalinity, and calcium. These parameters may be used to determine the Langelier Saturation Index (LSI) of water, which is a corrosivity index and is a measure of water's ability to dissolve or precipitate calcium carbonate. This determination will help utilities optimize their corrosion control treatment. Under this regulation, there are two ways in which a utility is considered to have "optimized" corrosion control:

- Demonstrate to regulatory agency that it has performed corrosion control steps "equivalent" to those required by EPA.
- If the difference between the highest level of lead in the source water and the 90th percentile tap samples is less than the practical quantitation level (PQL) for lead (0.005 ppm). That is, the level of lead in the water entering the distribution system must be below the action level, and, optimally, the concentration of lead added through the distribution system itself is less than the PQL.

The Final Lead and Copper Rule Short-Term Revisions and Clarifications (also known as the Lead and Copper Rule Minor Revisions [LCRMR]) were promulgated on October 10, 2007. The compliance date for the rule was April 7, 2008. The LCRMR does not change the action levels for lead or copper; however, it requires utilities to provide a notification of tap water monitoring results for lead to home and building occupants.

In 2021, the LCRR defined a trigger level (TL) of 0.01 ppm for the system's 90th percentile level, additional actions upon system-wide action level exceedance (ALE), and additional actions upon individual tap sample ALE. When the 90th percentile value exceeds the TL, systems are now required to implement additional planning, monitoring, and reevaluation of current corrosion control treatment. When the 90th percentile value exceeds the AL, systems are now required to notify all customers within 24 hours, begin semi-annual sampling, and either install corrosion control treatment (CCT) or re-optimize their system. Lastly, individual tap sample ALE will require 72-hour notice and "find-and-fix" efforts including to identify the lead source and take action to reduce lead levels.

Additionally, multiple components of the LCRR focus on closing compliance loopholes for the LCR. For sampling, prioritization is added to sample site selections through a tiered program. Additionally, fifth-liter sampling is required from homes with LSLs and sampling instructions that recommend aerator cleaning or pre-stagnation flushing prior to sampling are prohibited. An LSL Inventory will also be required, including annual updates. Systems which have LSLs, galvanized requiring replacement, or service lines with an unknown lead status will then also be required to create an LSL Replacement Plan. Partial LSL replacements will no longer be allowed, with the public-side replacement now required when a private-side line is replaced and vice versa. Lastly, communicating lead health risks, providing education materials, and conducting targeted outreach to customers with LSLs further bolsters the LCRR's efforts to get lead out and reduce customers' exposure.

2.1.2.3 Arsenic Rule

EPA published the Final Arsenic Rule on January 22, 2001, which mandated that the arsenic MCL in drinking water would be 10 parts per billion (ppb), a reduction from 50 ppb. It also established an MCLG of zero for arsenic. Due to delays subsequent to promulgation of the final rule, the effective date for compliance by public water systems was postponed until January 23, 2006.

2.1.2.4 Radionuclides Rule

On December 7, 2000, the EPA announced the Radionuclides Rule, which revised the existing standards for radionuclides and established a new standard for uranium. The rule became effective on December 8, 2003, and monitoring requirements were phased in between December 2000 and December 2003. The rule requires systems to determine initial compliance using an average of four quarterly samples, or appropriate grandfathered data under State direction. The requirements of the rule are presented in Table 4.

Table 4 Regulated Contaminants Per Radionuclides Rule

Regulated Radionuclide	MCL	MCLG
Beta/photon emitters(1)	4 mrem/yr	0 mrem/yr
Gross alpha particle	15 pCi/L	0 pCi/L
Combined radium 226/228	5 pCi/L	0 pCi/L
Uranium	0.030 ppm	0 ppm

Notes:
(1) A total of 168 beta particles and photon emitters may be used to calculate compliance with the MCL.

2.1.3 Microbial and Disinfection Byproduct Regulations

Over the past three decades, EPA has promulgated a series of increasingly complex drinking water regulations intended to protect the public from microbial pathogens such as viruses, *Giardia*, and *Cryptosporidium* that may be present in water supplies, and from disinfection byproducts (DBP). The family of regulations that focus on microbial pathogen control includes:

- Surface Water Treatment Rule (SWTR, 1989) & Interim Enhanced Santa Cruz River Treatment Rule (IESWTR, 1998).
- Filter Backwash Recycling Rule (FBRR, 2001).
- Long-Term 1 (LT1ESWTR, 2002) & 2 (LT2ESWTR, 2006) Enhanced Surface Water Treatment Rule.
- Ground Water Rule (GWR, 2006).
- Total Coliform Rule (TCR, 1989) & Revised Total Coliform Rule (RTCR, 2013).

Regulations intended to minimize the formation of DBPs in drinking water include:

- Total Trihalomethane Rule (TTHM Rule, 1979).
- Stage 1 (FR, 1998) & 2 (Stage 2 D/DBP Rule, 2006) Disinfectants and Disinfection Byproducts Rule.

Collectively, these regulations have come to be known as the Microbials and Disinfection Byproducts (MDBP) Rules and are intended to balance the risk-risk tradeoff between health concerns related to exposure to pathogenic microorganisms and exposure to disinfection byproducts. The monitoring and compliance requirements of the MDBP Rules are complex and to a large extent system specific. Based on recognition that simultaneous compliance with the provisions of the MDBP Rules requires a well-planned and highly coordinated approach, EPA has developed a series of guidance manuals to help drinking water providers manage the often-conflicting objectives of these rules.

Notably, some regulations do not apply to Tucson Water, considering the utility does not include surface water treatment in its portfolio. These non-applicable regulations include the SWTR, IESWTR, FBRR, LT1ESTWR, and LT2ESWTR and are described in Appendix A. The remainder of the MDBP rules are described here.

2.1.3.1 Ground Water Rule (GWR)

The GWR was proposed on May 10, 2000, and was published in November 2006. The GWR specifies the appropriate use of disinfection in groundwater and contains other provisions to protect public health. This rule is of importance to Tucson Water because all potable supplies are from groundwater (see note about CAP supplies in Section 1.1). The final requirements of the GWR are:

Sanitary Survey – Water systems will be required to perform a sanitary survey every three years to review the following eight elements:

- Source.
- Treatment.
- Distribution system.
- Finished water storage.
- Pumps, pump facilities, and control.
- Monitoring, reporting, and data verification.
- Water system management and operations.
- Water system operator compliance with state requirements.

Source Water Monitoring – A groundwater system (GWS) with a distribution system TCR sample that tests positive for total coliform is required to conduct triggered source water monitoring to evaluate whether the total coliform presence in the distribution system is due to fecal contamination in the groundwater supply. A GWS that does not provide at least 4-log treatment of viruses must conduct triggered source water monitoring upon being notified that a TCR sample is total coliform-positive. Within 24 hours of receiving the total coliform-positive notice, the system must collect at least one groundwater sample from each groundwater source (unless the GWS has an approved triggered source water monitoring plan that specifies the applicable source for collecting source samples). The GWS must test the groundwater source sample(s) for the presence of one of three State-specified fecal indicators (*E. coli*, enterococci, or coliphage). If the source sample is fecal indicator-positive, this rule requires the GWS to notify the State and the public. Unless directed by the State to take immediate corrective action, the GWS must collect and test five additional source water samples for the presence of the same State-specified fecal indicator within 24 hours. If any one of the five additional source water samples tests positive for the State-specified fecal indicator (*E. coli*, enterococci, or coliphage), this rule requires the GWS to notify the State and the public and comply with the treatment technique requirements, which require the system to take one of four corrective actions discussed in the following section.

Treatment Technique Requirements – The GWR requires a GWS to take corrective action if a significant deficiency is identified during a sanitary survey. Also, the rule requires a GWS to take corrective action if one of the five additional groundwater source samples (or at State discretion, the initial source sample) has tested positive for fecal contamination (i.e., the sample is positive for one of the three fecal indicators and is not invalidated by the State). Corrective action requires one or more of the following steps: correct all significant deficiencies; provide an alternate source of water; eliminate the source of contamination; or provide treatment that reliably achieves at least 4-log treatment of viruses. Furthermore, the GWS must inform the public served by the water system of any uncorrected significant deficiencies and/or fecal contamination in the groundwater source.

Compliance Monitoring – Compliance monitoring requirements are the final defense against viral and bacterial pathogens. All GWS that provide at least 4-log treatment of viruses using chemical disinfection, membrane filtration, or a State-approved alternative treatment technology must conduct compliance monitoring to demonstrate maintenance of the minimum disinfectant residual concentration. Additional State-specified monitoring requirements apply to membrane filtration and alternative treatment.

2.1.3.2 Stage 1 and Stage 2 Disinfectants and Disinfection Byproducts Rule

The Stage 1 Disinfectants and Disinfection Byproducts Rule (D/DBPR) was finalized on December 16, 1998 and became effective for public water systems serving more than 10,000 people on January 1, 2002. It establishes MCLs for DBPs and maximum residual disinfection levels (MRDL) for disinfectants. The Stage 1 D/DBPR revised the MCL for TTHMs from 0.1 ppm (100 ppb) under the 1979 Total Trihalomethane Rule to 0.08 ppm (80 ppb). The Stage 1 D/DBPR also establishes an MCL for the sum of five haloacetic acids (HAA5) at 60 ppb, and establishes the MCL for bromate at 10 ppb. MCL compliance is calculated using the running annual average (RAA) of all locations from all monitoring locations across the system, computed quarterly. The MRDL for chlorine is established at 4.0 ppm.

The rule also requires total organic carbon (TOC) monitoring and TOC removal by enhanced coagulation or enhanced softening. The rule further specifies the percentage of influent TOC that must be removed based on the raw water TOC and alkalinity levels, as shown in Table 5.

Table 5 Percentage of TOC Reduction Required Per Stage 1 D/DBPR

Raw Water TOC (ppm)	Raw Water Alkalinity (mg/L as $CaCO_3$)		
	< 60	60 – 120	> 120
> 2.0 – 4.0	35%	25%	15%
> 4.0 – 8.0	45%	35%	25%
> 8.0	50%	40%	30%

Abbreviation:
mg/L = milligrams per liter; ppm = parts per million

The Stage 2 version of the D/DBPR rule was finalized in December 2005 and published in the Federal Register on January 4, 2006. It strengthens the initial requirements of the Stage 1 rule and aims at reducing occurrences of DBP concentration spikes in the distribution system. Utilities are required to conduct an evaluation of their distribution system, known as an Initial Distribution System Evaluation, to identify locations with high DBP concentrations. Once identified, these locations are established as the sampling sites for compliance monitoring.

MCLs for TTHMs and HAA5 remain unchanged. However, the rule requires that MCL compliance be calculated using the locational running annual average (LRAA), i.e., each sampling site must not individually exceed the MCLs. Systems are also required to determine if they have exceeded an operational evaluation level, which is identified using compliance monitoring results. A system that exceeds an operational evaluation level is required to submit a report to their state identifying actions that may be taken to mitigate future high DBP levels.

The MCL for bromate remains at 10 ppb, based upon current alternative technology utilization and upon current understanding of bromate formation as a result of bromide concentrations. EPA is committed to review the bromate MCL as part of a 6-year review to determine whether the MCL should remain at 10 ppb or be reduced to 5 ppb or lower.

Table 6 summarizes the requirements of the Stage 1 and Stage 2 D/DBPRs.

Table 6 Stage 1 and Stage 2 D/DBPR Regulated Contaminants and Disinfectants

Regulated Contaminant	Stage 1 DBPR		Stage 2 DBPR	
	MCL (ppm)	MCLG (ppm)	MCL (ppm)	MCLG (ppm)
TTHM	0.080		Unchanged[1]	
Chloroform		-		0.07
Bromodichloromethane		Zero		Unchanged[1]
Dibromochloromethane		0.06		Unchanged[1]
Bromoform		Zero		Unchanged[1]
HAA5	0.060		Unchanged[1]	
Monochloroacetic acid		-		
Dichloroacetic acid		Zero		Unchanged[1]
Trichloroacetic acid		0.3		0.2
Bromoacetic acid		-		-
Dibromoacetic acid		-		-
Bromate (plants that use ozone)	0.010	Zero	Unchanged[1]	Unchanged[1]
Chlorite (plants that use chlorine dioxide)	1.0	0.8	Unchanged[1]	Unchanged[1]
Regulated Disinfectants	MRDL[2] (ppm)	MRDLG[2] (ppm)	MRDL (ppm)	MRDLG (ppm)
Chlorine	4.0 as Cl_2	4	Unchanged[1]	Unchanged[1]
Chloramines	4.0 as Cl_2	4	Unchanged[1]	Unchanged[1]
Chlorine Dioxide	0.8	0.8	Unchanged[1]	Unchanged[1]

Notes:

(1) Stage 2 DBPR did not revise the MCL or MRDL for this contaminant/disinfectant. However, MCL compliance was updated to be calculated using the Locational Running Annual Average.

(2) Stage 1 DBPR included MRDLs and maximum residual disinfection level goals (MRDLG) for disinfectants, which are similar to MCLs and MCLGs.

2.1.3.3 Total Coliform Rule and Revised Total Coliform Rule

The EPA is required to review and revise, as appropriate, each of the NPDWRs no less often than every six years. In July 2003, the EPA determined that it was appropriate to revise the TCR to provide even greater protection against waterborne pathogens in the distribution system. The EPA proposed specific revisions to the TCR on July 14, 2010, and released the draft Proposed TCR Assessments and Corrective Actions Guidance Manual for comment on August 13, 2010. The final RTCR was signed by the EPA administrator on December 20, 2012 and published in the Federal Register on February 13, 2013. The 1989 TCR remained effective until March 31, 2016. The compliance date for the RTCR requirement was April 1, 2016.

The RTCR establishes an MCL and MCLG of zero for *E. coli*, which is a more specific indicator of fecal contamination than total coliforms. The rule eliminates the MCL and MCLG for total coliform, replacing it with a treatment technique requirement instead. Under the treatment technique requirements, a system that exceeds a specified frequency of total coliform occurrence (greater than 5 percent of samples) or that incurs an *E. coli* MCL violation must assess the distribution system and correct any sanitary defects found. The rule also requires systems to reconsider choices for the analytical methods used to control false positives and negatives.

2.1.4 Secondary Water Quality Issues

Taste and odor compounds and total dissolved solids (TDS) are water quality characteristics that are drinking water concerns. They do not pose a threat to public health but are concerns because of secondary, non-health related issues. Future regulation of taste and odor compounds and total dissolved solids is unlikely, but secondary standards exist for these water quality parameters and are discussed in the following sections.

2.1.4.1 Taste and Odor Compounds

Concentrations of taste and odor compounds in water above a threshold odor number (TON) of 3 can affect consumers' perception of drinking water quality and safety. Taste and odor compounds can lead to reduced water consumption and reliance on bottled water for drinking. T&O-causing compounds can often be removed during the water treatment process using powdered activated carbon, ozone oxidation, filtration with granular activated carbon media, and other methods. However, the optimal treatment approach depends on the constituent(s) producing the adverse T&O.

2.1.4.2 Total Dissolved Solids

Total dissolved solids are the quantity of salts dissolved in drinking water. TDS include:

- Anions – carbonate, chloride, sulfate, etc.
- Cations – sodium, calcium, magnesium, etc.

TDS are derived from several sources, including natural geologic formations, irrigation return flows, residential sources (human waste, water softeners, food waste), and industrial sources. The potential impacts of high TDS in drinking water are:

- Objectionable mineral taste.
- Color.
- Infrastructure corrosion or scaling (depending on water chemistry).
- Reduced applications for reclaimed water.

No NPDWR exists for TDS, but EPA has issued a secondary standard of 500 ppm. The World Health Organization has established a recommended TDS standard of 1,000 ppm for taste.

2.2 Potential Future Regulatory Requirements

The Safe Drinking Water Act and its amendments require that the EPA reevaluate existing drinking water regulations on a periodic basis and develop and promulgate new standards and regulations as necessary to protect public health. At any given time, there may be many contaminants at various stages of the rulemaking and revision process, such as information gathering, regulation development, public comment, or periodic review. This section summarizes potential future regulations beginning from those closest to new regulation and roughly ordered toward more distant likelihood/timing of regulation.

2.2.1 Proposed Rules

2.2.1.1 Regulatory Determination 4

On February 20, 2020, EPA announced and requested public comment on the preliminary regulatory determinations for eight Contaminant Candidate List (CCL) 4 contaminants. EPA made preliminary determinations to regulate perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) in drinking water and to not regulate six contaminants (1,1-dichloroethane, acetochlor, methyl bromide [bromomethane], metolachlor, nitrobenzene, and Research Department eXplosive [RDX]).

2.2.2 Contaminants of Emerging Concern and Other Contaminants on the Planning Horizon

Table 7 presents contaminants that may be regulated by the EPA and indicates the approximate probability of regulation. More detail about these contaminants follows.

Table 7 Contaminants on the Regulatory Horizon

Contaminant	Regulatory Framework	Probability(1)
PFAS	2016 reviewed HA; UCMR3; CCL4; UCMR5, 2020 proposal to regulate	Imminent
cVOCs	2011 decision to regulate	Likely
Brominated DBPs	UCMR4; 3rd Six Year Review	Possible
Cyanotoxins	2015 health advisories (HA); UCMR4; CCL4	Possible
Strontium	2014 preliminary decision to regulate	Possible
Chlorate	3rd Six Year Review; Pesticide Office	Possible
Nitrosamines (including NDMA)	3rd Six Year Review	Maybe
Cr(VI)	UCMR3; CCL4	Maybe
1,4-dioxane	UCMR3; CCL4	Maybe
Manganese	UCMR4; CCL4	Maybe
Perchlorate	2011 decision to regulate; NRDC settlement	2020 decision not to regulate (2011 decision withdrawn)

Notes:
(1) "Imminent"—proposed and final MCL expected within 2 years. Based on AWWA Government Affairs (Roberson, 2015); "Likely" – regulation in 5 years; "Possible" – 50/50 chance of final regulation in 5-10 years; "Maybe" – anything can happen.

2.2.2.1 Per and Polyfluoroalkyl Substances

Per- and polyfluoroalkyl substances (PFAS) are a group of man-made chemicals consisting of PFOS, PFOA, and many other per- and polyfluoronated chemical compounds. These compounds are manufactured and used in a variety of industries, most notably for stain- and water-repellent fabrics, nonstick products such as Teflon, and aqueous film-forming foams (AFFF), used in fighting aircraft fires. As part of a series of phase-outs, the United States no longer manufactures certain PFAS, including PFOS and PFOA. However, these compounds are still produced internationally and can enter the United States through imported consumer goods.

PFAS have been classified through research as probable human carcinogens and linked to other additional health-related risks such as obesity, immune system suppression, and endocrine disruption. Most notably, the chemical structures of long-chain PFAS make them bioaccumulative in humans and wildlife, and persistent in the environment.

In January 2009, EPA established a provisional health advisory (PHA) of 400 parts per trillion (ppt) for PFOA and 200 ppt for PFOS to assess the potential risk from short-term exposure of these chemicals through drinking water. On May 19, 2016, US EPA released its final Health Advisory Level (HAL) for PFOA and PFOS in drinking water (70 ppt total). On February 22, 2021, the EPA reissued the final regulatory determinations for CCL4, making the determination to regulate both PFOS and PFOA in drinking water. EPA will move forward with the NPDWR development process. On July 19, 2021, the EPA draft CCL5 also incorporated five additional PFAS for consideration and the proposed UCMR5 includes 29 PFAS compounds (see Section 2.2.3).

With Regulatory Determination 4, the EPA has 24 months to propose potential MCLs for PFOA and/or PFOS. In October 2021, the EPA released its PFAS Strategic Roadmap (EPA 2021), which laid out the following priorities and dates:

- **Drinking Water**—MCLs for PFOA and PFOS are to be proposed in Fall 2022 and finalized in Fall 2023. Twenty-nine PFAS are to be measured in 2023-2025 as part of UCMR5.
- **Cleanup**—PFOA and PFOS are to be designated Superfund (CERCLA) hazardous substances by Summer 2023.
- **Toxics**—more toxicity tests for PFAS (particularly new PFAS) are to be conducted under the Toxic Substances Control Act.
- **Monitoring**—EPA Method 1633 can measure up to 40 PFAS in eight environmental matrices and was released in September 2021 (multi-lab validation expected Fall 2022). "Total PFAS" quantification methods are to be developed (2021-2022). The National Lakes Assessment will evaluate PFAS in fish tissue in Summer 2022.
- **Research**—funding is to be directed to treatment, environmental justice, and quantifying toxicity, exposure, and ecological effects.
- **Wastewater**—ambient water quality criteria are to be released in Winter 2022; industrial effluent limits are to be proposed in Summer 2023.

The PFAS Strategic Roadmap emphasizes full consideration of the lifecycle of PFAS and multiple exposure pathways, holding polluters accountable (including enhanced reporting requirements), and preventing future PFAS pollution.

Currently, Arizona follows the regulatory requirements established by the EPA and is not anticipated to establish regulatory or guidance PFAS concentrations that are lower than EPA established concentrations or health advisory levels. Nevertheless, Tucson Water has operational targets for a variety of PFAS compounds in the potable system (Table 8).

Table 8 Tucson Water Operational Targets for PFAS

Parameter	Units	Value
PFOS	ppt	7
PFOA	ppt	11
PFHxS	ppt	7
PFOS + PFOA + PFHxS + PFHpA(1)	ppt	18
PFHxA	ppt	200,000
PFBS	ppt	420

Notes:
(1) When PFOS, PFOA, PFHxS, and PFHpA are present, combined concentrations should not exceed the operational target.
Abbreviations:
PFHxS = perfluorohexane sulfonic acid; PFHpA = perfluoroheptanoic acid; PFHxA = perfluorohexanoic acid;
PFBS = perfluorobutane sulfonic acid

2.2.2.2 Volatile Organic Compounds

The EPA announced in February 2011 that it plans to regulate a group of up to 16 carcinogenic VOCs (including eight currently regulated compounds and eight unregulated compounds) with one NPDWR. The proposed Carcinogenic VOC Rule (cVOC Rule) would regulate a group of contaminants together, acknowledging the cumulative and potentially synergistic effects of exposure to multiple contaminants. The EPA also indicated they would reduce the MCLs for individual VOCs, including TCE and PCE, via the cVOC Rule.

The rule was expected to be finalized sometime in 2015; however, EPA determined in January 2017 as part of its third 6-year review that it was not appropriate at the time to revise the drinking water standards for these contaminants. As of 2021, the newly proposed timetable for the potential cVOC Rule publication has been pushed to 2022, with the final rule in 2023.

2.2.2.3 Non-Regulated Disinfection Byproducts

The EPA continually considers whether additional regulation of DBPs is warranted, as illustrated by the inclusion of several unregulated DBPs on the fourth CCL, the decision to consider revisions to the Stage 1 and 2 D/DBPRs based on the Third Six Year Review cycle, and inclusion of several classes of unregulated DBPs through the UCMR. Unregulated brominated HAAs, haloacetonitriles (HAN), halonitromethanes (HNM), haloketones (HK), and nitrosamines are among the most common non-regulated DBPs. Research into these nonregulated DBPs has indicated a potential for greater toxicity than some regulated DBPs. Since more brominated DBPs can be more toxic, EPA required monitoring for HAA9 under UCRM4. Based on a review of UCMR4 data, HAA6Br and HAA9 concentrations in Tucson Water's distribution system samples are low, with a maximum measured HAA9 concentration of 15.7 μg/L.

2.2.2.4 Algal Toxins

Poor water quality in lakes, reservoirs, and rivers is a significant and growing threat for water utilities. In particular, harmful algal blooms (HAB), which produce cyanotoxins, can cause direct harm to people and animals. The "do not drink" advisories that have occurred in several places across the U.S. highlight the detrimental impacts these events can have on the communities and the water utilities charged with supplying safe drinking water to them. Currently, the majority of lakes and reservoirs in the U.S. do not have the means to quantify their risk/vulnerability to HABs. While it is well known that the growth of cyanobacteria in lakes and reservoirs is favored by high nutrient concentrations, elevated temperatures, thermal stratification, and high levels of sunlight, the dynamic seasonal and temporal combinations of these factors is not well understood in individual circumstances. This has limited our ability to create a general system for quantifying the risk of, and making predictions for, HABs. Three cyanotoxins were listed on CCL3, and in 2015, EPA issued 10-day health advisories for microcystins (0.3 ppb for infants and preschool children, 1.6 ppb for school-age children and adults) and cylindrospermopsin (0.7 ppb for infants and preschool children, 3.0 ppb for school-age children and adults).

2.2.2.5 Strontium

Strontium is not radioactive in its naturally occurring form, but radioactive strontium-90 is formed through nuclear fission and used in medicine and industry, as well as being present from nuclear testing and nuclear reactor waste. The element emits beta particles and thus falls under the umbrella of the Radionuclides Rule but could possibly be regulated on its own. The EPA made a preliminary determination to regulate in 2014.

2.2.2.6 Chlorate

Chlorate can form in water when sodium hypochlorite or chlorine dioxide are used for disinfection. As part of their Six-Year Review of the Microbial and DBP Rules, the EPA is currently considering the regulation of chlorate. Although it was also sampled as part of UCMR3, chlorate has not yet reached the regulatory determination assessment phase. As the Six-Year Review progresses, further steps towards regulation may occur, but potential MCL values or likelihood of regulation are unclear at this time.

2.2.2.7 Nitrosamines

Nitrosamines are a group of chemical compounds, a number of which are classified by the EPA as probable human carcinogens. Nitrosamines are a byproduct of manufacturing processes such as rocket fuels, foods, beverages, and can enter the treatment plant from upstream industrial and wastewater treatment plant discharges. These compounds can also be formed within the treatment plant or distribution system as a byproduct of chloramines and chlorine reacting with organic nitrogen precursors. More recently, it was found that nitrosamines can be an unintentional by-product of quaternary ammonium cationic polymer coagulants during chloramine disinfection.

A total of six nitrosamines were monitored as part of the Unregulated Contaminant Monitoring Rule (UCMR2). UCMR2 data indicated that *N*-nitrosodimethylamine (NDMA) is the predominant nitrosamine occurring in drinking water. Further, NDMA was detected three times more frequently in surface waters than ground waters and ten times more frequently in surface water plants using chloramines versus chlorine alone. NDMA was also detected at higher concentrations at maximum residence time locations in the distribution system as compared to entry points.

The EPA considered regulating the nitrosamines as a group since most of them have common treatment/control processes and considered setting the MCLG at zero since all the nitrosamines are probable carcinogens. With the publication of the draft CCL5, the EPA added six of the nitrosamines under the category of unregulated disinfection by-products, five of which were monitored under the UCMR2. The following six nitrosamines are in the draft CCL5:

- Nitrosodibutylamine (NDBA).
- N-Nitrosodiethylamine (NDEA).
- N-Nitrosodimethylamine (NDMA).
- N-Nitrosodi-n-propylamine (NDPA).
- N-Nitrosodiphenylamine (NDPhA).
- Nitrosopyrrolidine (NPYR).

2.2.2.8 Hexavalent Chromium

Chromium is a metallic ion that occurs naturally in water along with iron, though usually in significantly smaller amounts. It is also produced by steel manufacturing plants and can be discharged into surface water bodies from such plants. Chromium will quickly convert to the hexavalent form, Cr-VI, in the presence of oxygen. Cr-VI is carcinogenic and is being evaluated by the EPA for regulation.

The EPA is currently conducting an Integrated Risk Information System (IRIS) toxicological assessment of Cr-VI. The draft assessment for Cr-VI oral ingestion will be combined with the draft assessment for Cr-VI inhalation exposure. The IRIS Cr-VI assessment is still under draft development, with the most recent preliminary assessment materials having been released in March 2019.

2.2.2.9 1,4-dioxane

1,4-dioxane is a common synthetic compound utilized for chlorinated solvent stabilization that was found in 21 percent of all public water systems tested in the UCMR3 program. In addition, EPA considers this a high priority chemical and a likely carcinogenic compound. The latest Drinking Water Specific Risk Level Concentration from EPA is 0.35 ppb for the 10^{-6} cancer level (one in a million lifetime cancer risk). EPA's health advisory level for noncancer toxicity effects is 0.2 ppm, so the 0.35 ppb level for cancer effects is the more conservative level. Tucson Water's operational target for 1,4-dioxane is 0.35 ppb. The notable removal difficulty of 1,4-dioxane is one of the key concerns in addition to its ubiquity, as essentially no conventional drinking water treatment technologies can reliably remove it at drinking water levels; however, ultraviolet light-hydrogen peroxide advanced oxidation process (UV AOP) is effective at treating 1,4-dioxane to below the method reporting limit of 0.1 ppb.

2.2.2.10 Manganese

The EPA included manganese, a naturally occurring ion, in UCMR4 to help assess if a primary MCL (in addition to the existing secondary MCL) should be established. As of March 10, 2020, the EPA determined there was not enough information to proceed to the regulatory determination assessment phase.

The EPA, however, has established health advisory levels (HALs) for manganese. For all persons, EPA has a 1-day and 10-day HAL of 1 mg/L and a lifetime HAL of 0.3 mg/L. For bottle-fed infants younger than six months, the EPA also has a 10-day HAL health advisory level of 0.3 mg/L.

2.2.2.11 Perchlorate

Perchlorate is a manmade chemical that is used in the manufacture of rocket fuels and explosives. It can also occur naturally in the environment. The discovery of perchlorate in water supplies causes concern due to the potential harmful impact on the functioning of the thyroid gland. Perchlorate was included in the first three of four CCLs that EPA has published to date. Based on data collected from its UCM program and comments received from the public, the EPA made a determination to regulate perchlorate in drinking water in February 2011. In July 2020, the EPA withdrew the 2011 regulatory determination, and published a final determination to not issue a national regulation.

Despite a lack of a federal MCL, some states have developed their own MCLs for perchlorate. An MCL of 6 micrograms per liter (μg/L) became effective in California in October 2007. The state of Arizona has established an advisory level of 11 μg/L for perchlorate in drinking water.

2.2.2.12 Endocrine Disrupting Compounds, Pharmaceuticals, and Personal Care Products

Endocrine disrupting compounds (EDC) are chemicals, both naturally occurring and manmade, that interfere with the normal function of the endocrine or hormonal system in animals and humans. The EPA currently regulates certain suspected EDCs including atrazine, DDT, dioxin, lead, cadmium, and mercury. If adverse effects on the endocrine system are determined at concentrations lower than current MCLs, then revised regulations may be established for these compounds.

Pharmaceuticals and Personal Care Products (PPCPs), sometimes also EDCs, refer to all pharmaceuticals used for human health and cosmetic purposes, as well as veterinary drugs. Typical PPCPs include antifungal medication, oral contraceptive pills, over-the-counter medications, perfumes, detergents, insect repellents, steroids, and antibiotics. PPCPs can enter surface water bodies from a variety of sources including industrial and municipal effluents, agricultural runoff, and hospital residues. Currently PPCPs are not regulated by the EPA.

2.2.2.13 Microplastics

Microplastics, or small plastic particles occurring between 1 nanometer and 5 millimeters, are considered ubiquitous in drinking water, wastewater, and ambient water. Additionally, presence in groundwater is also indicated as a potential impact of landfill leachate. The tendency of microplastics to continuously break down in the treatment process to potentially size ranges that are more toxic, less detectable, and more difficult to remove, notable concerns for this microconstituent.

Current levels in drinking water range from less than 1 particle/L to more than 300 particles/L. Proposed ambient water thresholds are approximately 70 particles/L.

2.2.2.14 Fluoride

While fluoride is currently regulated in the NPDWR at an MCL and MCLG of 4.0 ppm, the natural occurrence of fluoride or addition of fluoride to drinking water at times gains public attention. In addition to the MCL and MCLG, a 2.0 ppm NSDWR adds nonregulatory guidance for this inorganic chemical. Despite the NPDWR and NSDWR, the presence of low levels of fluoride in drinking water are desirable for cavity prevention. Tucson Water does not add fluoride and all presence is naturally occurring within the distribution system.

2.2.3 Unregulated Contaminant Monitoring Rules

The UCM program requires that EPA issue a list of no more than 30 unregulated contaminants every five years, to be monitored by public water systems. Such periodic monitoring provides EPA with a basis for setting national drinking water regulations in the future.

Unregulated contaminant monitoring required as part of the UCM program is generally conducted using a tiered approach based on the level of development of analytical methods used. Assessment Monitoring (List 1) is conducted for contaminants that have analytical methods that are well established. Screening Survey (List 2) monitoring is conducted for contaminants whose analytical methods have generally been more recently developed and employ technologies that are not as widely used or for which laboratory capacity required to conduct larger-scale Assessment Monitoring may be insufficient. Pre-Screen Testing (List 3) is conducted for contaminants that have very new or specialized analytical methods.

The data collected through the UCMR program is stored in the National Drinking Water Contaminant Occurrence Database (NCOD) to facilitate analysis and review. To date, there have been four UCMR rules published by EPA. In the upcoming cycle from 2022 to 2026, the UCMR5 will be implemented which proposes twenty-nine per-and PFAS. The one additional contaminant for planned monitoring is lithium. Table 9 summarizes the five UCMR, their monitoring schedule, and the type of contaminants included in the list.

Table 9 Unregulated Contaminant Monitoring Rule History

	Monitoring Schedule	Contaminants Included
UCMR1	2001 – 2005	• 12 chemicals on List 1(1) • 14 chemicals on List 2(2)
UCMR2	2007 – 2011	• 10 chemicals on List 1(1) • 15 chemicals on List 2(3)
UCMR3	2012 – 2016	• 21 chemicals on List 1(1) • 7 hormones on List 2(3) • 2 viruses on List 3(4) pre-screening
UCMR4	2018 – 2020	• 10 cyanotoxins on List 1(1) • 20 chemicals on List 1(1)
UCMR5	2023 – 2025	• 30 chemicals on List(5)

Notes:
(1) All public water systems serving more than 10,000 people performed assessment monitoring for List 1 contaminants, along with a representative selection of 800 public water systems serving less than 10,000 people.
(2) A selection of 120 systems serving more than 10,000 people and 180 systems (a subset of the 800 List 1 systems) serving less than 10,000 people were assigned to monitor for List 2 contaminants.
(3) All public water systems serving more than 100,000 people, along with 320 public water systems serving 10,000 to 100,000 people and 480 public water systems serving less than 10,000 people, performed screening surveys for List 2 contaminants.
(4) A representative selection of 800 undisinfected groundwater serving public water systems serving 1,000 or fewer people participated in monitoring for two viruses and related pathogen indicators.
(5) All public water systems serving more than 3,3000 people, along with a representative selection of 800 public water systems serving less than 10,000 people, would perform monitoring for listed contaminants.

2.2.3.1 Contaminant Candidate Lists

Each of the UCMR lists that the EPA generates under the UCM program is largely based on the CCL (see Table 10). The CCL is a list that the EPA maintains of priority contaminants that are known to occur in public water systems but that are currently unregulated. The UCM program and CCL complement each other, and similar to the UCM program, the EPA uses the CCL to prioritize research and data collection efforts for future regulations. The EPA publishes the CCL periodically and decides whether to regulate at least five or more compounds present on the most recent list (called Regulatory Determinations/RegDet) every five years.

The SDWA specifies that contaminants on the CCL shall be regulated if the EPA Administrator determines that:

- The contaminant may have an adverse effect on the health of persons.
- The contaminant is known to occur, or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern.
- In the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems.

If the EPA makes a determination that regulation of a contaminant in the CCL is warranted, the Agency must develop and promulgate a NPDWR based on the timeline established by the 1996 SDWA Amendments. To date, four CCLs have been reviewed and prepared. EPA began the process of developing CCL 5 in 2018 by requesting nomination of chemicals, microbes, or other materials for consideration. The deadline for CCL 5 nominations was December 4, 2018.

Table 10 Contaminant Candidate List History

	Year Published	Contaminants Included	Proposed Regulations	Regulatory Determinations
CCL1	1998	• 10 microbial • 50 chemical	• 8 chemicals (including manganese) and 1 microorganism (*Acanthamoeba*)	• Not to advance regulation of 8 chemicals (including manganese) and 1 microorganism (*Acanthamoeba*)
CCL2	2005	• 9 microbial • 42 chemical	• 12 chemicals	• Not to advance regulation of 11 chemicals • More information needed on perchlorate
CCL3	2009	• 12 microbial • 104 chemicals	• 5 chemicals	• Preliminary determination to regulate strontium • Not to regulate 4 chemicals
CCL4	2016	• 12 microbial • 97 chemicals	• 8 chemicals	• Preliminary determinations to regulate PFOS & PFOA • Not to regulate 6 chemicals
CCL5	Nominations in 2018	• 12 microbial • 66 chemicals and 3 chemical groups	• TBD	• TBD

2.2.4 Monitoring and Planning for Unknowns

While compliance with existing regulations is paramount, potential new regulations are on the horizon. Also of interest are changes in source water quality that could change the concentrations of compounds currently found in water served to the public. This section details contaminants detected in monitoring of CAP water, Tucson's primary potable resource. The recharge, recovery, and blending of this water serves to lower potential water quality risks from CAP water.

2.2.4.1 Pathogens

Cryptosporidium and Giardia have both been detected at low concentrations in CAP water. When CAP water is recharged in surface basins, the soil retains pathogens and greatly reduces their concentrations. Disinfection of recovered CAP water also inactivates pathogens that may remain.

2.2.4.2 Turbidity, Organics, and Nutrients

Turbidity must be maintained at or below 0.3 NTU in 95 percent of finished water samples. While this has typically not been an issue of concern, climate change and forest fires increase the risk of turbidity and organic loading. The nutrient loading can also increase the potential for algal growth and the presence of algal toxins.

2.2.4.3 Disinfection By-products

Natural organic matter (NOM) in surface waters, including the CAP canal, results in the potential for formation of DBPs, including TTHM and HAA5. Furthermore, the free chlorine residual in the distribution system can increase the formation of DBPs. Absorption on soil during the recharge process for CAP, as well as blending with groundwater, helps to reduce the DBP formation potential of the recharged and recovered water.

2.2.4.4 Arsenic

Arsenic is naturally occurring in Colorado River water, but it is generally found at concentrations that are below the current MCL of 10 ppb. Arsenic data in the main and isolated systems are discussed in Section 2.4.2.3 and Appendix B.

2.2.4.5 Perchlorate

Perchlorate occurs in Colorado River water due to discharges from two chemical manufacturers in Henderson, Nevada. Remediation efforts by the Nevada Department of Environmental Quality have reduced the amount of perchlorate entering the river system, and there have been no detections of perchlorate in raw CAP water over the last three years. Recharge and recovery of Tucson Water's CAP allotment further reduce concentrations of perchlorate.

2.2.4.6 Uranium

Uranium is naturally occurring in the Colorado River at low concentrations, with risks coming from upstream mining near Moab, Utah, and other sites. As with other contaminants, Tucson Water's strategies for managing the recharged and recovered water serve to increase the utility's resilience against potential changes in CAP concentrations of uranium.

2.2.4.7 Summary of Monitoring and Planning for Unknowns

It is recommended that Tucson Water continue with a robust program for monitoring and planning for unknowns. By continuing the Sentry Program, the utility will maintain data throughout the distribution system. Adding CAP raw water as a sample point will increase Tucson Water's ability to monitor constituents entering their system. Additionally, the Sentry Program would give Tucson Water the ability to participate in research programs on opportunistic pathogens and better track guidance on mitigating risks associated with these pathogens. The utility may conduct public outreach and share water quality data with CAP and other municipal subcontractors. Additionally, it is recommended that Tucson Water identify action levels and a response plan for key contaminants in the CAP raw water. Such plans could help avoid any problems caused by these contaminants by not allowing them into Tucson Water's sources.

2.3 Colorado River and Central Arizona Project Water

2.3.1 Background

Tucson Water has an annual allocation of 144,191 acre-feet of Colorado River Water, conveyed to Tucson through the CAP aqueduct. As expected for a surface water that flows great distances from its originating watersheds, the Colorado River has much higher salinity levels than most of Tucson's high quality native groundwater (~260 ppm TDS per PAG 1994), and the salinity in Colorado River water increases as water evaporates along the 300-mile journey through the CAP canal. Because relatively little of the water entering the Tucson Active Management Area (TAMA) leaves via any route besides evaporation/evapotranspiration (approximately 20 percent of the salt loading leaves in groundwater and, at times, in the Santa Cruz River [United States Bureau of Reclamation (USBR), 2003]), the basin is accumulating salt. Other salt contributions, such as treated wastewater discharges and fertilizer application, increase this accumulation.

In 1984, the US Bureau of Reclamation (USBR, 1984) projected that TDS would reach 650 ppm in the potable supply by 2050 and 750 ppm by 2100. These projections were for direct use of CAP water without recharge and recovery; therefore, they are only applicable to TARP raw water (see Section 2.3.2). A decade later, the Pima Association of Governments (PAG, 1994) noted an increase in water softener use by households receiving CAP water. Water softeners sequester calcium and magnesium ions and release sodium ions. The Central Arizona Salinity Study (USBR, 2003) looked to quantify the amount of salt accumulation in the TAMA and calculated a value of 107,500 tons net salt accumulation in the year 2000. They projected that by 2015, the accumulation would nearly double, to 200,000 tons annually, due to full receipt (for use or local recharge) of the CAP allotments by area water providers.

Another study (Malcolm Pirnie, 2007) projected that Tucson Water's recharged and recovered CAP water, while initially significantly influenced by blending with the native groundwater, would eventually approach the same salinity as incoming CAP water, about 650 ppm. The study also noted that overall salt accumulation in the basin would increase even more rapidly due to increased water softener use.

2.3.2 CAP Aqueduct Water Quality Requirements

The CAP aqueduct was designed to deliver CAP (Project) water, which has a delivery standard of 747 ppm TDS (CAWCD and USBR, 2020). CAP also has guidance for the acceptance of Non-Project water (water wheeling) through the CAP canal (CAWCD and USBR, 2020), which would cap salinity levels for Non-Project water at 1,150 ppm TDS. The intent of the standards is to ensure that, if water providers in the TAMA purchase non-Project water and have it wheeled through the CAP canal, the TDS of all CAP water in the Tucson branch could increase above the existing level in delivered water (around 650 ppm) but would not exceed the delivery standard of 747 ppm.

CAP has historically monitored 143 compounds, most regulated under the SDWA. For future monitoring, they are moving to monitor a total of 300 contaminants, including contaminants of emerging concern (CECs) such as PFAS, cyanotoxins, and 1,4-dioxane. CAP conducts the monitoring program at three pumping plants, three additional sampling locations along the canal, and two locations at Lake Pleasant for the water that enters the CAP canal from the Agua Fria River. For Non-Project supplies to be introduced to the canal, according to the guidance (CAWCD and USBR, 2020), they would have to provide historic data for all monitored constituents or collect one year of data, with a priority list of constituents sampled quarterly and the other constituents sampled semi-annually. Non-Project supplies would then be monitored (similar quarterly/semi-annual testing) for a "proving period" of two years, with subsequent monitoring requirements based on classification of the water in one of three risk-of-exceedance categories.

2.3.3 CAP Recharge Water Quality Trends

The Colorado River Salinity Control Program (SCP) was instituted in 1985 through USBR (acting on behalf of the Secretary of the Interior) with the goal of reducing the salinity of the water throughout the Colorado River Basin. As seen in in Figure 4, salinity of Colorado River water below Parker Dam has not increased significantly in the past 40 years and is lower than modeling indicates it would have been without the SCP interventions. TDS in water entering the CAP canal has remained below the water quality standard limit of 747 ppm.

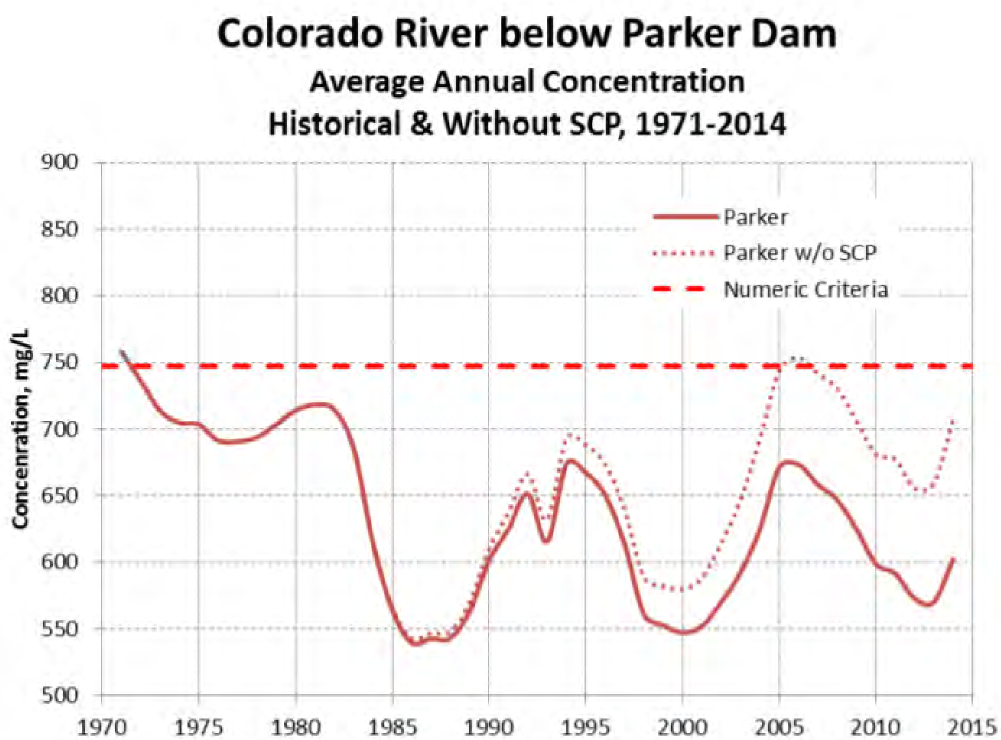


Figure 4 TDS Concentrations in Colorado River Below Parker Dam

CAP raw water reaching Tucson Water's Central Avra Valley Storage and Recovery Project (CAVSARP) facility has contained fairly steady TDS concentrations, as shown in Figure 5. In turn, the TDS in the recharged and recovered water has been fairly stable over time, rising gradually from about 480 ppm to about 540 ppm over the last decade.

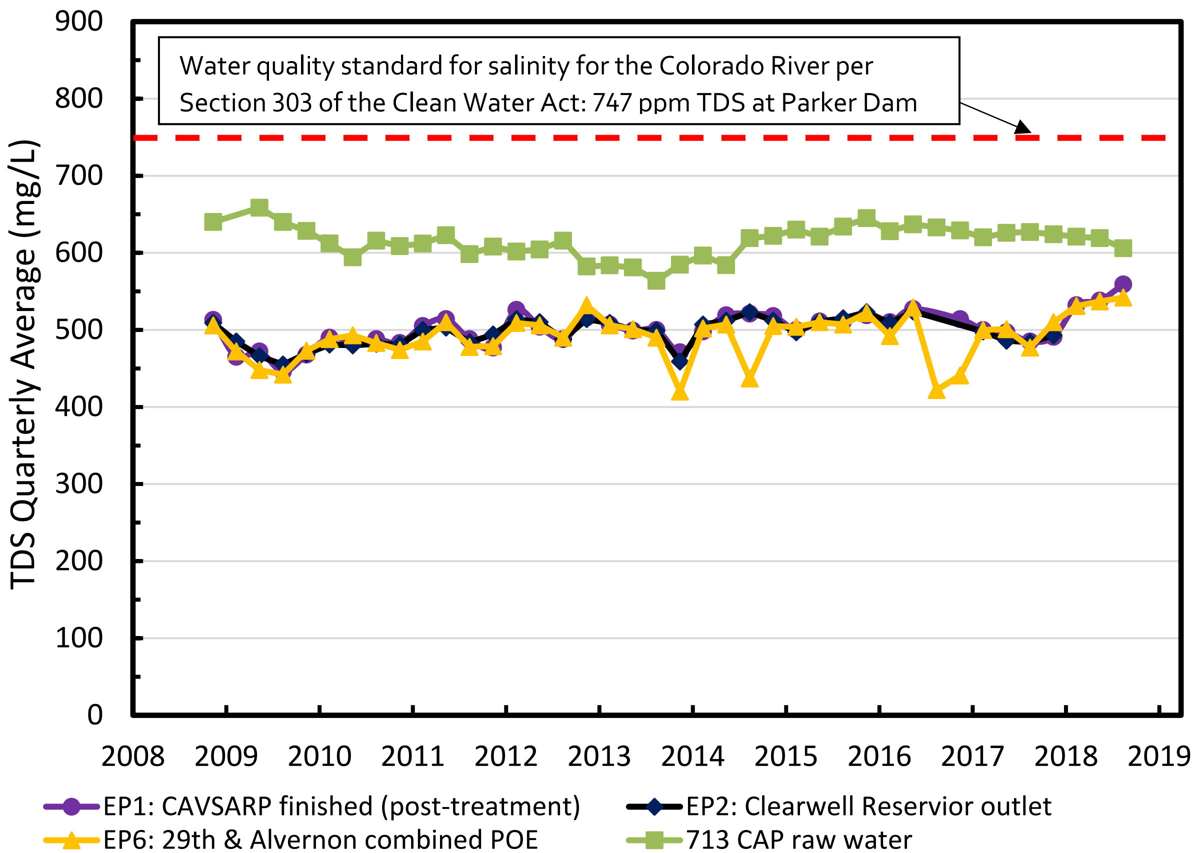


Figure 5 TDS Concentrations in Raw CAP Water and Recovered CAP Water

2.4 Potable Water System Compliance Review

2.4.1 National Primary and Secondary Drinking Water Regulations

As previously described, the NPDWRs are directly related to potential health impacts while NSDWRs are related to taste, odor, and aesthetic appeal of drinking water. During the time period of this analysis, Tucson Water met all current Federal and State regulations. This positive compliance pattern is expected to continue, including robust DBPR compliance. Opportunity to better characterize the distribution system impacts remain due to periodic source water changes due to the variety of sources in the One Water portfolio. Additionally, best management practices are always recommended to continue to be implemented to prevent aesthetic changes in the distribution system to increase customer satisfaction.

For more information on the primary and secondary water quality parameters, see Table A.1 and Table A.2, respectively. All figures for nitrate, fluoride, total dissolved solids, and alkalinity are shown in Appendix B.

2.4.1.1 Nitrate as N

The primary MCL for nitrate as nitrogen is 10 ppm. Data has historically remained within this MCL other than two data points in water quality zone (WQZ) 6 of the main system (Figure B.1). This well, D-047A, is now offline due to the elevated concentrations of nitrate. Additionally, nitrate as N remains within the appropriate range for the isolated systems, with Rancho del Sol's levels at the highest within those systems (Figure B.2).

2.4.1.2 Fluoride

The primary MCL for fluoride is 4 ppm with a secondary MCL at 2 ppm, as previously described in Section 2.2.4.2. All main system and Isolated Systems data is well below the MCL and MCLG as shown in Figures B.3 and B.4.

2.4.1.3 Total Dissolved Solids

The secondary MCL for TDS is 500 ppm due to aesthetic appeal of the water. As shown in Figure B.5, the TDS concentrations in the WQZs reflect a steady increase over the last 20 years, reflecting the contribution of recharged CAP water over time. Within the isolated systems, Silverbell West has a higher annual average TDS than any other isolated systems shown in Figure B.6. Altogether, 1,076 data points graphed were measured data points, while 65,989 of these points were estimated via conductivity for the combined main and isolated systems.

2.4.1.4 Alkalinity

There is no primary or secondary MCL for alkalinity; however, there is a secondary MCL for corrosivity indicating water must be non-corrosive. As shown in Figure B.7, WQZ 10 has the highest alkalinity outlier. Additionally, WQZ 1 has the highest maximum values typically than any other WQZ in the main system. All isolated system values remain consistent as shown in Figure B.8.

2.4.2 Chemical Contaminant Regulations

2.4.2.1 Phase II/V Rules

All Phase II/V Rule contaminants previously listed in Table 3 remain within compliance.

2.4.2.2 Lead and Copper Rule and the Lead and Copper Rule Revisions

To reduce the levels of lead and copper in the potable water system, the two most important things are to remove lead pipes from the system and to ensure finished water stability. Tucson Water has led the region in the identification, removal, and replacement of LSLs through its Get the Lead Out (GTLO) program since 1999. Tucson Water began inspecting service lines to determine the risk of LSL presence, which led to a distribution system materials inventory. With this program, more than 1,342 service lines have been assessed. Table 11 shows the numbers of known or suspected LSLs that were abandoned, inspected, replaced, are awaiting replacement, are under investigation, or were unable to be located.

Table 11 Lead Service Line Replacement Program "Get the Lead Out"

Status	Number of Service Lines
Abandoned service	118
Inspected & found copper	293
Requires inspection	26
Lead service line replaced	809
Lead service line awaiting replacement	1
Unable to locate	33
Under investigation	62
Total	**1,342**

When the recharged and recovered CAP water (see Section 2.3) was first introduced to the distribution system, Tucson Water increased the pH of the water to approximately 8.0 to help ensure chemical stability in the blend. The much higher salinity of the CAP water compared with the native groundwater created the possibility of increased corrosivity, and higher pH water helped to reduce corrosivity. Over the last 2 decades, Tucson Water was able to reduce the amount of pH adjustment and eventually stopped adjusting finished water pH as the distribution system became more acclimated to the higher salinity water.

As Table 12 shows, from 2016 through 2018, the maximum 90th percentile values for copper and lead concentrations in the distribution system were roughly an order of magnitude lower than the EPA action levels, indicating that these elements are well controlled in Tucson Water's system. In terms of historical compliance with the current LCR, Tucson Water has been in compliance with the 15 ppb action level for the entire period of time studied from 2011-2017.

Figure 6 and Figure 7 show the cumulative frequency distributions for copper and lead, respectively, for 2017, 2018, and 2019. All copper detections were well below the action level. For lead, there was one location that had samples over the action level; the lead service line to this location was replaced. Additional data about lead and copper can be found in Appendix C.

Table 12 Lead and Copper Rule Compliance

Parameter	Units	EPA Action Level	MCLG	Tucson Water Maximum 90th Percentile Value (2016-2018)
Copper	ppm	1.3	1.3	0.142
Lead	ppm	0.015	Zero	0.00107

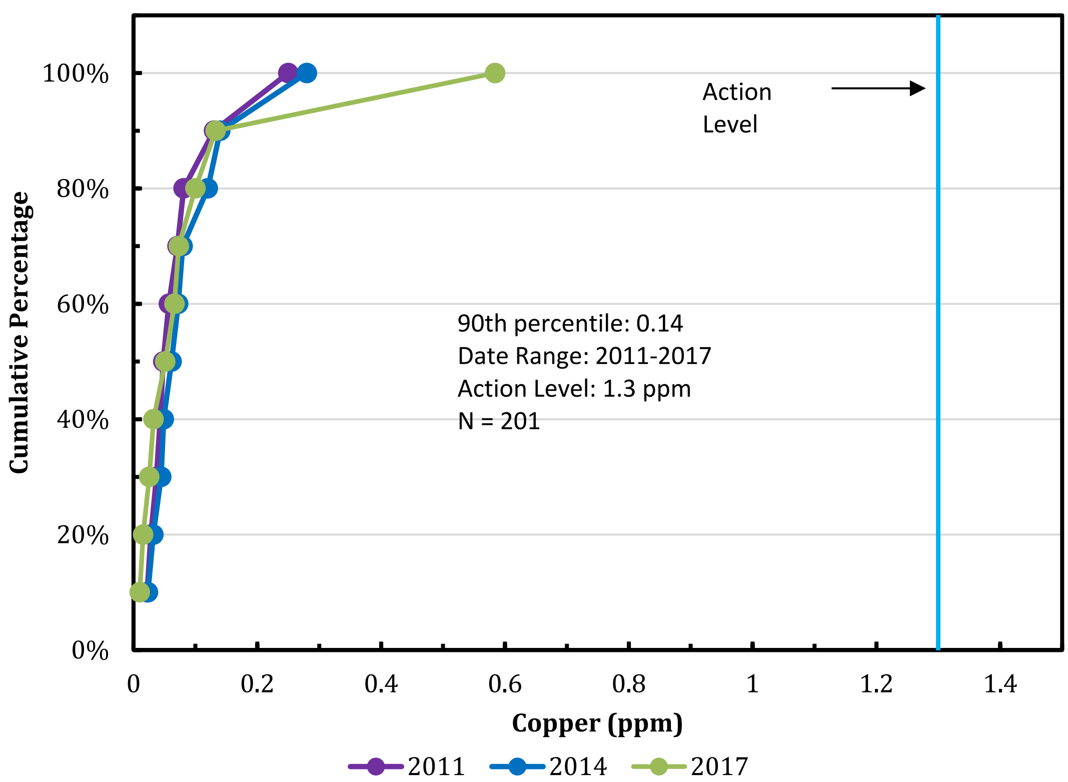


Figure 6 Main System Copper Cumulative Frequency Distribution

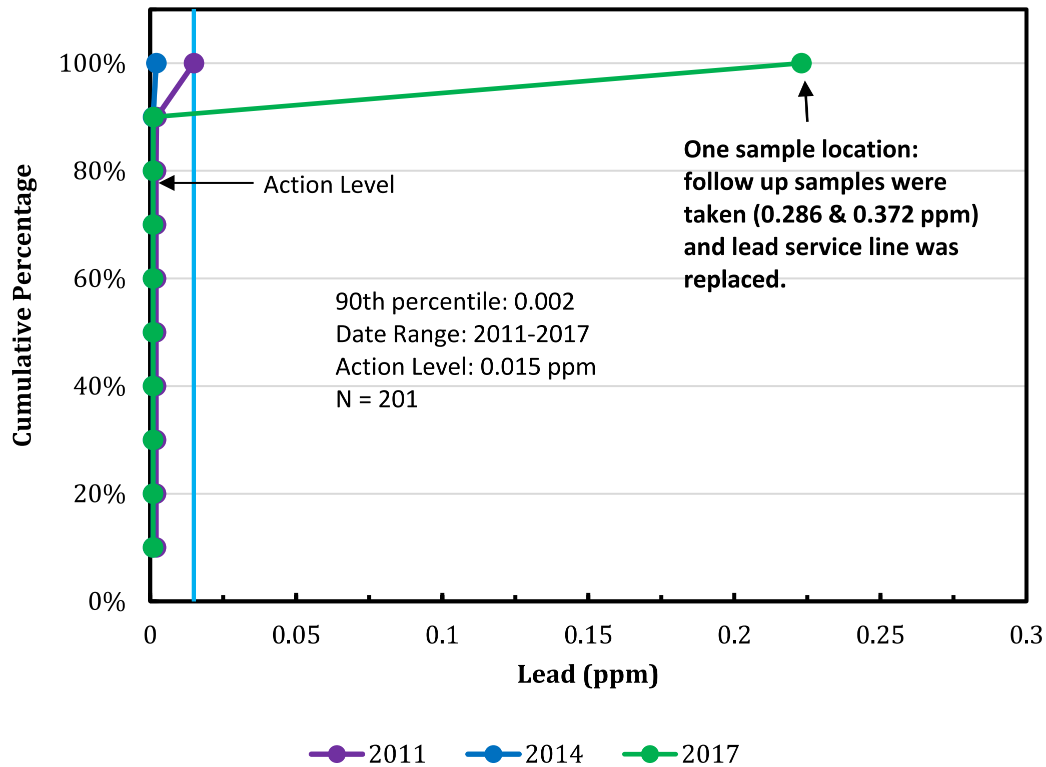


Figure 7 Main System Lead Cumulative Frequency Distribution

Tucson Water plans to carefully evaluate distribution system impacts if changing source water or treatment approaches. A flushing plan in the distribution system may help mitigate any water quality issues that arise from flow reversing direction in some pipes due to distribution system changes. A flushing standard operating procedure is given in Appendix D. Moreover, Tucson Water will calculate corrosion indices for each WQZ during times when no water is delivered through Snyder Hill Pump Station (SHPS).

Calculated values for the calcium carbonate precipitation potential (CCPP) in recharged and recovered CAP water are shown in Figure 8. EP1 samples the water recovered from the CAVSARP; EP2 samples the water from the Clearwell Reservoir, the highwater storage for recovered water; and EP6 samples the water where it enters the distribution system and blends with other system water. The CCPP calculates the quantity of calcium carbonate that will precipitate or dissolve. Positive values indicate calcium carbonate will precipitate. Negative values indicate calcium carbonate will dissolve. A stable water is considered to be one in which the CCPP is between 4 and 10 (slightly scale forming), and most of Tucson Water's samples fall into this range.

Calculated values for the Langelier Saturation Index (LSI) are shown in Figure 9. LSI calculates the pH of calcium carbonate stabilization. Positive values indicate calcium carbonate will precipitate. Negative values indicate calcium carbonate will dissolve. A balanced LSI is near zero (± 0.5), and most of Tucson Water's samples fall into this range.

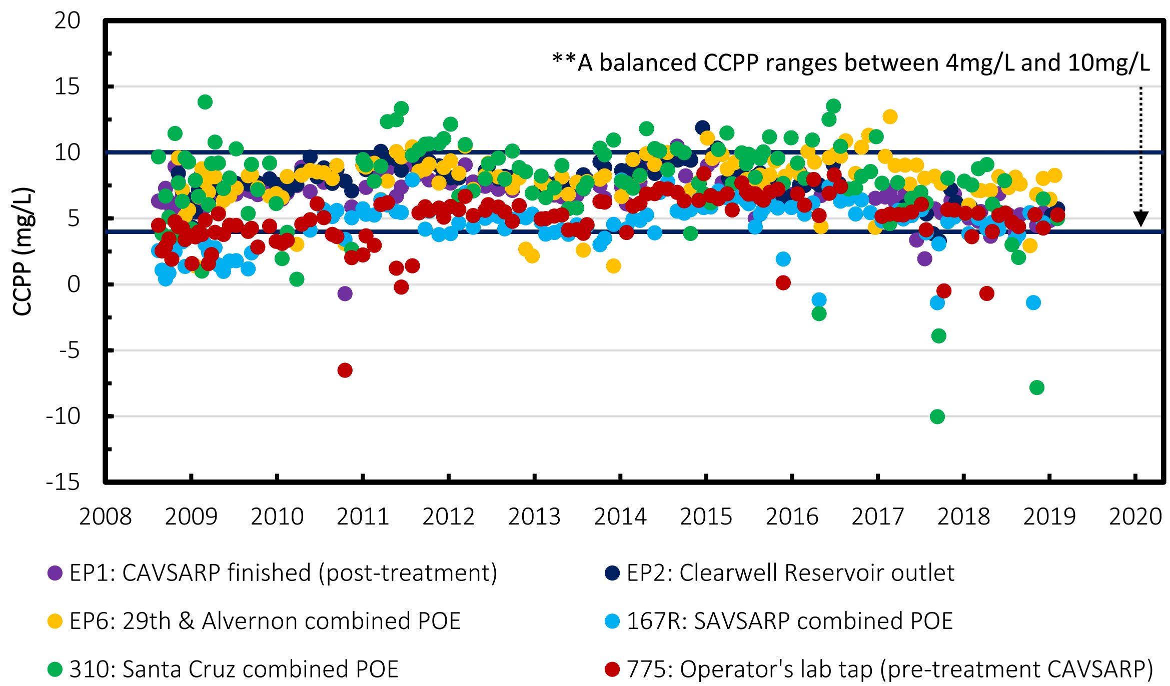


Figure 8 Calcium Carbonate Precipitation Potential (CCPP)

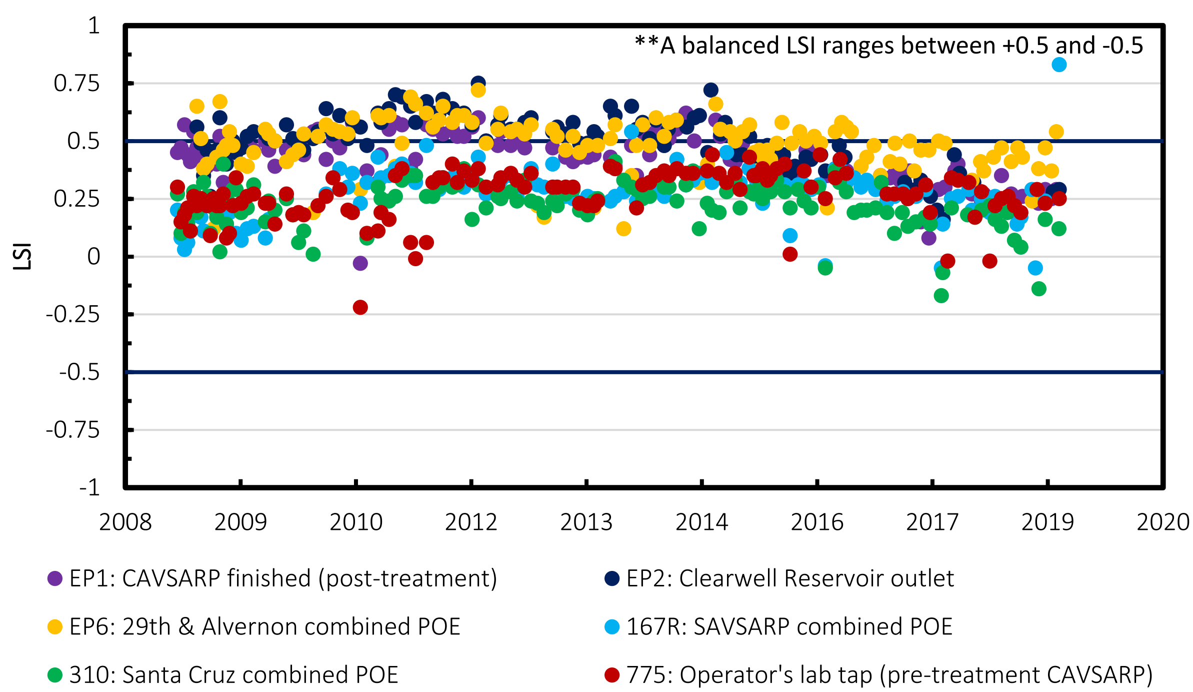


Figure 9 Langelier Saturation Index (LSI)

In addition to LCR compliance, historical data indicates that Tucson Water also has no history of the 10 ppb trigger level which begins in 2024. The data indicates that the system is well positioned for the LCRR with the current plan to continue identifying service line material as part of everyday operations and maintenance to fulfill the LSL inventory requirement by the 2024 compliance deadline. Tucson Water will begin researching machine learning to identify more service lines. Altogether, 200,000 service lines are within the service area; however, only 3,000-4,000 are considered an unknown material.

The additional requirements of the LCRR beyond those of the LCR, fall into six focus areas:

- Identifying areas most impacted.
- Strengthening treatment requirements.
- Systematically replacing lead service lines.
- Increasing sample reliability.
- Improving risk communication.
- Protecting children in schools and childcare facilities.

Complying with all the provisions of the LCRR will still require actions by Tucson Water despite the already low levels of copper and lead in the distribution system, due to the additional requirements imposed by the rule revisions. The projected effects and strategy for compliance are given in Table 13.

Table 13 Summary and Insight for Lead and Copper Rule Revisions

Focus Area	Rule Requirement	Impact to Tucson Water
Identifying areas most impacted	• Complete an LSL inventory within 3 years of rule promulgation. • Systems without LSLs must demonstrate their absence.	• Tucson Water will need to develop a LSL inventory by January 16, 2024. • The LSL inventory is in the early stages. Known LSLs have been identified and removed per the GTLO Program, but known galvanized requiring replacements (GRR) exist (<200). 3,000-4,000 service lines are lead status unknown. Reference material includes building construction records, and tap cards.
Strengthening treatment requirements	• 10 ppb trigger level (TL) for lead, in addition to the current 15 ppb action level (AL). • If the TL is exceeded based on 90th percentile lead concentrations, systems must re-optimize CCT or conduct a study if CCT is not currently in place. • Calcium hardness adjustment is no longer a lead CCT option and phosphate inhibitors must be orthophosphate. • Calcium, conductivity, and temperature analyses are no longer required as part of the water quality parameter (WQP) sampling. • If an individual tap sample exceeds 15 ppb lead, systems must collect a follow-up sample, conduct WQP monitoring at or near the site (0.5-mile radius, similar pressure zone), and perform a corrective action. This is termed a "find-and-fix" approach.	• No historical data indicates a potential for action level exceedance or trigger level exceedance.
Systematically replacing lead service lines	• Systems with lead above the TL for lead must develop a goal for LSL replacement; 3% LSL replaced per year with systems above the AL. • No partial LSLs can be conducted. • Utilities must replace their portion of an LSL within 45 days if the customer replaces their portion.	• Tucson Water is subject to public notification requirements for any lead status unknown locations. Galvanized lines on both the public and private side will also trigger notification requirements unless information is identified that confirms the pipes were never downstream of an LSL.
Increasing sample reliability	• Prioritize sample collection from sites served by LSLs. • For sites with LSLs, the 5th liter should be collected. • Collect samples in wide-mouth bottles with no cleaning, flushing, etc. prior to sample collection.	• Tucson Water may need to update its lead and copper sampling list to meet the revised tiering structure if any LSLs or GRR service lines are identified.

Focus Area	Rule Requirement	Impact to Tucson Water
Improving risk communication	• Utilities must notify individual tap sample consumers within 3 days of a 15 ppb lead sample detection. • Utilities must inform customers served by an LSL or lead status unknown service line. • Consumer Confidence Report (CCR) must provide updated health effects language and information regarding LSL replacement programs. • Utilities must notify system-wide customers of lead AL exceedance within 24 hours. • Systems must improve public access to lead information, including LSL locations, and respond to requests for LSL information, deliver educational materials to customers during water-related work that could disturb LSLs, and provide increased information to health care providers.	• Tucson Water will need to develop a plan and materials to comply with the new notification requirements for lead status unknown locations and any other materials (e.g., galvanized requiring replacement) that trigger additional communication.
Protecting children in schools and childcare facilities	• Develop a list of schools and childcare facilities by the 2024 compliance deadline. • Test 20% of licensed childcare facilities and elementary schools each year. • Provide testing to secondary schools on request. • Provide information and communicate results to users of the facility, parents, Primacy Agency, and the local or state health department.	• Tucson Water will need to sample 20% of schools and licensed childcare facilities within the city annually, or all facilities over the 5-year period. The Arizona Department of Human Services has begun screening water for lead in licensed facilities as early as 2017, which may be coordinated with LCRR requirements pending confirmation with ADEQ.

2.4.2.3 Arsenic Rule

The NPDWR MCL for arsenic is 0.01 ppm while the MCLG remains at zero. Arsenic data in the main system and isolated systems are below the MCL. However, WQZ 1 has one data point that has come close to the MCL as shown in Figure B.13. All isolated systems data, shown in Figure B.14, remains well below the MCL. When adjusting for discretionary sampling at specific wells, Figure B.15 shows the average annual arsenic concentration is well below the MCL.

2.4.2.4 Radionuclides Rule

The gross alpha particles MCL is 15 pCi/L with no MCLG. Adjusted gross alpha remains below the MCL in the main system as shown in Figure B.16. One adjusted gross alpha data point for Valley View in the Isolated Systems, shown in Figure B.17, is higher than the MCL.

2.4.3 Microbial and Disinfection Byproduct Regulations

2.4.3.1 Stage 1 and Stage 2 Disinfection Byproducts Rule

Data for the 2016-2018 study period are shown below in Table 14 which indicates Tucson Water remains below the minimum reporting limit (MRL) for bromate, chloramine, chlorine dioxide, chlorite, and total organic carbon. The remaining three parameters, free chlorine, haloacetic acids, and total trihalomethanes, remain well below the MCL and MCLG, if an MCLG is established.

Table 14 Stage 1 and Stage 2 Disinfection Byproducts Rule Compliance

Parameter	Units	EPA Primary MCL, MRDL, or TT	EPA MCLG	Maximum Detection (2016-2018)
Bromate	ppm	0.010	Zero	< MRL
Chloramine (As Free Chlorine)	ppm	4.0	4.0	< MRL
Chlorine Dioxide	ppm	0.8	0.8	< MRL
Chlorite	ppm	1.0	0.8	< MRL
Free Chlorine	ppm	4.0	4.0	0.99(1)
Haloacetic Acids (5)	ppm	0.060 LRAA	None	0.0038
Total Organic Carbon	ppm	TT	None	< MRL
Total Trihalomethanes	ppm	0.080 LRAA	None	0.021

Notes:
(1) Free chlorine is measured monthly and reported as an annual average value.

2.4.3.2 Total Trihalomethanes

The MCL for TTHM is 0.08 ppm based on a LRAA. All TTHM data for the main system and isolated system is below 0.08 ppm. Additional data on TTHMs in the main and isolated systems are shown in Figure B.9 and Figure B.10, respectively.

2.4.3.3 Haloacetic Acids (5)

The MCL for HAA5 is 0.06 ppm based on a LRAA. All HAA5s are well below the MCL for the main system and isolated systems. Additional data on HAA5s in the main and isolated systems are shown in Figure B.11 and Figure B.12, respectively.

2.4.4 Potential Future Regulatory Requirements and Contaminants of Emerging Concern

2.4.4.1 Potential Future Regulatory Requirements

As discussed in Section 2.2.3, contaminants on the UCMR lists may be regulated in the future. Table 15 and Table 16 show contaminants from UCMR3 and UCMR4, respectively, that have been detected in Tucson Water's wells or distribution system sampling points. In cases where the compound has a health advisory level, a relative health risk was also calculated, which is the maximum detection divided by the health advisory, such that a value of one would reflect a contaminant occurring at the health advisory level. For the UCMR3 and UCMR4 contaminants detected, none were measured at levels higher than the existing health advisory, so no exceedances would be expected if the contaminants were to be regulated at the existing health advisory level. As toxicology data is gathered, however, it is possible that maximum contaminant levels could be issued that are lower than the existing health advisory.

The highest relative health risk was found for 1,4-dioxane, at 0.629. In the case of this contaminant, Tucson Water has managed and treated its supplies, such as by shutting down some wells with detection and by treating TARP groundwater to remove 1,4-dioxane (see Section 3.3.1.2) to mitigate 1,4-dioxane levels in the distribution system.

UCMR Programs

Table 15 UCMR3 Compounds Detected

Parameter	Units	Maximum Detection	Minimum Reporting Level	Health Advisory	Relative Health Risk(1)	Percent of Locations with Detections(2)	Sample Point with Highest Detection
1,4-dioxane	ppb	0.22	0.07	0.35(3)	0.629	10%	SP-830
Chlorate	ppb	1,100	20	-	-	100%	C-016B
Chromium (total)	ppb	2.2	0.2	100(4)	0.022	80%	310
Chromium-6	ppb	2.3	0.03	-	-	100%	310
HCFC-22	ppb	0.09	0.08	-	-	10%	C-112A
Molybdenum	ppb	13	1	40	0.325	80%	SP-830
Strontium	ppb	1,200	0.3	4,000	0.3	100%	AV-021A
Vanadium	ppb	9.8	0.2			100%	EP1

Notes:
(1) Relative health risk calculated as the maximum detection divided by the health advisory.
(2) Sample size is ten well locations; two samples were collected from each well.
(3) This is the lowest HAL for 1,4-dioxane, representing a 10^{-6} excess lifetime cancer risk.
(4) Value is a maximum contaminant level.

UCMR4

Table 16 UCMR4 Compounds Detected

Parameter	Units	Maximum Detection	Minimum Reporting Level	MCL	Relative Health Risk(1)	Percent of Locations with Detections(2)	Sample Point with Highest Detection
Haloacetic acids (5)	ppb	7.7	-	60	0.128	100%	SP-860
Haloacetic acids (6)	ppb	9.1	-	-	-	100%	SP-860
Haloacetic acids (9)	ppb	15.7	-	-	-	100%	SP-860

Notes:
(1) Relative health risk calculated as the maximum detection divided by the maximum contaminant level.
(2) Sample size is eight well locations; one sample was collected from each well.

Together, the UCMR and Sentry Program offer a comprehensive summary of emerging contaminants in Tucson Water's supplies. Refer to Appendix E for the 2020 report and results from the Sentry Program. An increased number of contaminants detected through UCMR and other monitoring does not equate to increased risk and in many cases is due to increasingly sensitive analytical methods. It is recommended that Tucson Water continue its monitoring programs and compare results to health-based guidance.

2.4.4.2 Impaired Groundwater

The CECs causing the most risk to Tucson Water's potable supply wells are 1,4-dioxane and PFAS, but other contaminants are also present in Tucson area groundwater, as shown in Figure 10. An approximate delineation of PFAS groundwater contamination in Pima County is also given in Figure 10. Contamination plumes appear to originate from two areas, the Morris Air National Guard facility near Tucson International Airport and the Davis Monthan Air Force Base (DMAFB). The AFFFs used in fighting aircraft fires (and training to fight such fires) are currently thought to be the major sources of PFAS contamination in these areas. PFAS is also present in treated wastewater, so additional PFAS is thought to be released to the environment at the outfalls of the Agua Nueva and Tres Rios water reclamation facilities near Prince Road and Ina Road, respectively, along Interstate 10. Additionally, PFAS contamination occurs in groundwater at locations along the Santa Cruz River and other surface water features, with no clear point source. There are also high concentrations of 1,4-dioxane in the TARP plume and in groundwater near the Santa Cruz River and Cañada del Oro wash north of Tucson. As seen in Figure 10, Tucson Water has numerous potable water production wells within or near the areas of groundwater contamination shown. To help meet Tucson Water's operating targets for 1,4-dioxane and PFAS, if any well has contaminant concentrations above the utility's operational water quality target, the well is taken out of service. See Appendix F for a summary table of out-of-service wells.

Detail about the wells affected by PFAS near TARP and DMAFB can be seen in Figure 11. In 2021, ADEQ began construction of the Central Tucson PFAS Project Demonstration Facility (Carollo Engineers, Inc. [Carollo] 2021) at Well C-007, on the east side of Figure 11. The project is a demonstration-scale installation consisting of sediment removal and ion exchange (IX) for the adsorption of PFAS compounds. Because it is a demonstration program, the treated water is being discharged to a storm sewer, but the demonstration could pave the way toward wellhead IX treatment in areas of groundwater impaired by high levels of PFAS.

In the northwest portion of the PFAS and 1,4-dioxane plumes, Tucson Water conducted the Northwest Area Wells Alternatives Evaluation (Carollo 2020), identifying nine wells for potential centralized treatment in three clusters. Treatment proposed for the sites would be UV AOP and GAC.

PFAS and 1,4-dioxane have already restricted use of Tucson Water's groundwater supplies. It is recommended that the utility continue its monitoring programs and compare the results to health-based guidance while continuing to prioritize and implement strategic groundwater treatment efforts.

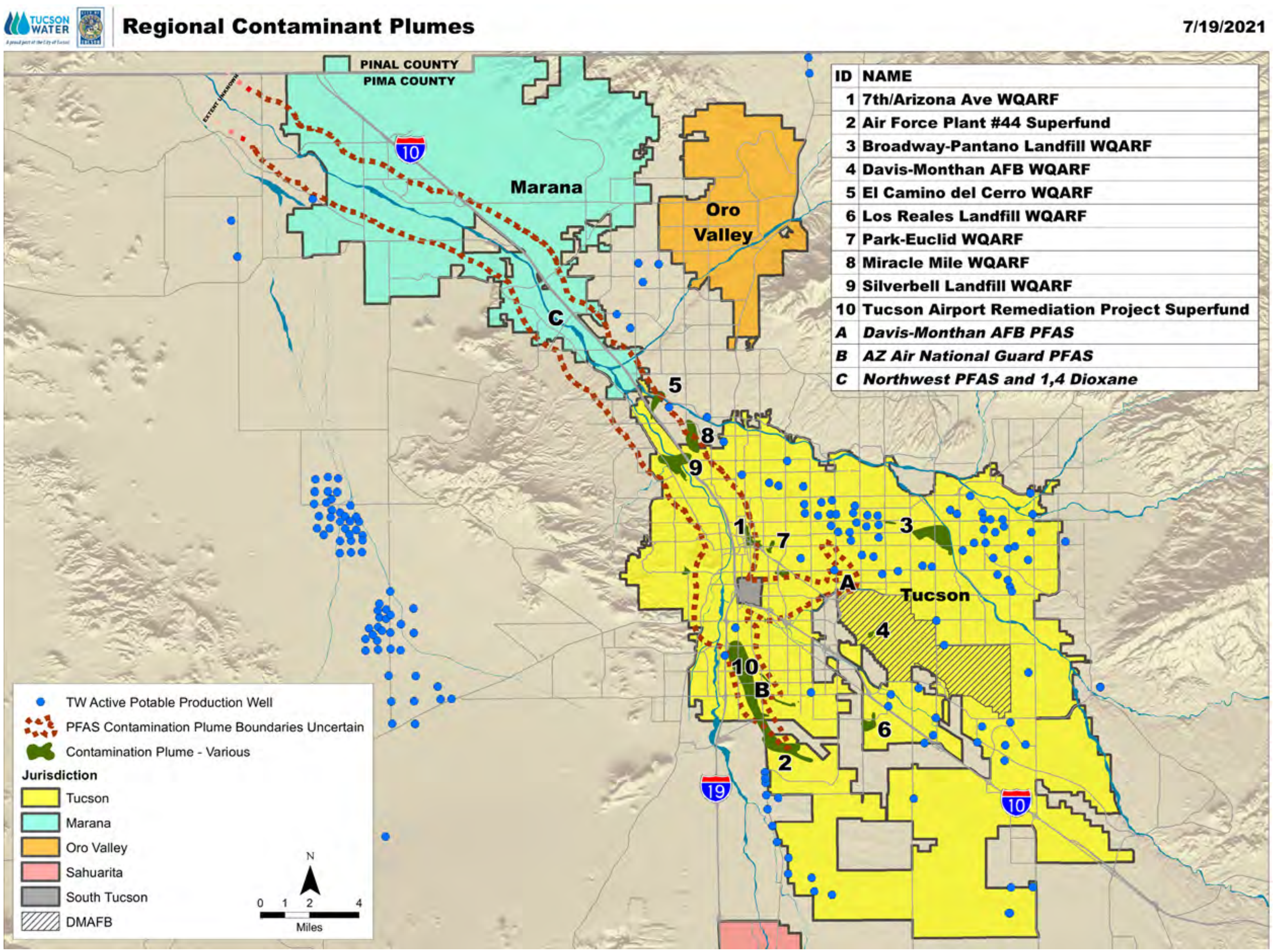


Figure 10 Regional Contaminant Plumes, Including Superfund and Water Quality Assurance Revolving Fund Sites

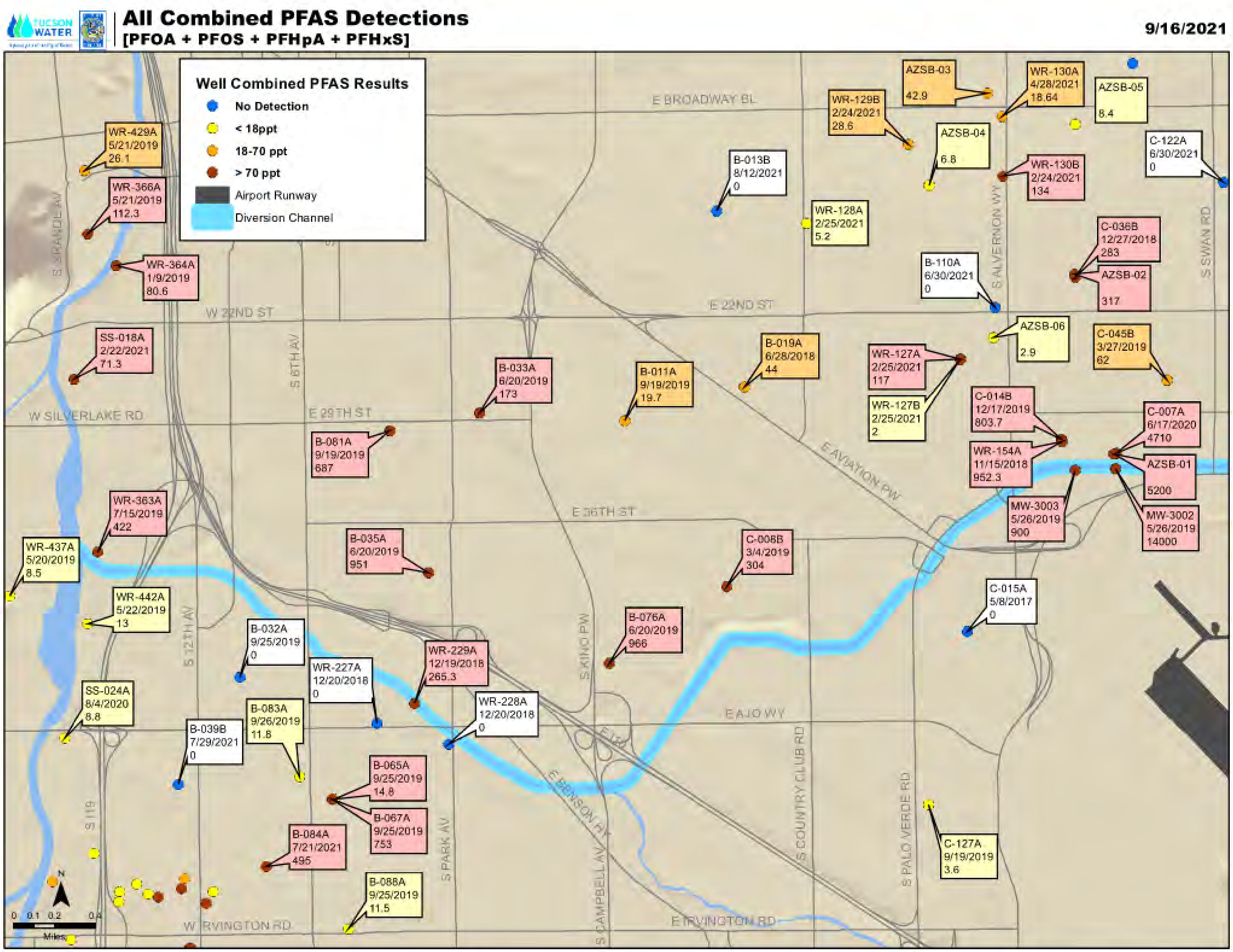


Figure 11 PFAS Detections in Wells Near TARP and DMAFB

3.0 Recycled Water Quality

Tucson Water owns and operates a municipal recycled water system (RWS) comprised of treatment facilities, aquifer storage and recovery wells, storage tanks, booster pumping stations, and distribution system piping located throughout a 390 square-mile service area. The system serves major irrigation customers, other non-potable uses, and underground storage. The supplies for the recycled water system are final effluent from Pima County Regional Wastewater Reclamation Department's Agua Nueva Wastewater Reclamation Facility (WRF), located on the east bank of the Santa Cruz River in northern Tucson, and remediated groundwater from the Silverbell Landfill Water Quality Assurance Revolving Fund (WQARF) site, located on the west bank of the Santa Cruz River south of Agua Nueva WRF. Tucson Water also maintains a series of infiltration basins at the Sweetwater Wetlands for aquifer storage and recovery of the recycled water. This section discusses water quality considerations in the recycled water system.

3.1 Recycled Water Regulations

Recycled water in the State of Arizona must meet water quality standards outlined in state statutes. Additionally, water released to surface watercourses or groundwater recharge facilities must have the appropriate discharge permits.

3.1.1 Water Quality Standards

3.1.1.1 Recycled Water Quality Standards

Tucson Water supplies Class A+ reclaimed (recycled) water, as defined by the Arizona Administrative Code (A.A.C.), Section R18-11-303. Key treatment processes required for the A+ designation are secondary treatment, filtration, nitrogen removal, and disinfection. Additionally, the state requires that the water meet the standards shown in Table 17.

Table 17 ADEQ Class A+ Reclaimed Water Quality Requirements

Parameter	Units	Value
24- hour average turbidity prior to disinfection	NTU	≤2
Turbidity of treated water (single sample maximum)	NTU	≤5
Fecal coliform	-	No fecal coliforms in 4 of 7 daily samples each week Maximum single sample 23 / 100 ml
Total nitrogen	ppm	< 10 (5-sample geometric mean)

As the highest class of recycled water, Class A+ water can be used for any approved type of direct reuse listed in Table A of A.A.C. Section R18-11-303.

3.1.2 Water Pollution Control

3.1.2.1 Use of Recycled Water

Recycled water in Tucson is primarily used for landscape irrigation and groundwater recharge. The RWS supplies 17 golf courses, 37 parks, and 62 schools, including the University of Arizona and Pima Community College. The system also serves over 700 single family homes in a few neighborhoods that are connected to branches of the recycled water distribution system. Tucson Water also conducts groundwater recharge at the Sweetwater Wetlands aquifer storage and recovery facility and at South Houghton Area Recharge Project (SHARP), as well as sending recycled water to the Santa Cruz River Heritage Project, which has restored perennial flow to a section of the Santa Cruz River near downtown Tucson.

3.1.2.2 Aquifer Protection Permits

Aquifer Protection Permits (APP) are required for surface discharges and groundwater recharge of recycled water. These permits are administered by ADEQ and set volumetric and water quality limits for each facility involved in such discharge or recharge.

Sweetwater Wetlands

Tucson Water constructed the Sweetwater Wetlands facility just south of the now-decommissioned Roger Road Wastewater Treatment Plant, which was replaced by the Agua Nueva WRF. The utility produces recycled water from the Sweetwater Reclamation Facility, which treats effluent from Agua Nueva WRF with tertiary filtration and disinfection via chloramination. When demand in the RWS is low, water produced by the plant is recharged in surface basins, and when demand in the RWS is high, water from the plant is sent directly into the RWS and can be supplemented with water recovered via a series of extraction wells near the basins.

The APP (issued 2003, revised 2014) for the facility prescribes a sampling point for discharge monitoring after the recycled water booster pumps and before the metering vaults. Tucson Water maintains a separate APP for discharge of the filter backwash water to the wetlands. Key water quality requirements of the APP are shown in Table 18. Additionally, the facility is required to conduct semi-annual monitoring of a list of 13 metals and 24 VOCs and semi-volatile organic compounds (SVOCs).

Table 18 Sweetwater Wetlands APP Water Quality Requirements

Parameter	Units	Value	Sampling Frequency	Reporting Frequency
Daily Flow (as calculated at flowmeters in filtration building)	mgd	No limit specified	Daily	Quarterly
Monthly Average Flow	mgd	9.5	Monthly (calculated)	Quarterly
E. coli	CFU or MPN	Non-detect in 4 of 7 daily samples each week Maximum single sample 15 / 100 mL	Daily	Quarterly
Turbidity of Treated Water (single sample maximum)	NTU	≤5	Daily	Quarterly
Enteric Virus (4 of 7 samples)	PFU	None detected per 40 liter sample	Monthly	Quarterly
Total Nitrogen (5-sample geometric mean)	ppm	No limit specified	Quarterly	Quarterly
Nitrate/Nitrite	ppm	No limit specified	Quarterly	Quarterly
Total Kjeldahl Nitrogen (TKN)	ppm	No limit specified	Quarterly	Quarterly

Abbreviations:
mgd = million gallons per day; CFU = colony forming units; MPN = most probable number; PFU = plague-forming unit; ppm = parts per million

Santa Cruz River Heritage Project

The Santa Cruz River Heritage Project discharges recycled water produced by the Sweetwater Reclamation Facility to the Santa Cruz River. The project restores perennial flow to a section of the river that used to flow year-round but has been ephemeral for nearly a century due to the decline of local groundwater levels. Key provisions of the APP are summarized in Table 19. Additionally, the facility is required to conduct quarterly monitoring of a list of 13 metals and semi-annual monitoring of 24 VOCs and SVOCs, both at the point of discharge and in the groundwater at the point of compliance, a monitoring well near the eastern bank of the Santa Cruz River, near Verdugo Park, approximately one quarter mile downstream of the outfall.

Table 19 Santa Cruz River Heritage Project APP Water Quality Requirements

Parameter	Units	Value	Sampling Frequency	Reporting Frequency
Daily Flow (as calculated at flowmeters in filtration building)	mgd	No limit specified	Daily	Quarterly
Annual Average Flow	ac-ft	4,000	Annually (calculated)	Annually
E. coli	MPN	Non-detect in 4 of 7 daily samples each week Maximum single sample 15 / 100 mL	Daily	Quarterly
Total Nitrogen (5-sample geometric mean)	ppm	No limit specified	Monthly (calculated)	Quarterly
Nitrate-Nitrite as N	ppm	≤10	Monthly	Quarterly
Nitrate as N	ppm	≤10	Monthly	Quarterly
Nitrite as N	ppm	≤1	Monthly	Quarterly
Total Kjeldahl Nitrogen (TKN)	ppm	No limit specified	Monthly	Quarterly

Abbreviations:
mgd = million gallons per day; MPN = most probable number; PFU = plague-forming unit

SHARP

SHARP was developed to recharge groundwater supplies in the southeast part of Tucson. Recycled water from the Sweetwater Reclamation Facility is conveyed to SHARP for recharge during low demand times. The APP requirements for the point of discharge and points of compliance (two monitoring wells) are summarized in Table 20. Additionally, the facility is required to conduct quarterly monitoring of a list of 13 metals and annual monitoring 24 VOCs and SVOCs, both at the point of discharge (semi-annual for VOCs and SVOCs) and in the groundwater at the points of compliance.

Table 20 SHARP APP Water Quality Requirements

Parameter	Units	Value	Sampling Frequency	Reporting Frequency
Daily Flow (as calculated at flowmeters in filtration building)	mgd	No limit specified	Daily	Quarterly
Annual Average Flow	ac-ft	4,000	Annually (calculated)	Annually
E. coli	MPN	Non-detect in 4 of 7 daily samples each week Maximum single sample 15 / 100 mL	Daily	Quarterly
Total Nitrogen (5-sample geometric mean)	ppm	No limit specified	Monthly (calculated)	Quarterly
Nitrate-Nitrite as N	ppm	≤10	Monthly	Quarterly
Nitrate as N	ppm	≤10	Monthly	Quarterly
Nitrite as N	ppm	≤1	Monthly	Quarterly
Total Kjeldahl Nitrogen (TKN)	ppm	No limit specified	Monthly	Quarterly

3.1.2.3 Arizona Pollutant Discharge Elimination System (AZPDES)

AZPDES is the Arizona implementation of the National Pollutant Discharge Elimination System (NPDES), which, under the Clean Water Act, regulates water quality of discharges to waters of the United States.

Santa Cruz River Heritage Project

The Santa Cruz River Heritage Project, because it discharges to a water of the US, must maintain an AZPDES permit in addition to an APP. Water quality requirements at the outfall for the Heritage Project are summarized in Table 21.

Table 21 Santa Cruz River Heritage Project AZPDES Water Quality Requirements

Parameter	Units	Monthly Average Value(1)	Daily Maximum Value(1)	Monitoring Frequency
Discharge Flow	mgd	No limit specified	No limit specified	Continuous
E. coli	CFU/100mL	126	575	4x monthly
Total Residual Chlorine	ppb	9.0	18	Weekly
Ammonia	ppm	No limit specified	No limit specified	Semi-Monthly
Ammonia Impact Ratio	-	1	2	Semi-Monthly
Cyanide	ppb	7.9	16	Quarterly
Iron	ppb	819	1640	Quarterly
Lead	ppb	5	11	Quarterly
Hardness	ppm	No limit specified	No limit specified	Quarterly
Selenium	ppb	2	3	Quarterly
pH	S.U.	6.5 – 9.0	6.5 – 9.0	Weekly
Temperature	Deg. C	No limit specified	No limit specified	Semi-Monthly
Total Chromium	ppb	No limit specified	No limit specified	Quarterly
Chromium VI	ppb	8	16	Quarterly
Copper	ppb	15	31	Quarterly
Mercury	ppb	0.01	0.02	Quarterly
Silver	ppb	7.3	15	Quarterly
Whole Effluent Toxicity (WET) – green algae	TUc	1.6	1.0	Annually
WET – fathead minnow	TUc	1.6	1.0	Annually
WET – water flea	TUc	1.6	1.0	Annually

Notes:

(1) Limits given as concentration values. A mass limit also applies; it is equivalent to the concentration limit in ppm times the flow rate (mgd) times 3.785 conversion factor.

Abbreviations:

ppm = parts per million; S.U. = standard units; TUc = chronic toxic unit

TARP (Heritage Project Irvington Outfall)

The TARP outfall to the Santa Cruz River, also known as the Heritage Project Irvington Outfall, likewise discharges to a water of the US and must maintain an AZPDES permit. Water quality requirements at the outfall for the Heritage Project Irvington Outfall are summarized in Table 22.

Table 22 TARP Heritage Project Irvington Outfall AZPDES Water Quality Requirements

Parameter	Units	Monthly Average Value[(1)]	Daily Maximum Value[(1)]	Monitoring Frequency
Discharge Flow	mgd	No limit specified	No limit specified	Continuous
1,4-dioxane	ppb	0.35	0.35	Monthly
Antimony	ppb	986	986	Quarterly
Beryllium	ppb	8.7	8.7	Quarterly
Cadmium	ppb	6.18	6.18	Quarterly
Cyanide	ppb	16	16	Quarterly
Iron	ppb	1,642	1,642	Quarterly
Lead	ppb	8.81	8.81	Quarterly
Hardness	ppm	No limit specified	No limit specified	Quarterly
Selenium	ppb	3	3	Quarterly
PFOA	ppt	No limit specified	No limit specified	Monthly
PFOS	ppt	No limit specified	No limit specified	Monthly
PFOA + PFOS	ppt	70	70[(2)]	Monthly
pH	S.U.	6.5 – 9.0	6.5 – 9.0	Weekly
Temperature	Deg. C	No limit specified	No limit specified	Semi-Monthly
Total Chromium	ppb	No limit specified	No limit specified[(2)]	Quarterly
Trichloroethene (TCE)	ppb	5.0	5.0	
Chromium VI	ppb	No limit specified	No limit specified	Quarterly[(3)]
Silver	ppb	10.8	10.8	Quarterly
Thallium	ppb	109	109	Quarterly
Sulfides	ppb	No limit specified	No limit specified[(4)]	Quarterly
Hydrogen Sulfide	ppb	3	3	Monthly[(4)]
Whole Effluent Toxicity (WET) – green algae	TUc	1.6	1.0	Annually
WET – fathead minnow	TUc	1.6	1.0	Annually
WET – water flea	TUc	1.6	1.0	Annually

Notes:
(1) Limits given as concentration values. A mass limit also applies; it is equivalent to the concentration limit in ppm times the flow rate (mgd) times 3.785 conversion factor.
(2) If PFOA + PFOS exceeds 18 ppt, ADEQ must be notified.
(3) If total chromium exceeds 8 ppb, chromium VI must be monitored for the rest of the permit. Otherwise, chromium VI sampling is not required.
(4) Any detection of sulfides (detection limit must be no higher than 100 ppb) will trigger monthly monitoring of hydrogen sulfide. Otherwise, hydrogen sulfide monitoring is not required.
Abbreviations:
ppm = parts per million; S.U. = standard units; TUc = chronic toxic unit

3.2 Source Water Changes and Anticipated Water Quality Effects

Tucson Water also owns and operates the Tucson Airport Remediation Project (TARP) Water Treatment Plant (WTP). Groundwater contaminated with trichloroethene (TCE), as well as the unregulated compounds 1,4-dioxane and PFAS, is treated at the plant and was introduced into Tucson Water's potable water system until June 21, 2021. Due to rising PFAS levels in the raw water for TARP, Tucson Water is constructing infrastructure to redirect TARP treated water to both the recycled water distribution system and the Santa Cruz River. Discharge of some TARP treated water to the Santa Cruz River commenced on November 2, 2021.

According to the EPA Superfund Consent Decree for TARP, TCE must be removed to below 1.5 ppb based on a 90-day weighted average of sample analysis results, and TARP has consistently produced water with TCE below the method reporting limit of 0.5 ppb since the plant was brought online in 1994. TARP's existing treatment process is an UV AOP followed by granular activated carbon (GAC).

Treated water produced by TARP has met and will continue to meet existing drinking water quality regulations, which are more stringent than the recycled water standards detailed in Section 3.1.1.1. Therefore, introduction of the TARP treated water to the RWS will generally improve the quality of water supplied through the system. It is anticipated that TARP treated water will supply most RWS demands in the winter (with excess flow going to SHARP) and a portion of the demand in other seasons.

3.3 Contaminants of Emerging Concern

While contaminants of emerging concern are not regulated in recycled water, they can nevertheless affect aquifer water quality when used for irrigation or underground storage. This section discusses these implications.

3.3.1 Occurrence of Emerging Contaminants in Reclaimed Water

Two primary CEC are present in the recycled water, PFAS and 1,4-dioxane. Both contaminants are also present in the raw water for TARP, but 1,4-dioxane is removed nearly completely by the UV AOP, and concentrations of PFAS are reduced significantly by the GAC system, as discussed below.

3.3.1.1 Per and Polyfluoroalkyl Substances

According to analysis performed by Tucson Water in 2018 and 2019, PFAS has been detected in the recycled water recovery wells at the Sweetwater Wetlands, due to PFAS present in the recycled water itself. Combined totals of PFOS and PFOA ranged from 80 to 265 ppt, as shown in Figure 12. Therefore, all recycled water recovered from Sweetwater has PFOS + PFOA concentrations that exceed the water quality operational target of 70 ppt. Because the water is nonpotable, Tucson Water can serve recycled water with any level of PFAS without needing to notify any customers, but PFAS in recycled water affects groundwater supplies in areas receiving recycled water, particularly groundwater recharge facilities, so Tucson Water would like to minimize, to the extent practical, the concentrations of PFAS in the RWS.

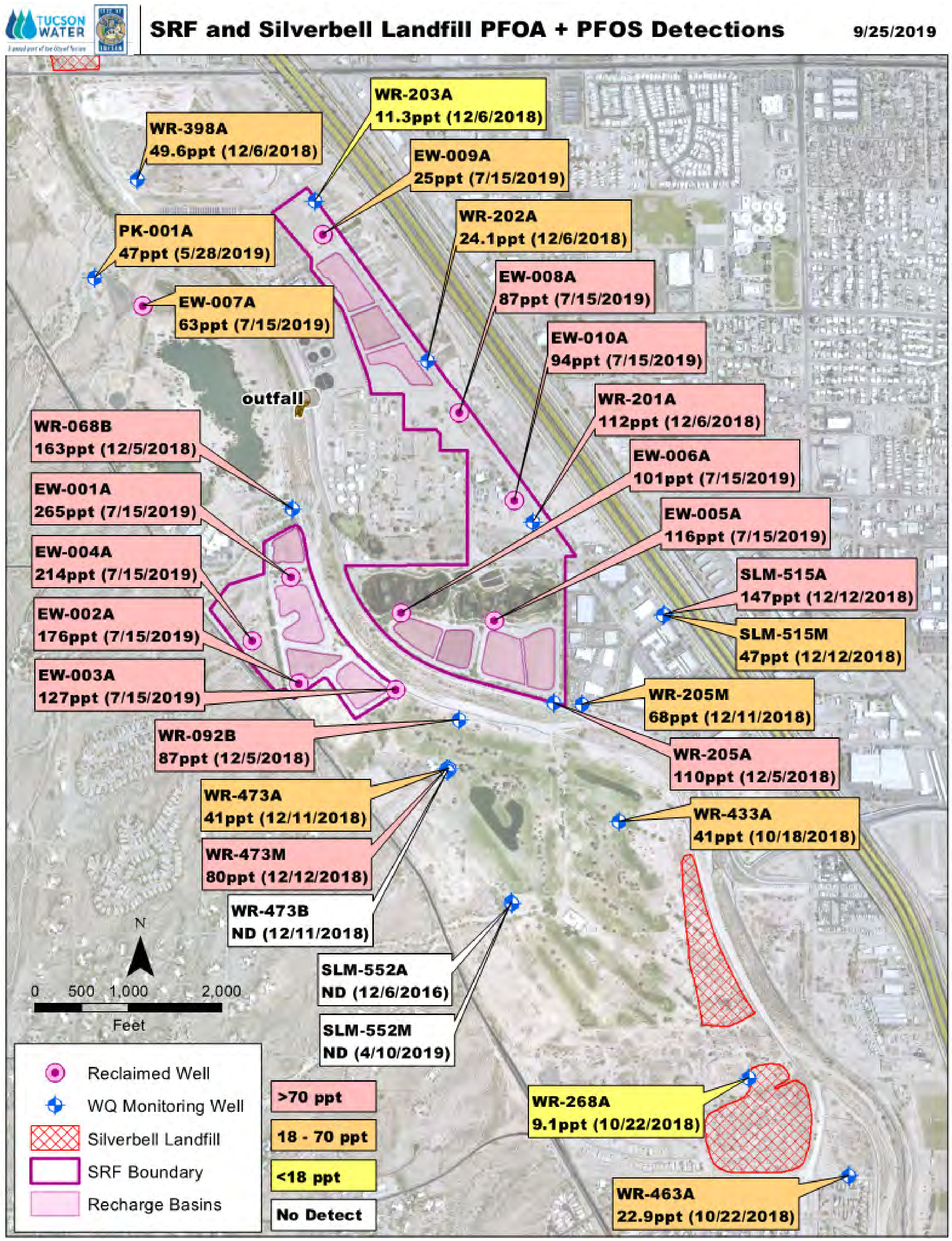


Figure 12 PFAS Detections in Recycled Water Recovery Wells and Nearby Monitoring Wells

Tucson Water is required by the AZPDES permit (see Table 22) to maintain a PFOS + PFOA concentration of no more than 70 ppt in TARP treated water and will notify ADEQ and other parties (PAG, Pima County, and the Town of Marana) if PFOS + PFOA exceeds 18 ppt. The GAC at the TARP WTP was originally installed to quench residual hydrogen peroxide from the UV AOP but also functions for adsorption of PFAS. It works particularly well for longer-chain PFAS such as PFOS and PFOA. As the GAC adsorbs PFAS, the adsorption sites gradually fill up, and eventually when few sites remain, the compounds break through into the treated water. When concentrations in the treated water approach the operational target, the GAC will be changed out to restore the adsorptive capacity of the beds. Using TARP treated water in the RWS will substantially reduce the concentrations of PFAS served through the system.

3.3.1.2 1,4-dioxane

The contaminant 1,4-dioxane is also found at low levels in Tucson Water's recycled water; Figure 13 displays the concentrations measured in 2018 and 2019 in recovery and monitoring wells near the Sweetwater Wetlands. The concentrations range from approximately 0.5 to 1.0 ppm, greater than the HAL of 0.35 ppb.

The UV AOP at TARP was constructed specifically for the purpose of destroying 1,4-dioxane and as such, removes the compound to below the MRL of 0.1 ppb. Therefore, introducing TARP treated water to the RWS will decrease the concentrations of 1,4-dioxane and should reduce the compound to non-detectable levels during the winter when the TARP water is anticipated to be the dominant supply.

3.3.1.3 Potential Treatment for the Recycled Water System

Tucson Water considered treating recycled water (from extraction wells, Agua Nueva effluent, and the Silverbell Landfill pump and treat system) with ion exchange and UV AOP to remove PFAS and 1,4-dioxane, respectively. At this time, the primary method of reducing the concentrations of CECs in the RWS will be the introduction of TARP treated water. It is worth noting that because the TARP raw water is not under the same wastewater influence as the other RWS source waters, introduction of TARP treated water to the RWS is also anticipated to reduce the concentrations of all other CECs that have been detected in the RWS.

3.3.2 Tucson Water Sentry Program Monitoring

Tucson Water's Sentry Program conducts semi-annual monitoring of CECs throughout the distribution system. This voluntary program was started in 2008 to track and proactively manage CECs. See Appendix E for the 2020 report and results from this program.

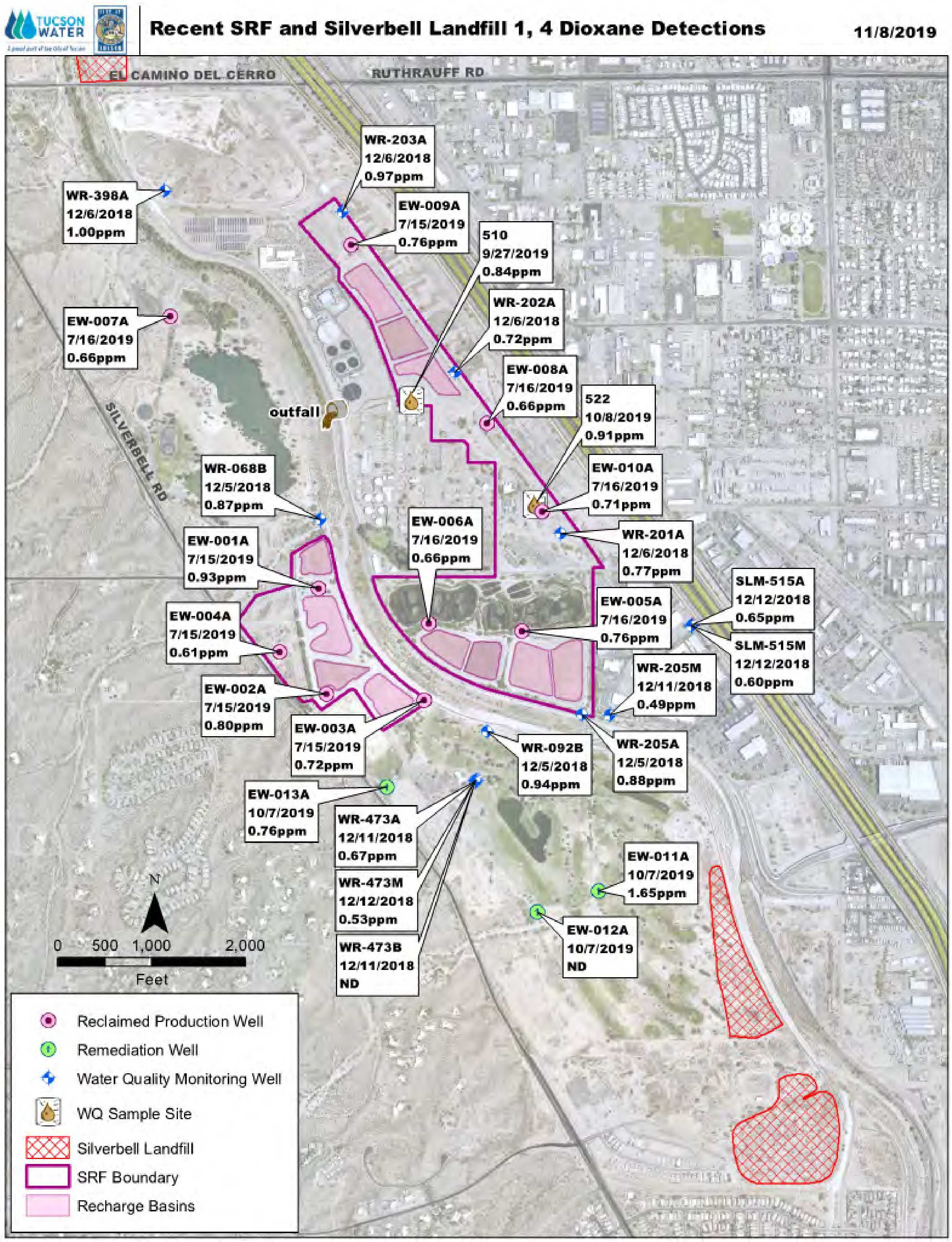


Figure 13 1,4-Dioxane Detections in Recycled Water Recovery Wells and Nearby Monitoring Wells

4.0 Conclusions

4.1 Primary Drinking Water Regulations

Tucson Water is meeting all current Federal and State regulations, and this current compliance pattern is expected to continue. Water quality information is available to customers at https://www.tucsonaz.gov/water/about-your-water-quality.

Tucson Water has an opportunity to anticipate future regulations and ensure the utility is ready to mitigate challenges to drinking water quality, whether from new or updated regulations or changes in raw water quality.

4.2 Emerging Contaminants

CECs have been detected in many locations in Tucson Water's distribution system. While the number of contaminants detected has increased in recent years, this does not necessarily equate to increased risk when contaminants remain at concentrations below health advisory levels. PFAS and 1,4-dioxane have already restricted use of Tucson Water's groundwater supplies, particularly in the vicinity of TARP, near DMAFB, and in the Northwest area.

Continued monitoring of CECs is recommended. Detected concentrations should be compared with health-based guidance to prioritize which water sources and contaminants need to be addressed and implement strategic groundwater treatment efforts.

4.3 Lead and Copper Rule and Lead and Copper Rule Revisions

Tucson Water is complying with the current LCR and is well positioned to comply with the new LCRR through continued implementation of the "Get the Lead Out" program. Any changes to source water or treatment technologies should be carefully evaluated to assess any possible effects on the distribution system.

4.4 Salinity and Basin-wide Salt Loading

While the Tucson basin experiences a net influx of salt every year, TDS management on the Colorado River through the SCP and in Tucson through recharge and recovery has ensured that TDS concentrations in CAP water and the recharged and recovered water are relatively stable. CAP has introduced draft standards for monitoring and delivery of Non-Project water, which are intended to maintain CAP aqueduct water quality but do allow Non-Project water entering the canal to have higher salinity levels than those present in Project water. If a Tucson-area provider begins ordering and receiving Non-Project water, the salt content of Tucson Water's CAP supply could increase, though not above the CAP delivery standard of 747 ppm TDS.

4.5 Planning for Known and Unknown Guidance

In addition to those covered by existing regulations and guidance, more contaminants are likely to be regulated in the future. Recharge, recovery, and blending mitigates CAP water quality risks by reducing contaminant concentrations. Tucson Water has a robust monitoring program and is well positioned to manage contaminants with known and unknown regulations and guidance. It is recommended for Tucson Water to stay engaged with the broader water industry, share water quality data with CAP and other users, and expand the Sentry Program to include raw CAP water.

4.6 Recycled Water

Tucson Water has investigated management options to address the presence of emerging contaminants in recycled water. Introduction of TARP treated water to the RWS will help to blend down the concentrations of emerging contaminants and curtail the use of Sweetwater extraction wells. Tucson Water may also implement treatment of CECs in recycled water at the Sweetwater Reclamation Facility; this decision may be influenced by future regulation of one or more CECs.

State regulations and EPA's Action Plan support a One Water approach to water reuse, recognizing that potable water, recycled water, groundwater, and stormwater contribute to the region's water portfolio and as such, represent important resources for the future. By understanding existing water quality data and planning for future potential regulations, Tucson Water is well positioned to use One Water resources wisely and continue to serve the high-quality water that customers have come to expect.

5.0 References

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Appendix A

WATER QUALITY REGULATIONS

Table A.1 Primary Drinking Water Regulations, Goals, and Tucson Water Maximum Detection (2016-2018)

Contaminant	MCL[1] or TT[2] (ppm)[3]	MCLG[4] (ppm)[3]	Arizona Primary MCL (ppm)[3]	Tucson Water Maximum Detection (2016-2018) (ppm)[3, 5]
Organic Chemicals				
Acrylamide	TT[6]	Zero	NA	-
Alachlor	0.002	Zero	0.002	-
Atrazine	0.003	0.003	0.003	0.00008
Benzene	0.005	Zero	0.005	-
Benzo(a)pyrene (PAHs)	0.0002	Zero	0.0002	-
Carbofuran	0.04	0.04	0.04	-
Carbon tetrachloride	0.005	Zero	0.005	-
Chlordane	0.002	Zero	0.002	-
Chlorobenzene	0.1	0.1	0.1	-
2,4-D	0.07	0.07	0.07	-
Dalapon	0.2	0.2	0.2	-
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Zero	0.0002	-
o-Dichlorobenzene	0.6	0.6	0.6	-
p-Dichlorobenzene	0.075	0.075	0.075	-
1,2-Dichloroethane	0.005	Zero	0.005	-
1,1-Dichloroethylene	0.007	0.007	0.007	-
cis-1,2-Dichloroethylene	0.07	0.07	0.07	-
trans-1,2-Dichloroethylene	0.1	0.1	0.1	-
Dichloromethane	0.005	Zero	0.005	-
1,2-Dichloropropane	0.005	Zero	0.005	-
Di(2-ethylhexyl) adipate	0.4	0.4	0.4	-
Di(2-ethylhexyl) phthalate	0.006	Zero	0.006	-
Dinoseb	0.007	0.007	0.007	-
Dioxin (2,3,7,8-TCDD)	0.00000003	Zero	0.00000003	-
Diquat	0.02	0.02	0.02	-
Endothall	0.1	0.1	0.1	-
Endrin	0.002	0.002	0.002	-
Epichlorohydrin	TT[6]	Zero	NA	-
Ethylbenzene	0.7	0.7	0.7	-
Ethylene dibromide	0.00005	Zero	0.00005	-
Glyphosate	0.7	0.7	0.7	-
Heptachlor	0.0004	Zero	0.0004	-
Heptachlor epoxide	0.0002	Zero	0.0002	-
Hexachlorobenzene	0.001	Zero	0.001	-
Hexachlorocyclopentadiene	0.05	0.05	0.05	-
Lindane	0.0002	0.0002	0.0002	-
Methoxychlor	0.04	0.04	0.04	-
Oxamyl (Vydate)	0.2	0.2	0.2	-
Pentachlorophenol	0.001	Zero	0.001	-
Picloram	0.5	0.5	0.5	-
Polychlorinated Biphenyls (PCBs)	0.0005	Zero	0.0005	-
Simazine	0.004	0.004	0.004	0.00011

Contaminant	MCL[1] or TT[2] (ppm)[3]	MCLG[4] (ppm)[3]	Arizona Primary MCL (ppm)[3]	Tucson Water Maximum Detection (2016-2018) (ppm)[3, 5]
Styrene	0.1	0.1	0.1	-
Tetrachloroethylene	0.005	Zero	0.005	-
Toluene	1	1	1	-
Toxaphene	0.003	Zero	0.003	-
2,4,5-TP (Silvex)	0.05	0.05	0.05	-
1,2,4-Trichlorobenzene	0.07	0.07	0.07	-
1,1,1-Trichloroethane	0.2	0.2	0.2	-
1,1,2-Trichloroethane	0.005	0.003	0.005	-
Trichloroethylene	0.005	Zero	0.005	0.0007
Vinyl Chloride	0.002	Zero	0.002	-
Xylenes (total)	10	10	10	-
Inorganic Substances				
Antimony	0.006	0.006	0.006	-
Arsenic	0.010	Zero	0.050	0.0075
Asbestos (fibers/L > 10 µm)	7 million fibers/L	7 million fibers/L	7 million fibers/L	-
Barium	2	2	2	0.16
Beryllium	0.004	0.004	0.004	-
Cadmium	0.005	0.005	0.005	-
Chromium (total)	0.1	0.1	0.1	-
Copper[7]	TT AL=1.3	1.3	NA	0.142
Cyanide	0.2 (as free cyanide)	0.2	0.2	-
Fluoride	4.0	4	4	1.17
Lead[7]	TT AL=0.015	Zero	NA	0.00107[8]
Mercury (inorganic)	0.002	0.002	0.002	-
Nitrate (as N)	10	10	10	6.58
Nitrite (as N)	1	1	1	-
Selenium	0.05	0.05	0.05	0.0062
Thallium	0.002	0.0005	0.002	-
Radionuclides				
Gross Alpha	15 pCi/L	NA	15 pCi/L	6 pCi/L
Beta and photon radioactivity	4 mrem/yr	Zero	4 mrem/yr	-
Radium-226 + Radium-228	5 pCi/L	Zero	5 pCi/L	1.3 pCi/L
Uranium	0.030	Zero	NA	0.019
Microorganisms				
Cryptosporidium[9]	TT oocyst/100L	Zero	NA	-
Fecal coliform and *E. coli*	MCL[10]	Zero[10]	MCL[10]	-
Giardia lamblia[9]	TT cyst/100L	Zero	NA	-
Heterotrophic plate count (HPC)[9]	TT CFU/mL	NA	NA	-
Legionella[9]	TT #/mL	Zero	NA	-
Total Coliform[11]	5.0 percent #/mL	Zero	5 percent #/mL	0.8 percent[12]
Turbidity[9, 13]	0.3 NTU	NA	NA	-
Viruses[9]	TT #/mL	Zero	NA	-

Contaminant	MCL[1] or TT[2] (ppm)[3]	MCLG[4] (ppm)[3]	Arizona Primary MCL (ppm)[3]	Tucson Water Maximum Detection (2016-2018) (ppm)[3, 5]
Disinfectant Byproducts				
Bromate	0.010	Zero	NA	-
Chlorite	1	0.8	1.0	-
Haloacetic Acids (HAA5[14])	0.060[15]	NA[16]	NA	0.0038
Trihalomethanes (total)	0.080[15]	NA[16]	NA	0.021
Bromodichloromethane	-	Zero	NA	-
Bromoform	-	Zero	NA	-
Chloroform	-	0.07	NA	-
Dibromochloromethane	-	0.06	NA	-
Dichloroacetic acid	-	Zero	NA	-
Monochloroacetic acid	-	0.07	NA	-
Trichloroacetic acid	-	0.02	NA	-
Disinfectant Residuals				
Chloramines (as Cl_2)	4[17]	4[18]	NA	-
Chlorine (as Cl_2)	4[17]	4[18]	NA	0.99[19]
Chlorine Dioxide (as ClO_2)	0.8[17]	0.8[18]	NA	-

Notes:

(1) Maximum Contaminant Level (MCL): The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
(2) Treatment Technique (TT): A required process intended to reduce the level of a contaminant in drinking water.
(3) ppm unless otherwise noted
(4) Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water below which there is no known or expected health risk. MCLGs allow for a margin of safety and are non-enforceable public health goals.
(5) A dash indicates that sampling was conducted for the contaminant, but it was not detected above the method reporting limit.
(6) Each water system must certify annually, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05 percent dosed at 1 ppm (or equivalent); Epichlorohydrin = 0.01 percent dosed at 20 ppm (or equivalent).
(7) Lead and copper are regulated by a treatment technique to control corrosion in potable water systems. If 10% of tap water samples exceed the action level (AL), additional steps must be taken.
(8) Lead is reported as a 90th percentile value.
(9) The EPA's surface water treatment rule requires systems using surface water or ground water under the direct influence of surface water to disinfect and filter/meet the criteria to avoid filtration so that microbial contaminants are controlled.
(10) Routine samples containing fecal coliform or *E. coli* triggers a repeat sampling event. If the repeat sample is fecal coliform-positive, an acute MCL violation occurs. If the repeat sample is negative, and other repeat sampling is triggered. If the repeat sample is fecal coliform-positive, an acute MCL violation occurs.
(11) No more than 5.0 % samples total coliform positive in a month. Every sample that is coliform-positive must be analyzed for fecal coliforms and *E. coli*. If two consecutive samples are total coliform-positive and one is fecal coliform-positive, an acute MCL violation occurs.
(12) Follow up samples collected were negative.
(13) Performance standard: no more than 5 percent of monthly samples may exceed 0.3 NTU.
(14) Sum of concentrations of five haloacetic acid species (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid).
(15) Measured as locational running annual average at each monitoring site.
(16) The group itself does not have an MCLG, but some individual contaminants have an MCLG as shown in the table (bromodichloromethane, bromoform, chloroform, dibromochloromethane, dichloroacetic acid, monochloroacetic acid, trichloroacetic acid).
(17) Maximum Residual Disinfectant Level.
(18) Maximum Residual Disinfectant Level Goal.
(19) Free chlorine is measured monthly and reported as an annual average value.

Abbreviations:

ppm = parts per million; pCi/L = picocuries per liter; NTU = Nephelometric Turbidity Unit; cfu/mL = colony forming units per milliliter; #/mL = number of microbes per milliliter

Table A.2 Secondary Drinking Water Regulations and Goals

Contaminant	Units	EPA Secondary MCL(1)	Noticeable Effects above Secondary MCL	Tucson Water Maximum Detection (2016-2018)
Aluminum	ppm	0.05-0.2	colored water	
Chloride	ppm	250	salty taste	85(2)
Color	color units	15	visible tint	
Copper	ppm	1	metallic tasting; blue-green staining	
Corrosivity	-	non-corrosive	metallic taste; corroded pipes/fixture staining	
Fluoride	ppm	2	tooth discoloration	
Foaming Agents	ppm	0.5	frothy, cloudy; bitter taste; odor	
Iron	ppm	0.3	rusty color; sediment; metallic taste; orange staining	
Manganese	ppm	0.05	black color; black staining; bitter metallic taste	
Odor	TON[2]	3	"rotten egg", musty or chemical smell	
pH	-	6.5-8.5	low pH: bitter taste; corrosion high pH: slippery feel, deposits	7.7-7.9(2)
Silver	ppm	0.1	skin discoloration, graying of white part of the eye	
Sulfate	ppm	250	salty taste	187(2)
Total Dissolved Solids (TDS)	ppm	500	hardness, deposits, colored water, staining, salty taste	542(2)
Zinc	ppm	5	metallic taste	

Notes:
(1) Secondary Maximum Contaminant Level (MCL): The highest level of a contaminant that is recommended in drinking water based on aesthetic and corrosion considerations. Secondary MCLs are not enforceable standards.
(2) Measured at EP6 as the Clearwater Blend enters the distribution system.
Abbreviations:
ppm = parts per million; TON = Threshold Odor Number

Table A.3 Lead and Copper Rule

Parameter	Units	EPA Action Level	MCLG	Tucson Water Maximum 90th Percentile Value (2016-2018)
Copper	ppm	1.3	1.3	0.142
Lead	ppm	0.015	Zero	0.00107(1)

Notes:
(1) Lead is reported as a 90th percentile value.

Table A.4 Radionuclides Rule

Parameter	Units	EPA Primary MCL	MCLG	Tucson Water Maximum Detection (2016-2018)
Gross Alpha Particles	pCi/L	15	Zero	6
Beta and photon radioactivity(1)	mrem/yr	4	Zero	-
Radium-226 + Radium-228	pCi/L	5	Zero	1.3
Uranium	ppm	0.030	Zero	0.019

Notes:
(1) A total of 168 beta particles and photon emitters may be used to calculate compliance with the MCL.
Abbreviations:
ppm = parts per million; pCi/L = picocuries per liter

Table A.5 Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) Compliance

Parameter	Units	EPA Primary MCL, MRDL, or TT	EPA MCLG	Tucson Water Maximum Detection (2016-2018)
Bromate	ppm	0.010	Zero	< MRL
Chlorite	ppm	1.0	0.8	< MRL
Haloacetic Acids (HAA5(1))	ppm	0.060(2)	NA(3)	0.0038
Trihalomethanes (total)	ppm	0.080(2)	NA(3)	0.021
Chloramine (as Cl_2)	ppm	4(4)	4(5)	NA
Chlorine (as Cl_2)	ppm	4(4)	4(5)	0.99(6)
Chlorine Dioxide	ppm	0.8	0.8	NA
Total Organic Carbon	ppm	TT	NA	< MRL

Notes:
(1) Sum of concentrations of five haloacetic acid species (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, dibromoacetic acid).
(2) Measured as locational running annual average at each monitoring site.
(3) The group itself does not have an MCLG, but some individual contaminants have an MCLG as shown in the table (bromodichloromethane, bromoform, chloroform, dibromochloromethane, dichloroacetic acid, monochloroacetic acid, trichloroacetic acid).
(4) Maximum Residual Disinfectant Level.
(5) Maximum Residual Disinfectant Level Goal.
(6) Free chlorine is measured monthly and reported as an annual average value.

The following sections describe federal drinking water regulations that do not apply to Tucson Water due to the fact the utility doesn't use surface water directly. (CAP water becomes groundwater when it is recharged and recovered.)

A.1 Surface Water Treatment & Interim Enhanced Surface Water Treatment Rules

On June 29, 1989, the EPA published the final SWTR for drinking water systems using surface water sources. Tucson Water infiltrates CAP water to the ground before recovering the water through recovery wells; the water is considered groundwater at that point, so the SWTR does not apply. The SWTR requires that treatment be provided to reduce turbidity, *Giardia*, *Legionella*, viruses, and HPC bacteria, or the system must meet requirements for avoiding filtration, i.e. already low concentrations of these contaminants. The SWTR established treatment and performance standards to provide a minimum reduction of 99.9 percent (3-log) for *Giardia* cysts and 99.99 percent (4-log) for viruses. The overall reduction of *Giardia* and viruses is to be achieved through a combination of physical removal by pretreatment and filtration and inactivation by disinfection.

Treatment effectiveness under this rule is determined through turbidity measurements:

- The turbidity of representative samples of a system's combined filtered water must be less than or equal to 0.5 NTU in at least 95 percent of the measurements taken each month (subsequently reduced to 0.3 NTU by IESWTR).
- The turbidity level of representative samples of a system's combined filtered water must at no time exceed 5 NTU (subsequently reduced to 1 NTU by IESWTR).

Well-operated conventional treatment plants that meet or exceed the 0.5 NTU effluent turbidity standard are credited with a 2.5-log removal of *Giardia* cysts and a 2-log removal of viruses. The remainder of the overall 3-log *Giardia* cyst and 4-log virus treatment is to be provided by inactivation using disinfection.

The rule requires utilities to demonstrate compliance with primary disinfection requirements by meeting minimum "CT" requirements, where C is the residual disinfectant concentration in ppm, and T is the effective contact time with the disinfectant in minutes. The ability to meet minimum "CT" requirements is a function of the actual detention time downstream of disinfection, water temperature, pH, required log removal (*Giardia*, *Cryptosporidium*, or virus), disinfection type (i.e., chlorine), and disinfectant residual concentration.

In addition to primary disinfection requirements, the SWTR also requires protection against microbial contamination in the distribution system. Specifically, the SWTR outlines secondary disinfection or distribution system disinfection requirements to inactivate microbiological pathogens including *Legionella* and HPC bacteria. Secondary disinfection refers to application of a disinfectant to meet regulatory requirements for distribution system bacteriological quality as set forth in the TCR.

The IESWTR was promulgated by the EPA in 1998 and was the first regulation to specifically address chlorine resistant pathogens such as *Cryptosporidium*. In addition to the requirements of the SWTR, the rule establishes an MCLG of zero for *Cryptosporidium*. It also lowered the combined filter effluent turbidity standard to less than or equal to 0.3 NTU in 95 percent of all measurements. At no time can any turbidity measurement exceed 1 NTU. Systems that meet the turbidity standard are assumed to provide at least 2-log *Cryptosporidium* removal through filtration.

The rule also establishes criteria for systems that must establish a disinfection profile by collecting additional data related to the disinfection process and DBP formation.

A.2 Filter Backwash Recycling Rule

The FBRR was promulgated by the EPA in June 2001 and establishes regulations governing the way that certain recycle streams (spent filter backwash water, thickener supernatant, and liquids from dewatering processes) are handled within the treatment processes of conventional and direct filtration systems. Because Tucson Water does not use these processes in the potable water system, this rule does not apply. The purpose of the rule is to minimize *Cryptosporidium* concentrations in the treated water as a result of recycling sludge supernatant and filter backwash wastewater to the head of the treatment plant. The main requirement of the rule is that systems that recycle backwash waste must do so prior to the point of application of primary coagulant. The rule also requires utilities to submit a Recycle Notification Form to the State that includes a plant schematic showing the origin of all recycle flows and the typical recycle flows observed.

A.3 Long Term 1 & 2 Enhanced Surface Water Treatment Rules

The LT1ESWTR builds on the requirements of the SWTR and specifies treatment requirements to address *Cryptosporidium* and other microbial contaminants in public water systems serving less than 10,000 persons (therefore not applicable to Tucson Water). The rule balances the need for treatment with potential increases in disinfection by-products.

The LT2ESWTR was promulgated by the EPA in 2006 and requires proportional or watershed-based treatment levels based on *Cryptosporidium* levels in the source water. The rule assigns utilities to one of four 'bins', and each bin has associated requirements for additional *Cryptosporidium* treatment, as indicated in Table 5.

Table A.6 Cryptosporidium Inactivation Requirements Per LT2ESWTR

Bin No.	Average *Cryptosporidium* Concentration (oocysts/L)	Additional *Cryptosporidium* Treatment Required		
		Conventional Filtration, Diatomaceous Earth Filtration, or Slow Sand Filtration	Direct Filtration	Alternative Filtration Technologies
1	< 0.075	No additional treatment	No additional treatment	No additional treatment
2	0.075 to < 1.0	1 log(1)	1.5 log(1)	Note(3)
3	1.0 to < 3.0	2 log(2)	2.5 log(2)	Note(4)
4	≥ 3.0	2.5 log(2)	3 log(2)	Note(5)

Notes:
(1) Systems may use any technology or combination of technologies from toolbox.
(2) Systems must achieve at least 1 log of the required treatment using ozone, chlorine dioxide, UV, membranes, bag/cartridge filters, or in-bank filtration.
(3) Total *Cryptosporidium* removal and inactivation should be at least 4 log.
(4) Total *Cryptosporidium* removal and inactivation should be at least 5 log.
(5) Total *Cryptosporidium* removal and inactivation should be at least 5.5 log.

Appendix B

ADDITIONAL CONTAMINANT ANALYSIS

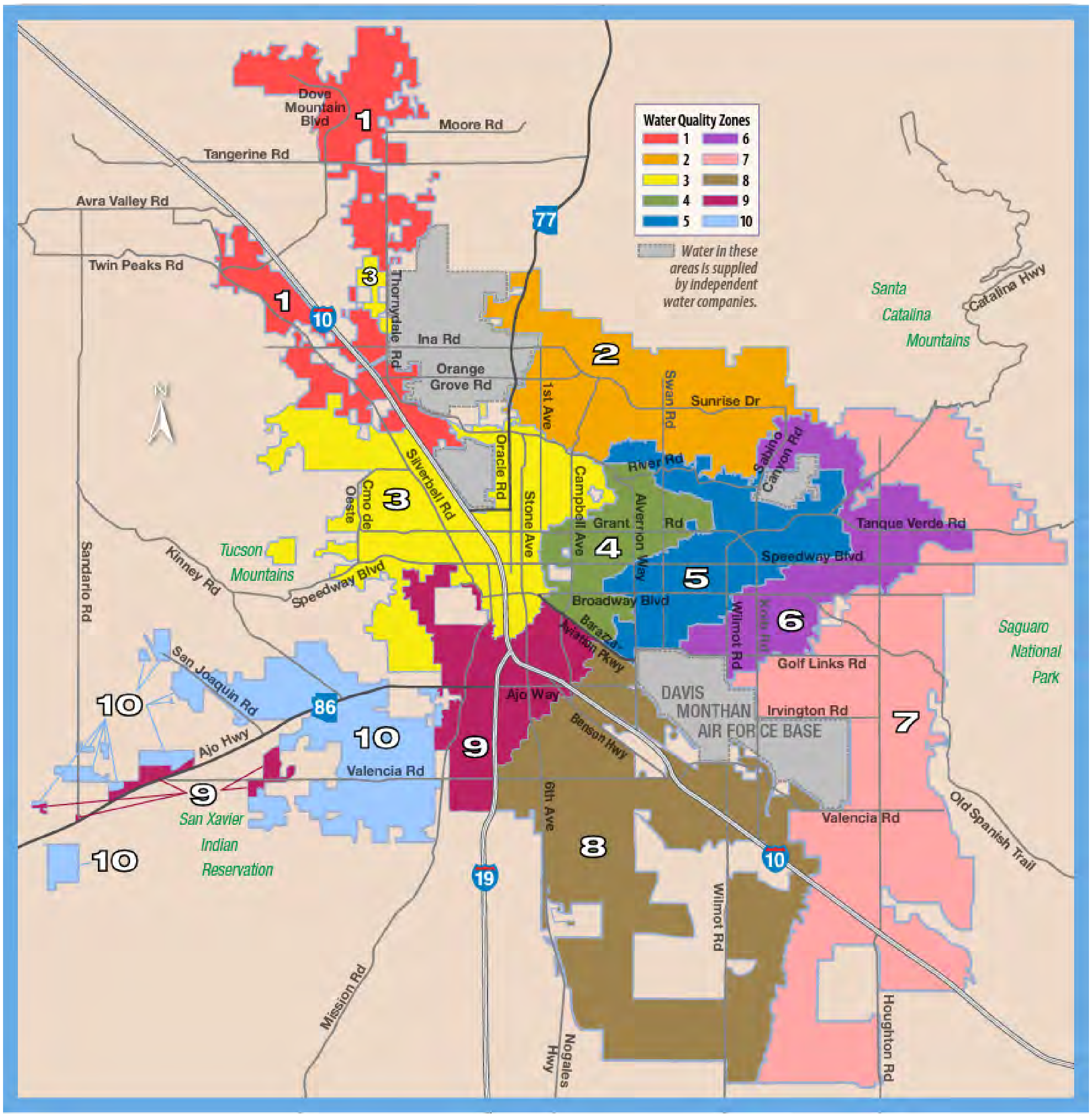


Figure B.1 Water Quality Zone Map

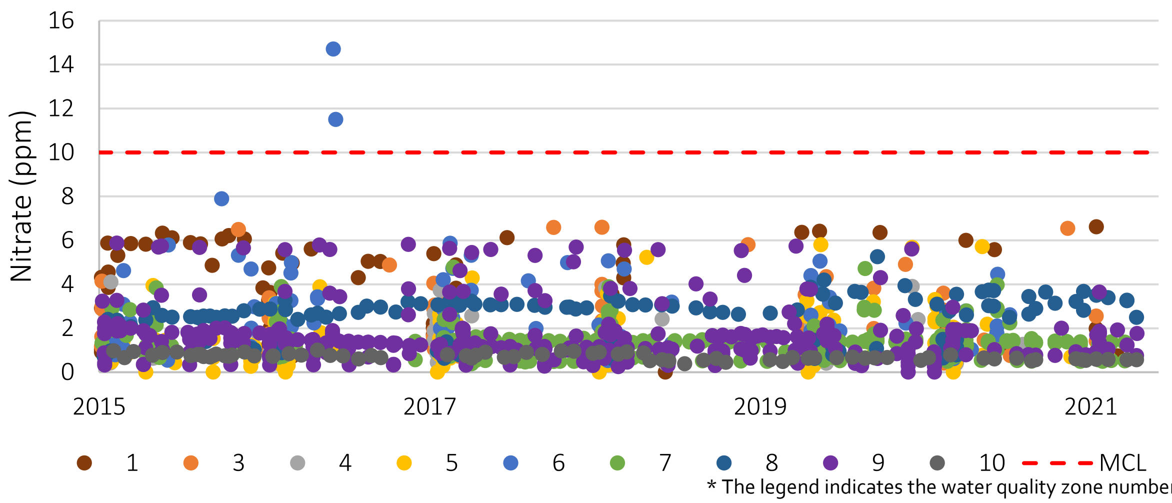


Figure B.2 All Data for Nitrate as N in the Main System

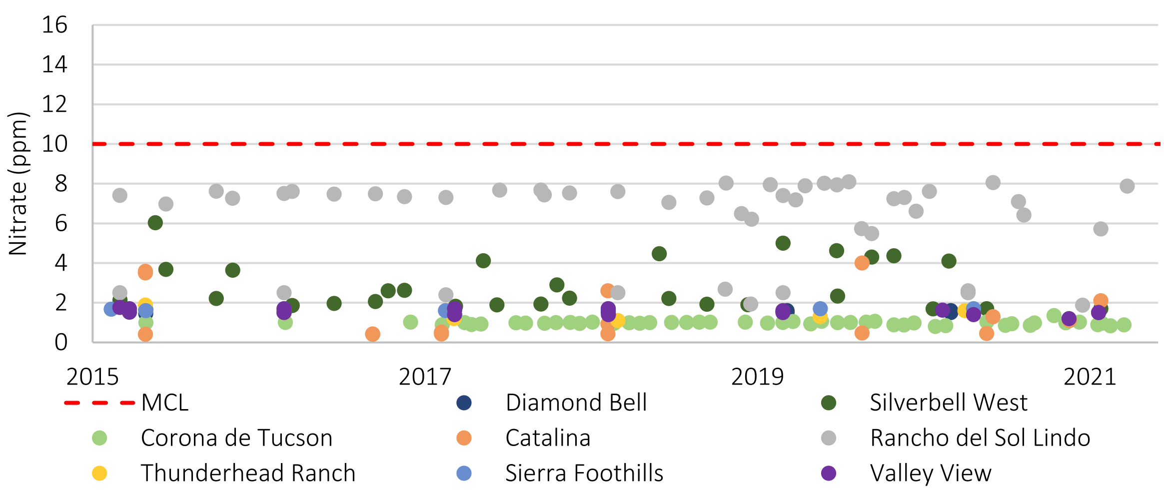


Figure B.3 All Data for Nitrate as N in Isolated Systems

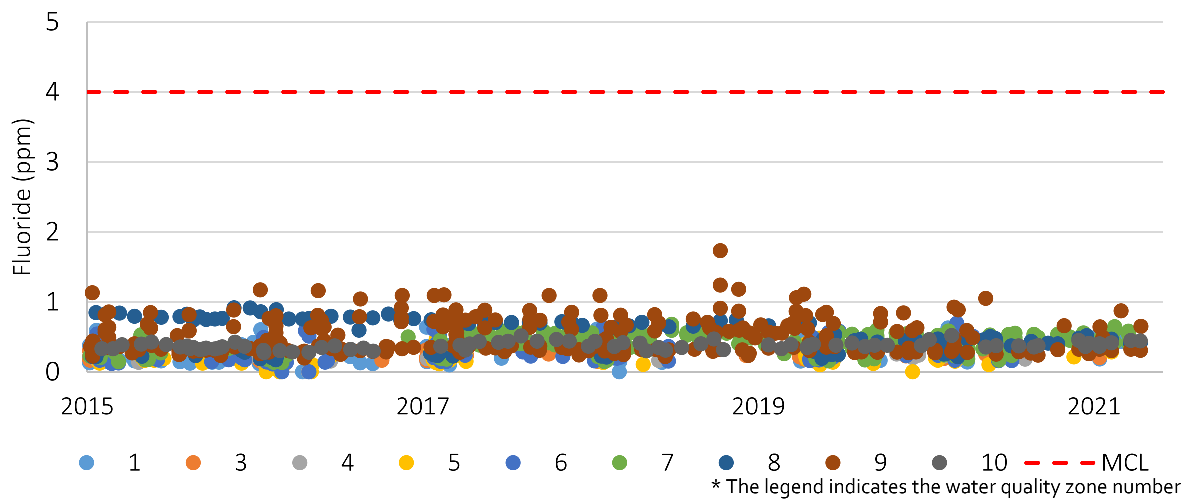


Figure B.4 All Data for Fluoride in the Main System

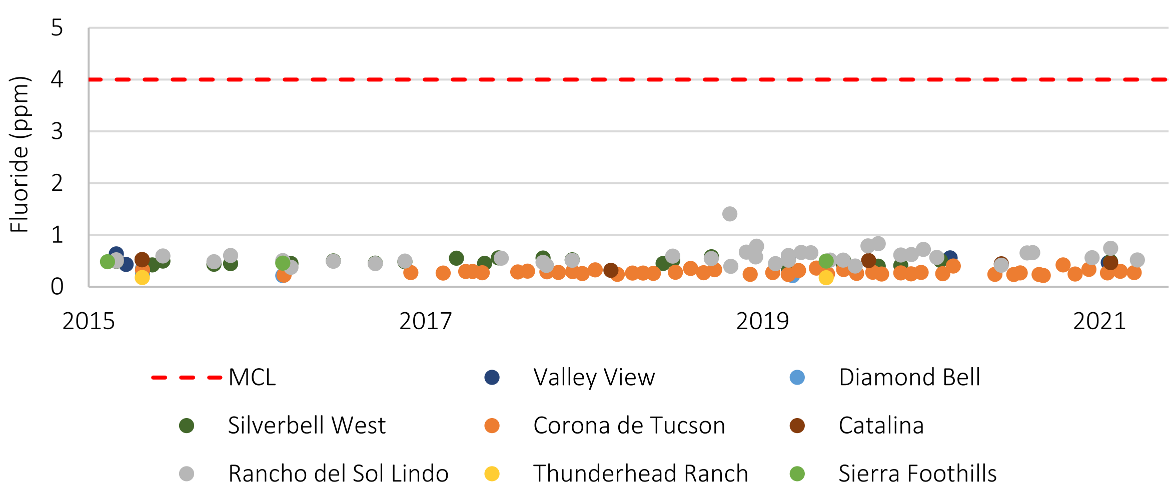


Figure B.5 All Data for Fluoride in Isolated Systems

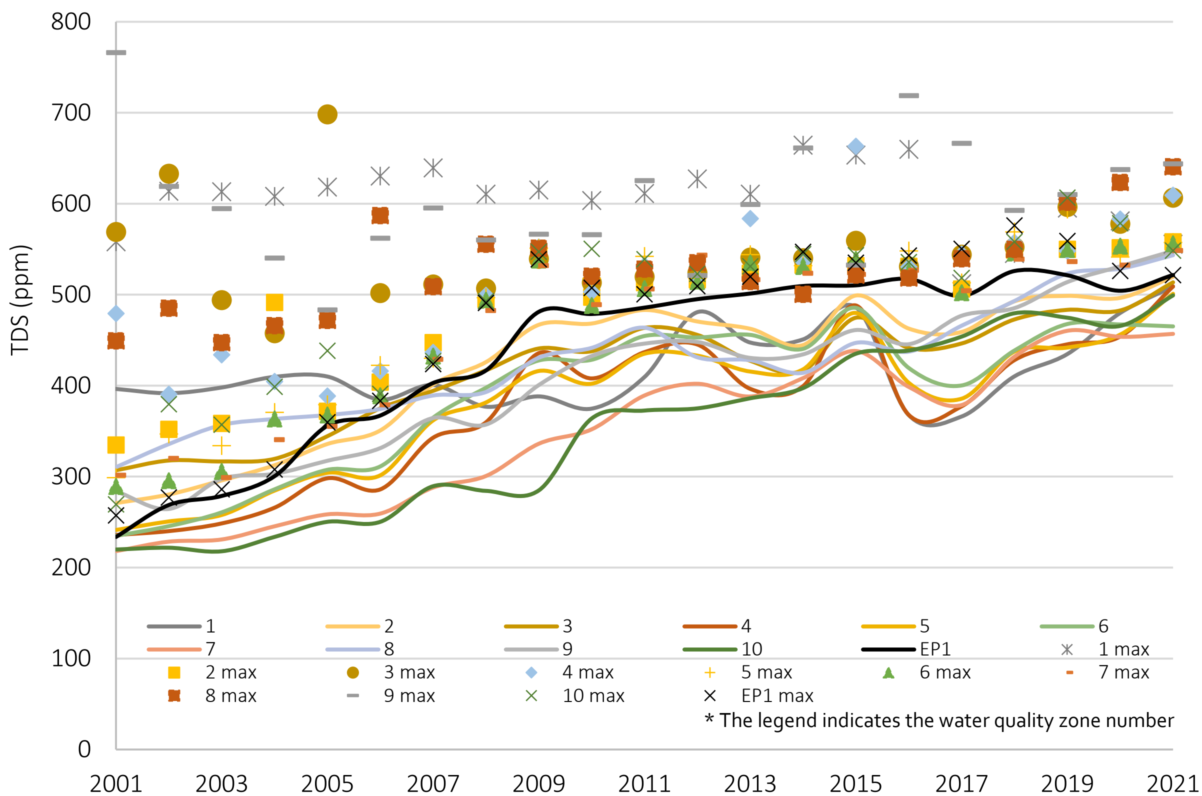


Figure B.6 Average Annual and Annual Max Total Dissolved Solids in the Main System

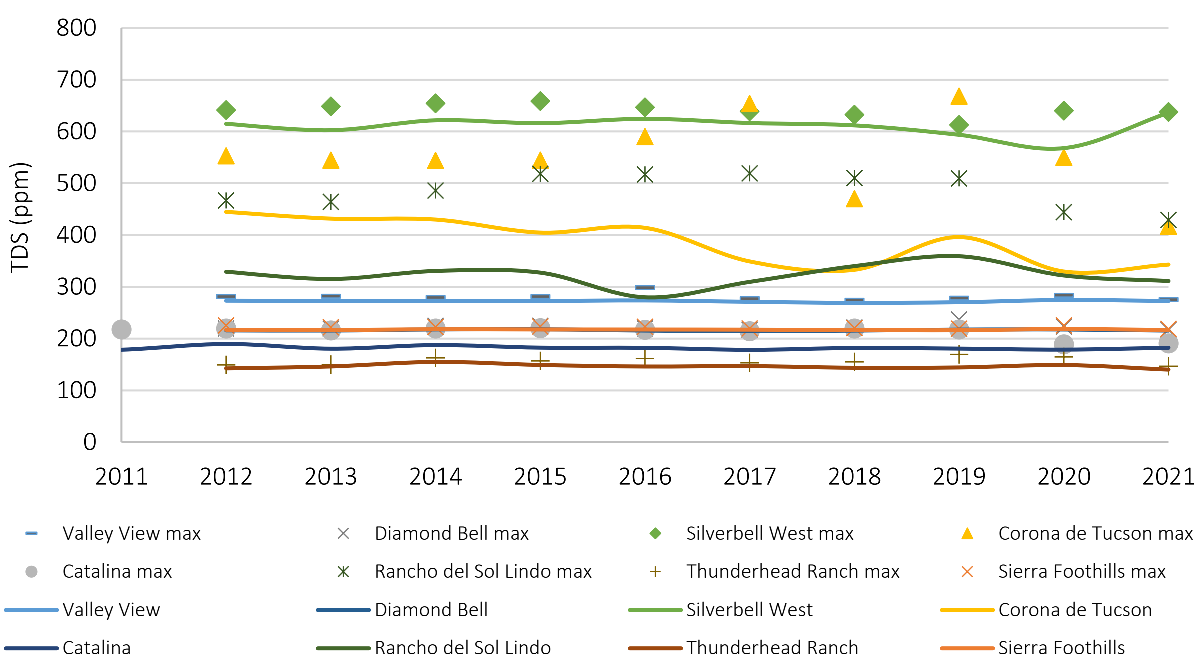


Figure B.7 Average Annual and Annual Max Total Dissolved Solids in Isolated Systems

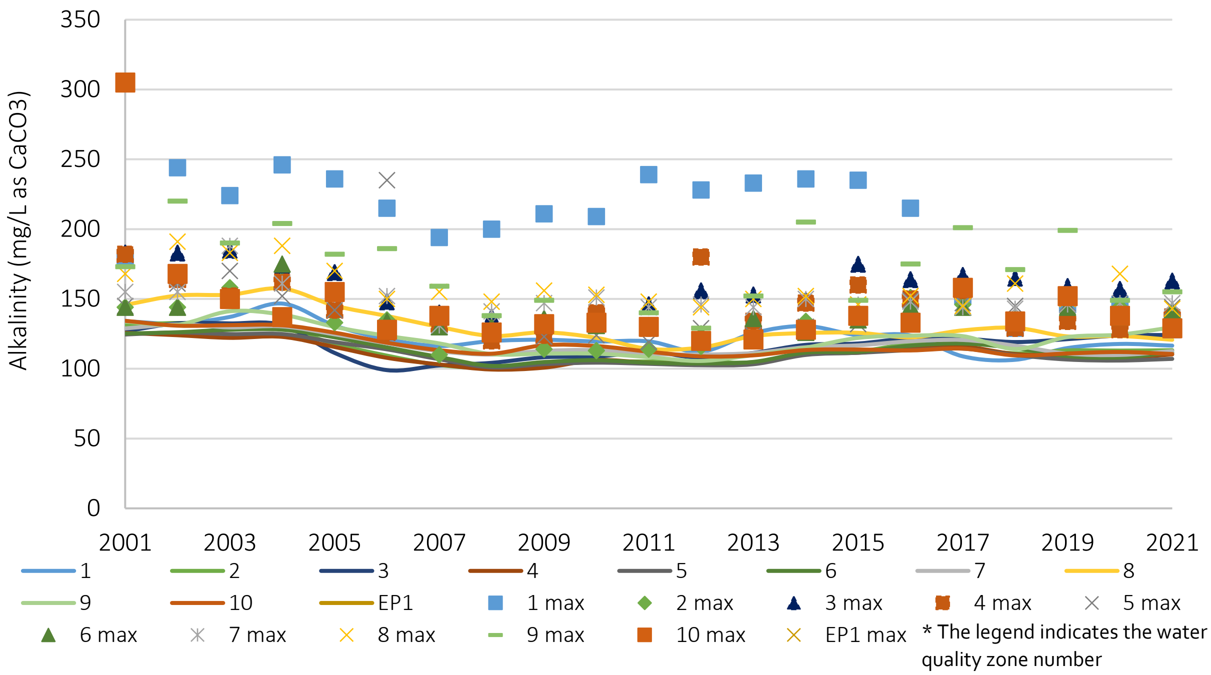


Figure B.8 Average Annual and Annual Max Alkalinity in the Main System

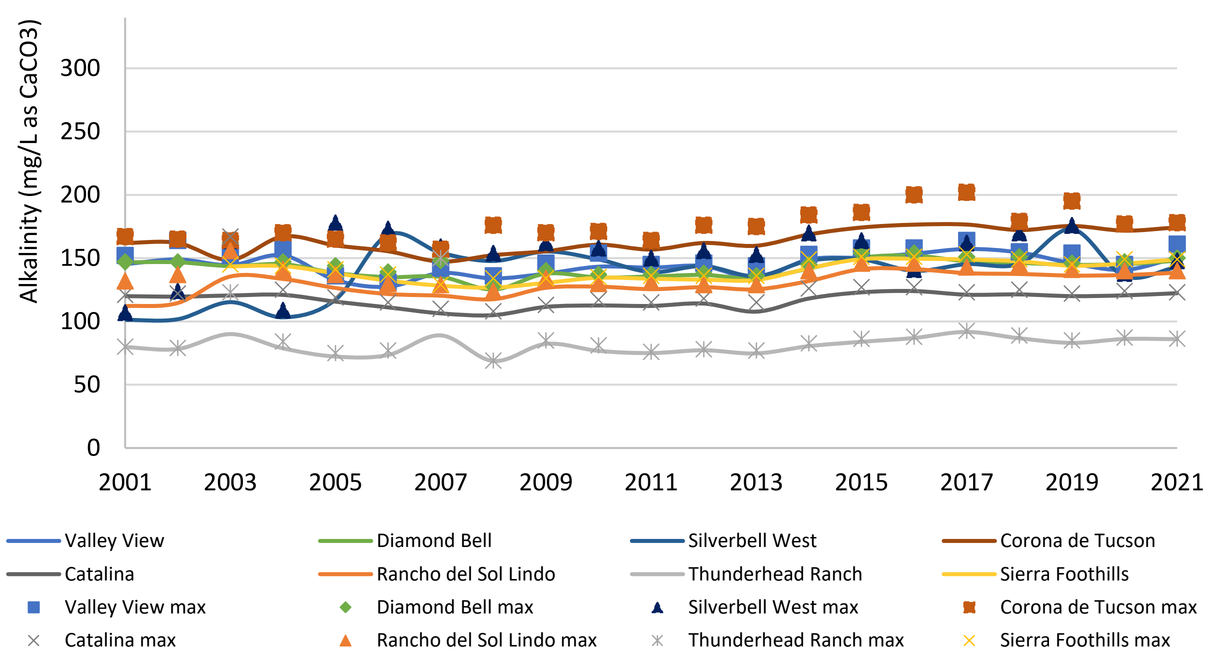


Figure B.9 Average Annual and Annual Max Alkalinity in Isolated Systems

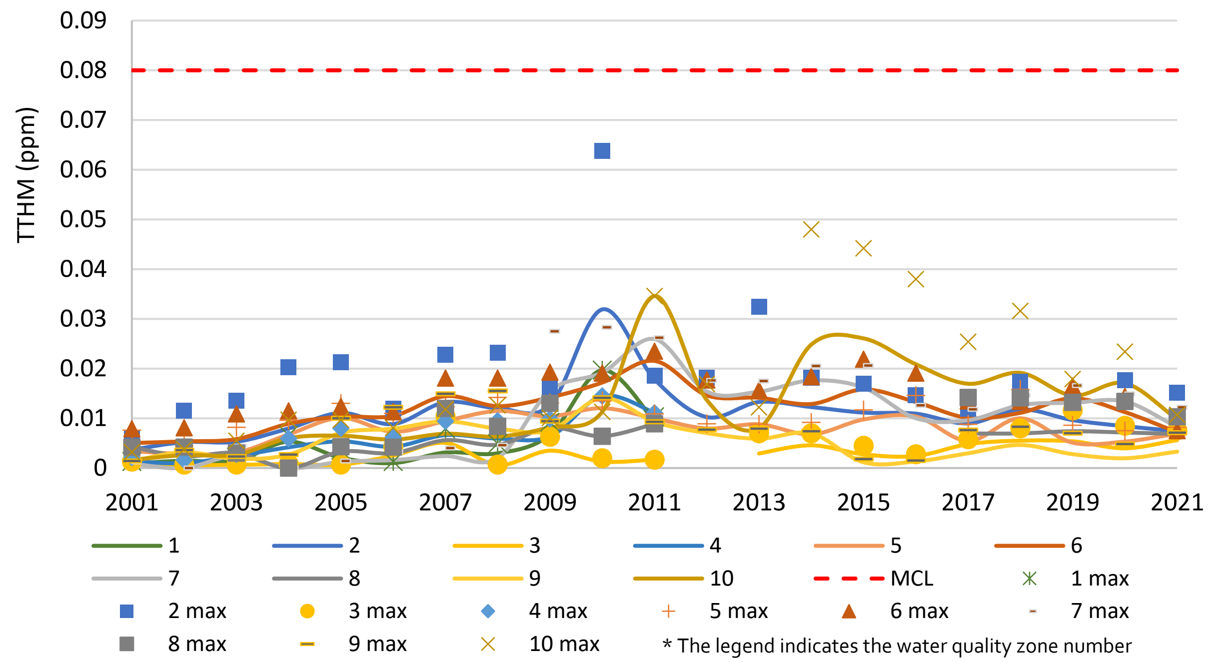


Figure B.10 Annual Average and Annual Max Total Trihalomethane in the Main System

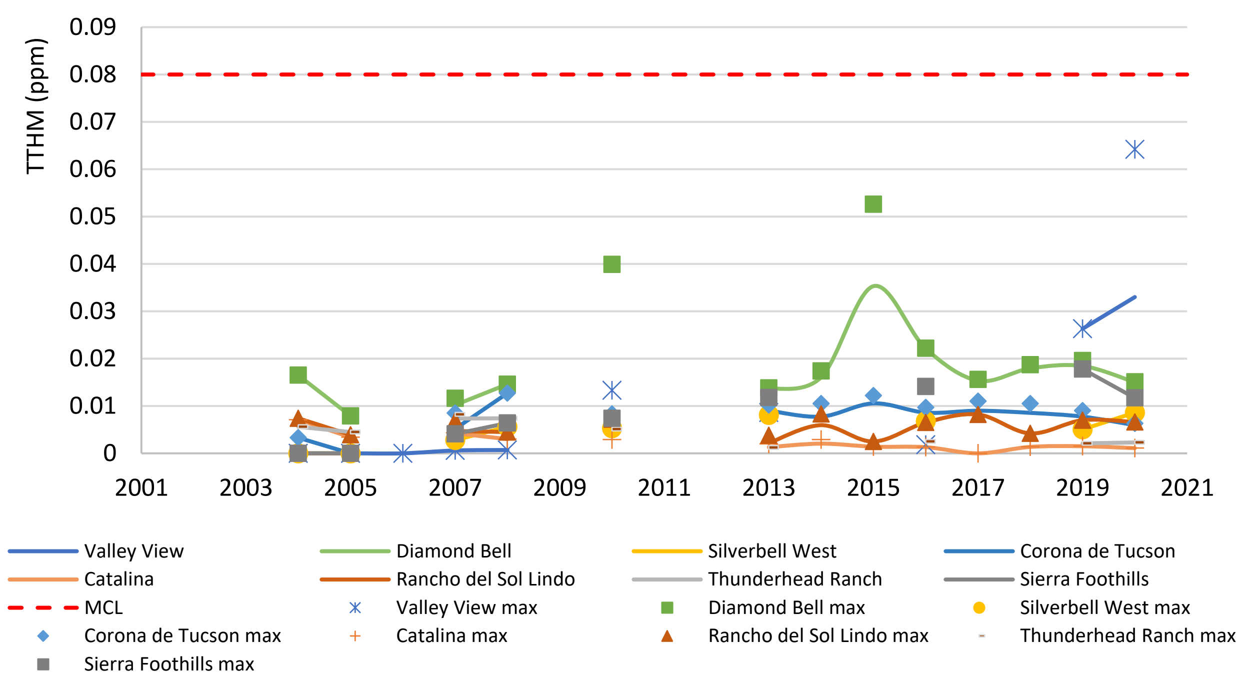


Figure B.11 Average Annual and Annual Max Total Trihalomethane in Isolated Systems

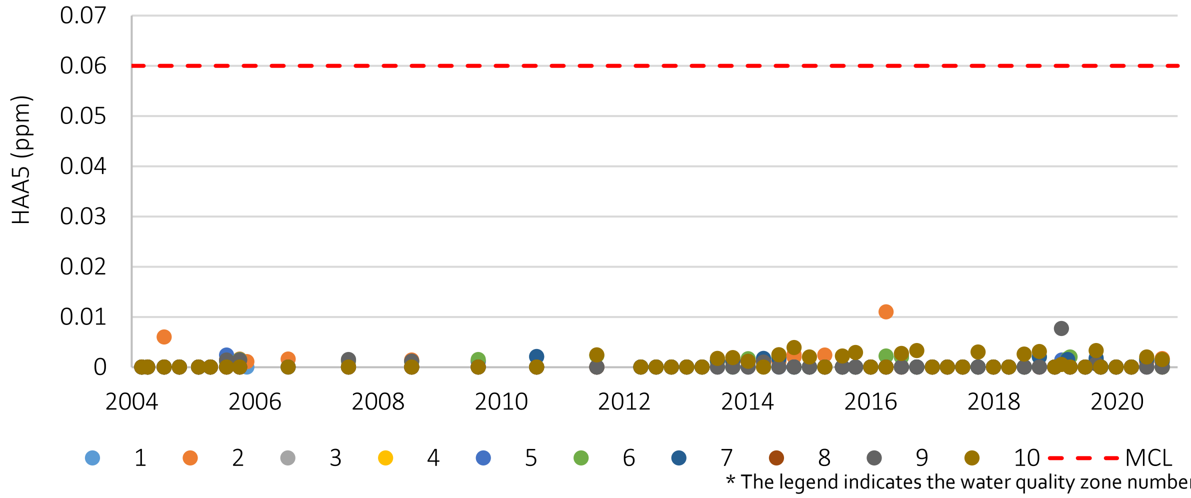


Figure B.12 Haloacetic Acids in the Main System

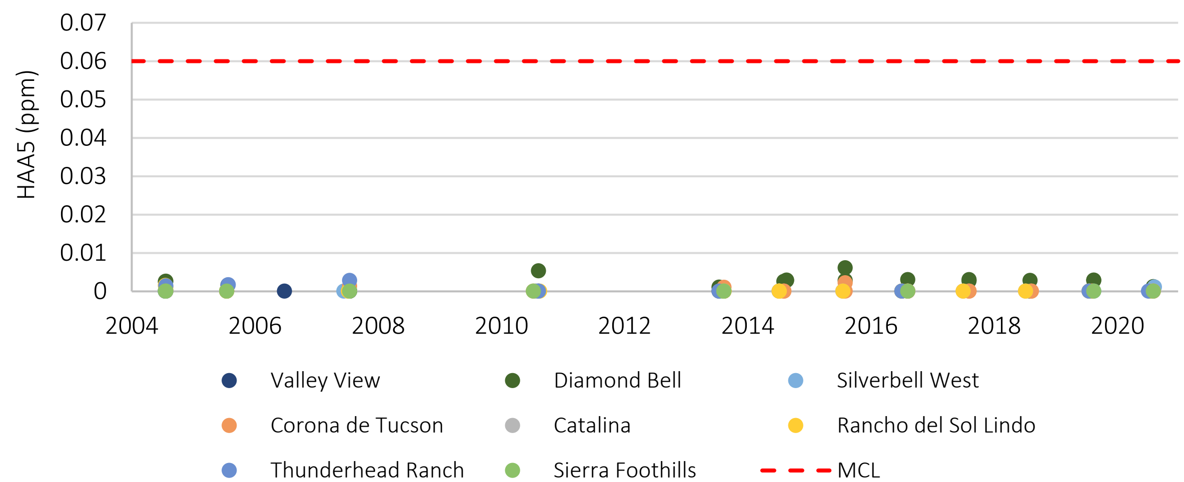


Figure B.13 Haloacetic Acids in Isolated Systems

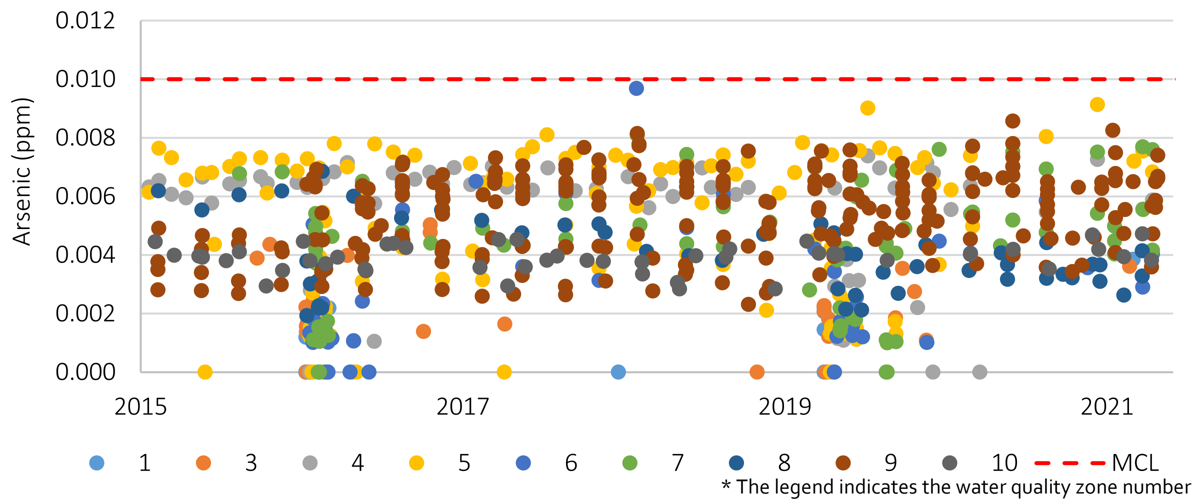


Figure B.14 All Data for Arsenic in the Main System

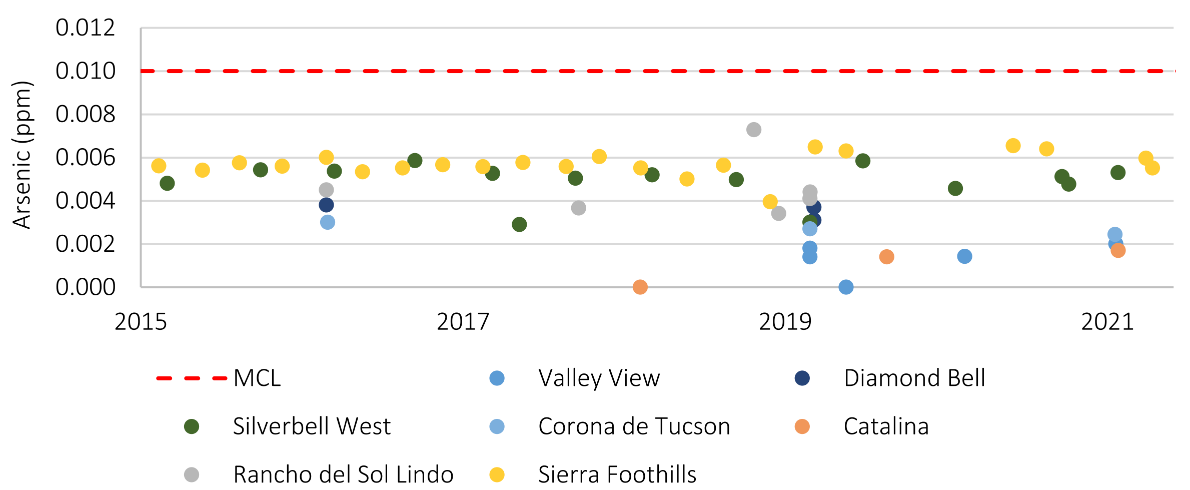


Figure B.15 All Data for Arsenic in Isolated Systems

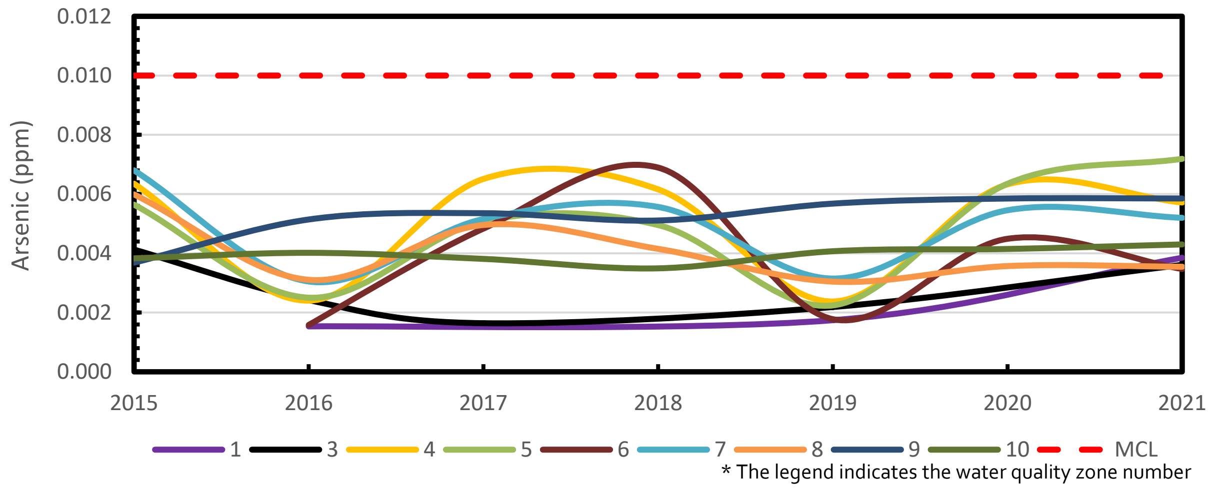


Figure B.16 Average Annual Arsenic of Wells by WQZ

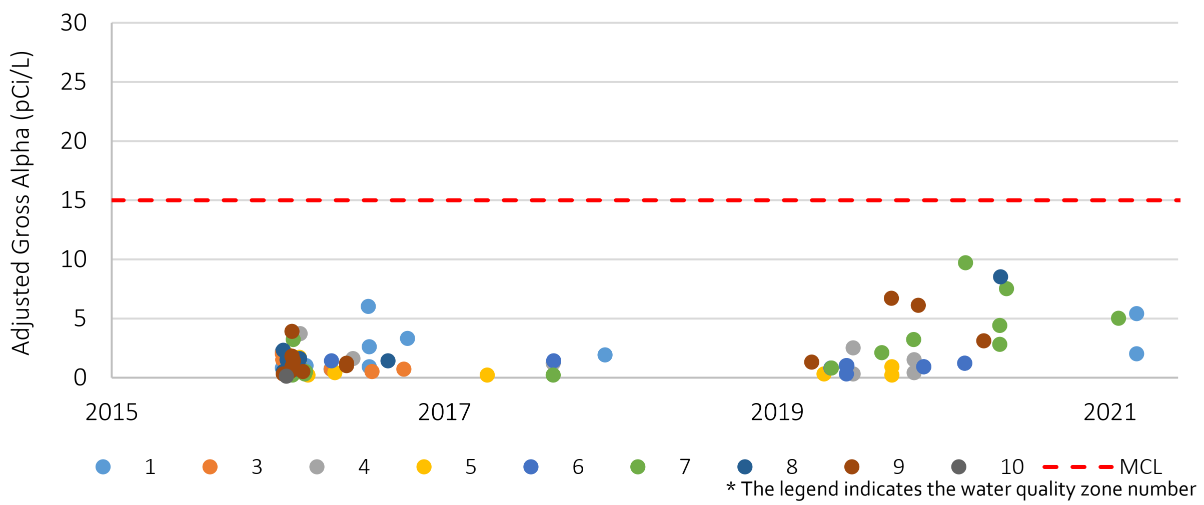


Figure B.17 Adjusted Gross Alpha in the Main System

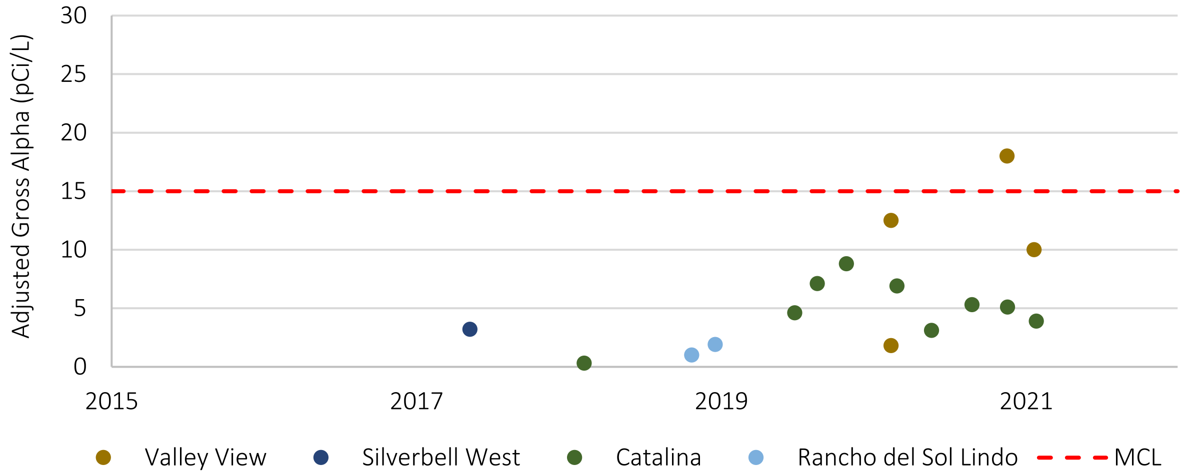


Figure B.18 Adjusted Gross Alpha in Isolated Systems

Appendix C

LEAD AND COPPER ANALYSIS

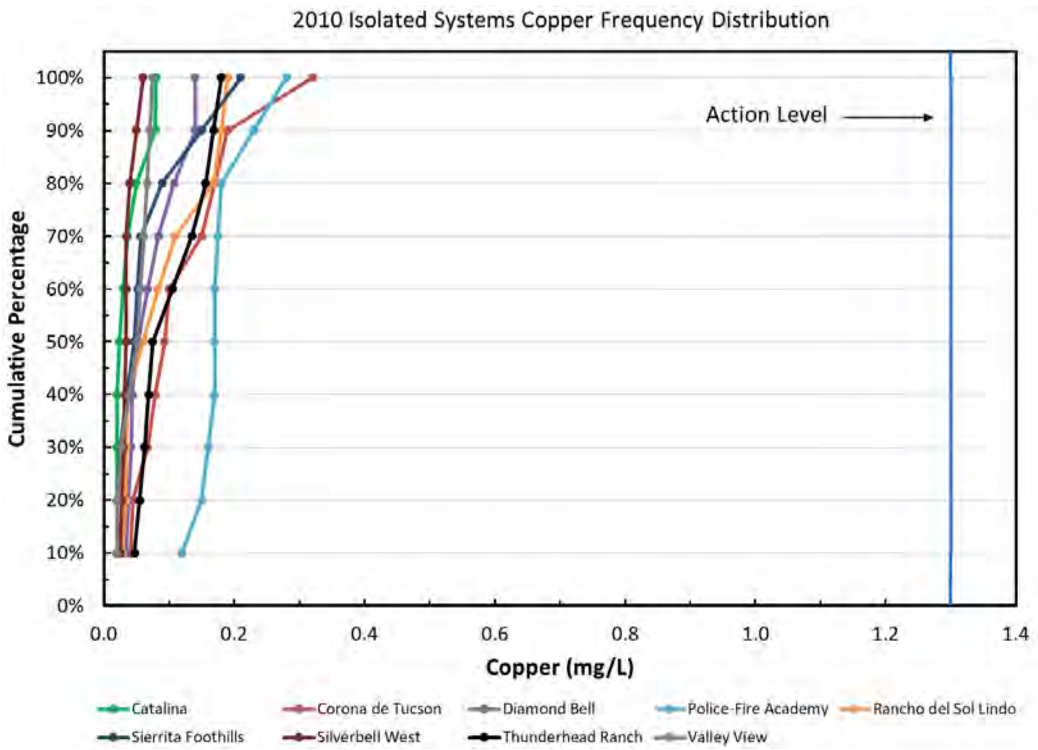


Figure C.1 2010 Isolated Systems Copper Frequency Distribution

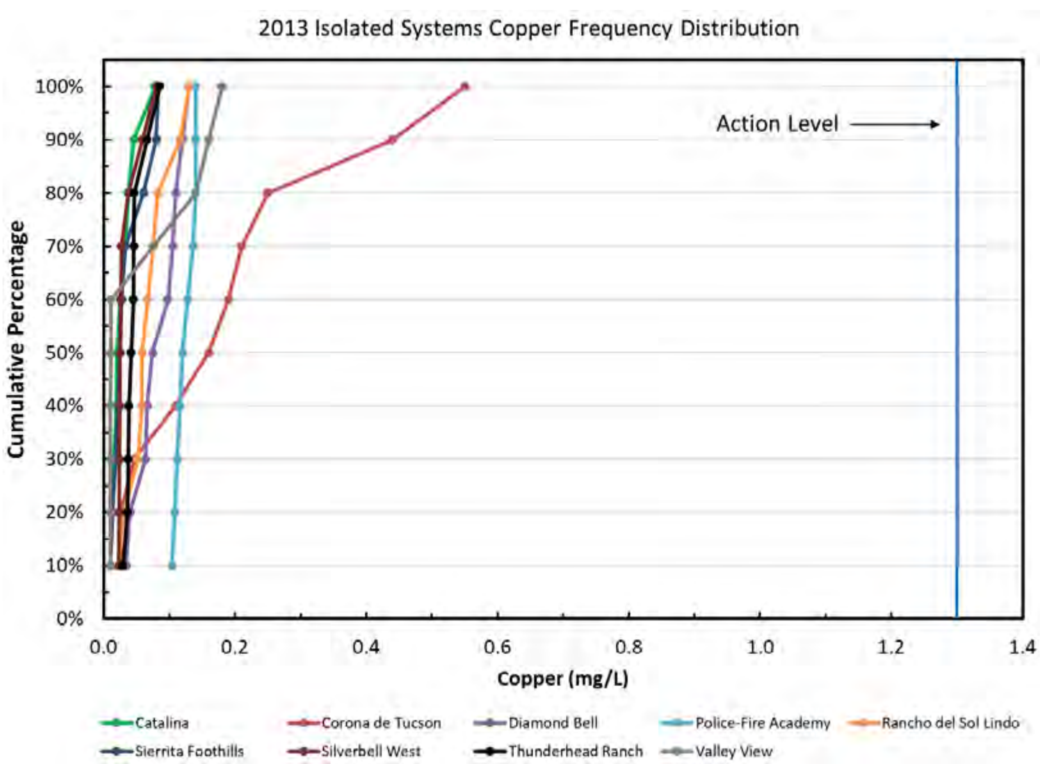


Figure C.2 2013 Isolated Systems Copper Frequency Distribution

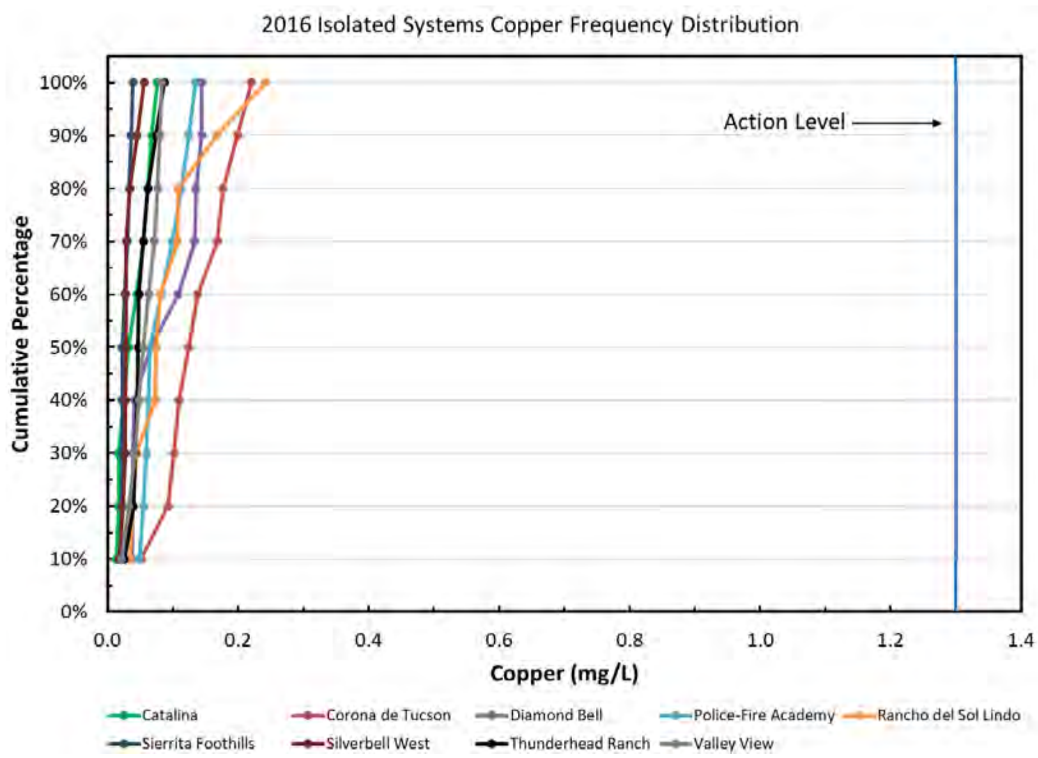


Figure C.3 2016 Isolated Systems Copper Frequency Distribution

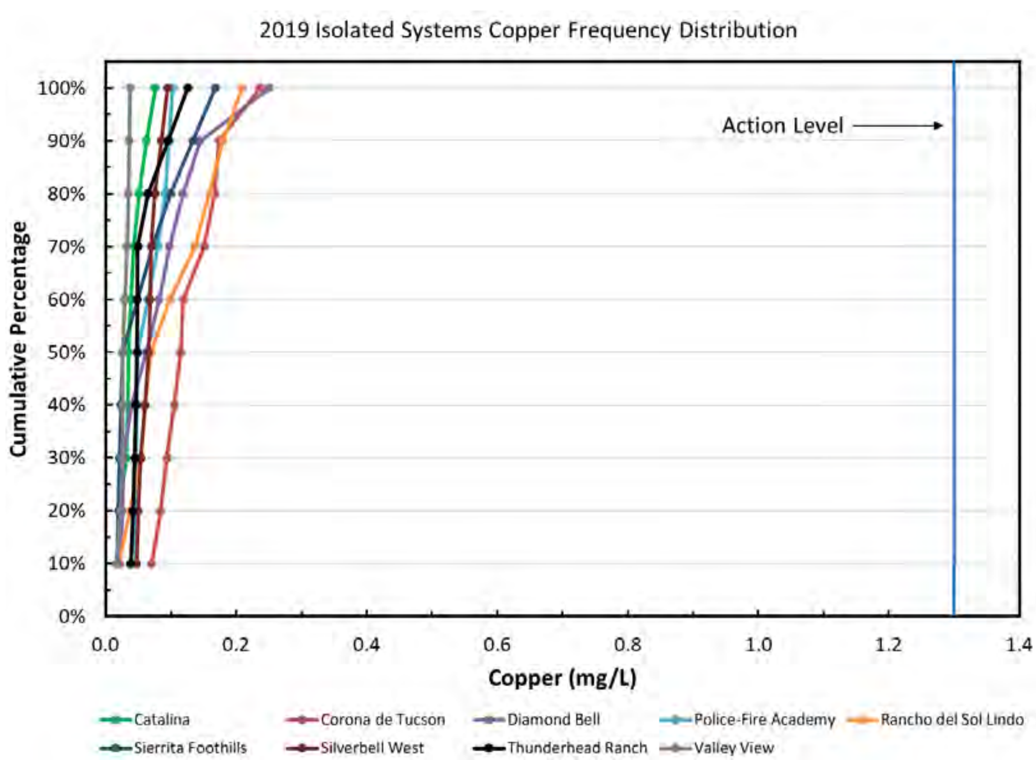


Figure C.4 2019 Isolated Systems Copper Frequency Distribution

Table C.1 90th Percentile Copper Data for Isolated Systems

System	90th Percentile (mg/L)	Number of Samples
Catalina	0.075	42
Corona de Tucson	0.220	86
Diamond Bell	0.137	46
Police-Fire Academy	0.170	21
Rancho del Sol Lindo	0.178	45
Sierrita Foothills	0.083	23
Silverbell West	0.072	20
Thunderhead Ranch	0.122	22
Valley View	0.083	21

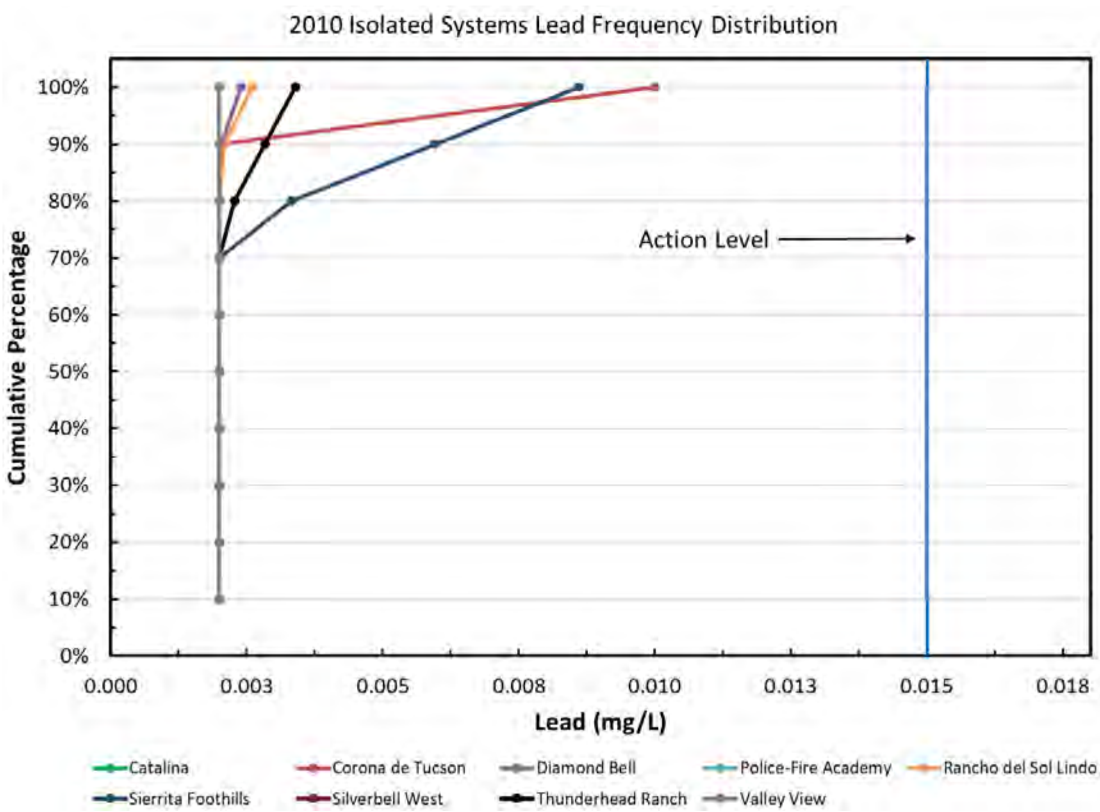


Figure C.5 2010 Isolated Systems Lead Frequency Distribution

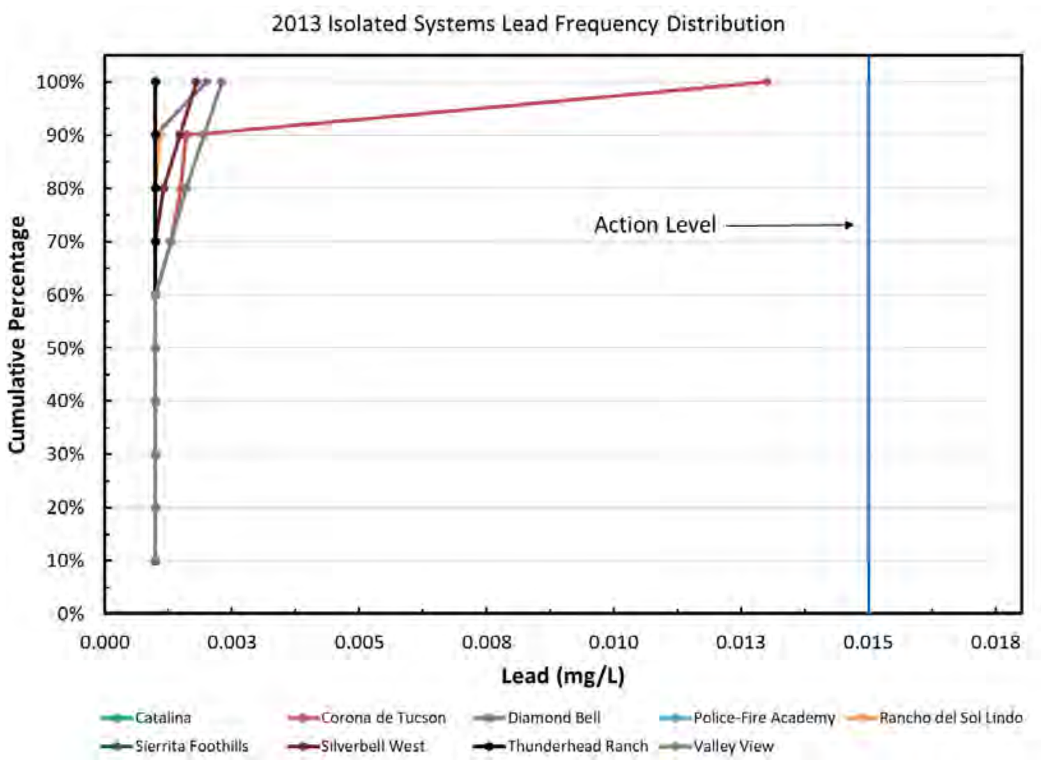


Figure C.6 2013 Isolated Systems Lead Frequency Distribution

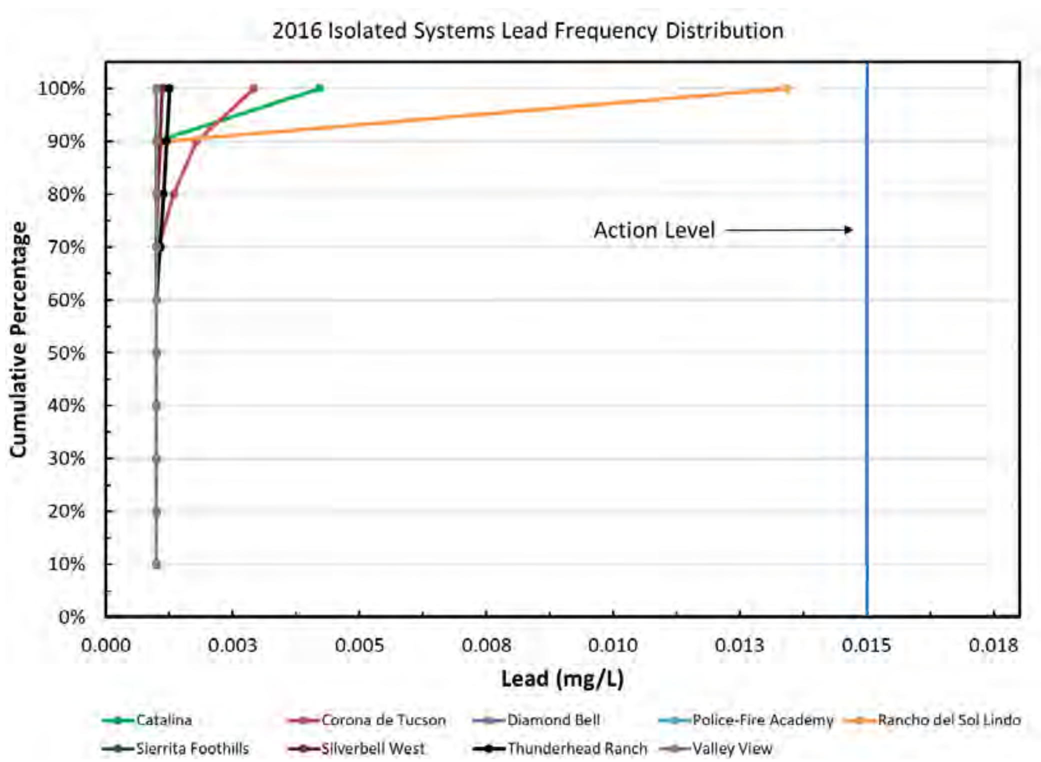


Figure C.7 2016 Isolated Systems Lead Frequency Distribution

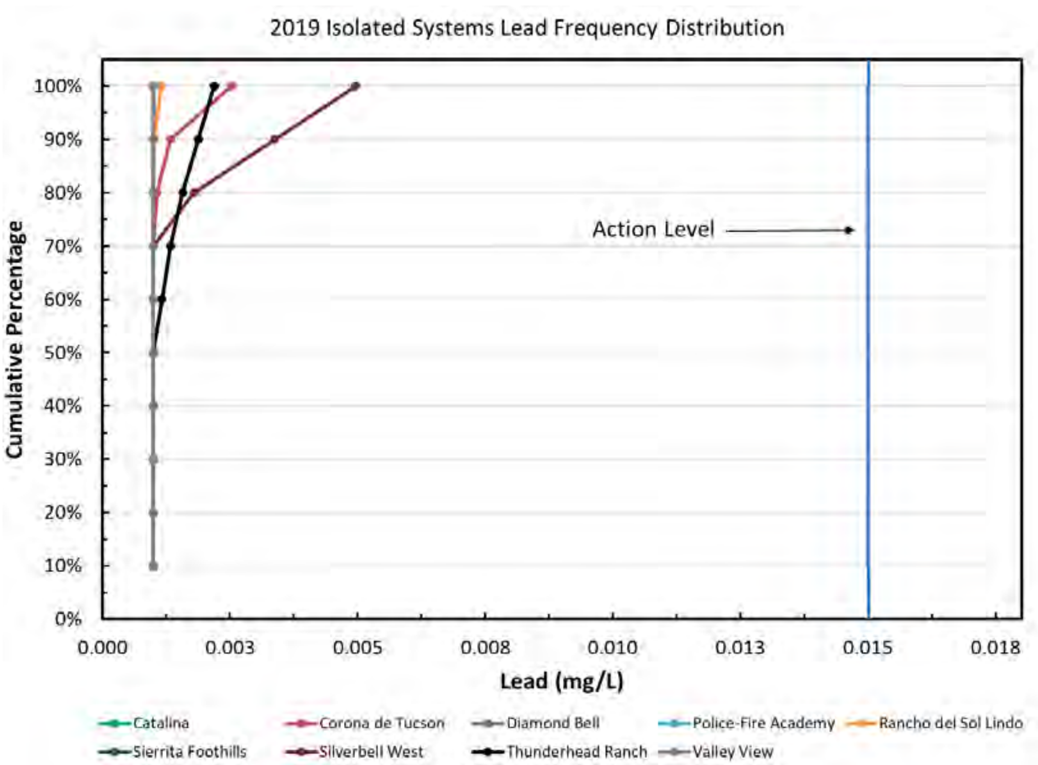


Figure C.8 2019 Isolated Systems Lead Frequency Distribution

Table C.2 90th Percentile Lead Data for Isolated Systems

System	90th Percentile (mg/L)	Number of Samples
Catalina	0.002	42
Corona de Tucson	0.002	86
Diamond Bell	0.002	46
Police-Fire Academy	0.002	21
Rancho del Sol Lindo	0.002	45
Sierrita Foothills	0.002	23
Silverbell West	0.002	20
Thunderhead Ranch	0.002	22
Valley View	0.002	21

Appendix D

FLUSHING SOP

PROJECT MEMORANDUM

ONE WATER 2100 MASTER PLAN

Tucson Water

Date: 12/22/2021

Project No.: 11442A00

Prepared By:	Aurelie Nabonnand, P.E. and Natalie Reilly, P.E.
Reviewed By:	Corin Marron, P.E.
Subject:	Conventional Flushing Standard Operating Procedure

Scope/Purpose

The purpose of this standard operating procedure (SOP) is to define the procedure for conventional flushing of a distribution area. This SOP includes a description of situations when conventional flushing is recommended, a summary of pre-flushing planning steps, and the flushing procedures.

Situations for Conventional Flushing

The conventional flushing method is performed by opening hydrants in targeted areas and discharging water until any accumulations are flushed and the water runs clear. Unidirectional flushing (UDF) is performed by isolating each pipeline, using the set sequences from the flushing program, to create flow in a single direction to clean pipe mains.

Conventional flushing is performed under different circumstances than main cleaning using UDF. Before performing conventional flushing, determine if UDF may be more applicable to the situation.

Conventional flushing is recommended under the following planned circumstances:

- After a customer complaint about water quality.
- Before bringing groundwater wells online after a period of downtime to avoid water quality concerns.
- During routine valve/fire hydrant maintenance.

Conventional flushing is recommended under the following unplanned circumstances:

- After a potential or real contamination, including super-chlorination/de-chlorination, in order to flush and restore service.
- After a main break.

Flushing Planning

This section summarizes the steps to be taken prior to performing the actual flushing, including the following:

1. Public outreach.
2. Governing agency coordination.
3. Tracking water discharges.
4. Personnel and safety measures.
5. System review and route selection (if flushing multiple hydrants is required).
6. Site safety considerations.

7. Sensitive area considerations.
8. Equipment.

1. Public Outreach

Public outreach should be performed before planned flushing and during the flushing event and includes the following:

- Mailers for planned flushing explaining water quality side-effects and reasons for flushing for planned flushing (two weeks prior to start of planned flushing event).
- Update to Tucson Water's Water Outages & Advisories online map (two weeks prior to start of planned flushing event).
- Social media notification (one week prior to start of planned flushing event and day of planned flushing event).
- Email notification to affected customers (one week prior to start of planned flushing event).
- Residential and/or commercial property notifications (one week prior to start of planned flushing event).
- Posted placards and signs at the flushing site (day of flushing event).

Public outreach should be performed during unplanned flushing events, such as a main break, and includes the following:

- Social media notification.
- Email notification to affected customers.
- Notify Ward office electronically.
- Update to Tucson Water's Water Outages & Advisories online map.
- Posted placards and signs at the flushing site.

Note, any media inquiries should be directed to the Tucson Water Public Information Office (PIO).

2. Governing Agency Coordination

Outreach to appropriate governing agencies should be performed before planned flushing or during the flushing event, if possible. If purging a well or flushing large quantities of water is expected, coordination with other governing agencies is required. Governing agencies could include one or more of the following:

- City of Tucson Department of Transportation (TDOT).
- City of Tucson Ward Offices.
- Pima County Transportation Department.
- Pima County Regional Wastewater Reclamation Department (PCRWRD).
- Municipalities including Marana, South Tucson, Oro Valley, Catalina, and Sahuarita.

Communication to governing agencies can occur through the dispatch center or directly to the agency's PIO and is recommended to be in both written correspondence and verbal communication. Ward offices should be notified in writing and/or via email depending on the size of the flushing event. Communication with an external agency PIO should come from Tucson Water PIO. Agencies can be directed to Tucson Water's Water Outages & Advisories online maps, which includes planned flushing events.

If discharge to the sanitary sewer is planned for a flushing event, coordination with Water Quality is required. Water Quality & Operations will report the flushing event to PCRWRD.

Note, Tucson Water's flushing procedures should comply with requirements of adjacent utilities and governing agencies.

3. Tracking Water Discharges

All water discharges must be tracked to meet two regulatory programs: Arizona Pollutant Discharge Elimination System Permit Program (AZPDES) and Tucson Water's Non-Revenue Water (NRW) tracking.

Tucson Water's AZPDES De Minimis permit, through the Arizona Department of Environmental Quality (ADEQ), allows discharges under the following circumstances that are related to conventional flushing:

- Discharges related to installation, maintenance, and repair of potable water supply systems (pipelines, tanks, wells, reservoirs, fire hydrants, etc.).
- Well development and maintenance, and aquifer testing. Discharges of water associated with drilling, rehabilitation and maintenance of non-potable water wells, wells being developed for potable use, and piezometers; and discharges from water supply and water quality evaluations.

All discharges must comply with the AZPDES De Minimis permit. Monitoring requirements for the AZPDES permit including the following:

- For potable water system discharge activities, monitoring flow rate, duration of flow, total residual chlorine, and constituents of concerns is required.
- For well test pumping and purging, monitoring flow rate, duration of flow, total residual chlorine, oil and grease, and constituents of concern is required.

Due to the new Environmental Protection Agency's (EPA) Navigable Waters Protection Rule (published September 3, 2021), Tucson Water is working with ADEQ on the dechlorination requirements for the AZPDES De Minimis permit. Further clarification is needed at the time of publishing this Flushing SOP. Water Quality should be contacted to determine if dechlorination is required based on the receiving water body.

Documentation of discharge quantity is also required for Tucson Water's NRW tracking to meet Arizona Department of Water Resources (ADWR) annual water loss regulation, which requires water loss totals not to exceed 10 percent annually.

Water Quality should be contacted prior to water discharge under the following circumstances:

- If discharge is greater than 500,000 gallons or longer than four hours (including non-potable water).
- If discharge leaves the property or impedes traffic requiring signate and/or a right of way (ROW) permit.
- If discharge is within a quarter mile or directly into a major wash

4. Personnel and Safety Measures

The Tucson Water personnel required to plan and perform the flushing and their roles and responsibilities are as follows:

- Water Operations Supervisor:
  - Work with Water Quality for scheduling and planning flushing events.
  - Post flushing event on Water Outages & Advisories online map.
  - Notify Tucson Water PIO before flushing event.
  - Assign field personnel for flushing event.

  - Review and approve discharge permits.
- Field Personnel – Utility Technician(s) or Well Maintenance Technician(s):
  - Notify dispatch office and include information such as location of flush, direction of flush, expected duration, and purpose for flush.
  - Review safety and sensitive area considerations before flushing.
  - Perform flushing activity.
  - Prepare records from flushing activities, including any maintenance concerns.
- Water Quality Technicians:
  - Collect samples.
- Water Quality Environmental Scientist:
  - Maintain flushing records.
  - Notify MS4 permittee holders.
- Dispatch Center:
  - Coordinate between on-site lead or supervisor and various contractors for traffic control as needed.
- Planner Scheduler (Liaison with Water Quality):
  - Develop flushing schedule.
  - Develop plans for flushing.
- Tucson Water PIO:
  - Public notifications to ward offices, social media, and other public domains, as required.
  - Communication with media.

Wachs Water will be assisting Tucson Water is valve and fire hydrant maintenance as well as UDF implementation.

The following personnel safety measures should be implemented before and during flushing events:

- Traffic control during the flushing event, including contact information for Tucson Water PIO, ROW permit, traffic cones, temporary signs, and additional equipment as needed for busy streets.
  - Signage warning of standing water for traffic and pedestrians should be used when needed.
- Personal protective equipment (PPE), including hard hat, high visibility clothing, safety glasses, work gloves, steel-toed boots, and knee pads as needed.
- Employees shall perform a pre-trip inspection in their vehicles prior to driving the vehicle. The inspection shall include but not be limited to all safety equipment, gear, lights, and personal protective equipment necessary to perform their job safely and in accordance with the applicable policies and procedures. In addition, the vehicle shall be inspected for fluid levels, damage, leaks etc. See Administrative Directive 6.01-1 for additional details. Vehicles shall be fueled before leaving the yard or at the end of the shift.

5. System Review and Route Selection

System review and route selection is a case-by-case process and will vary based on location and flushing purpose.

System maps, including geographic information system (GIS), as-builts, and asset history, should be reviewed before any flushing events. This review can help identify hydrants that are in busy intersections, near sensitive customers, or may result in hydraulic impacts to the system. Also, pipe diameters, valve locations, and other useful facility data can be identified during the system review. The flushing crew will select the hydrants to use based on operability and location from the system review. Tucson Water staff is asked to collect operational data every time a valve or hydrant is used, which can be helpful for determining the valves and hydrants to be used for flushing.

If multiple hydrants will be used for flushing, the best route for flushing, including the start hydrant, end hydrant, and sequence in between, should be identified before the flushing event. For planned flushing events, flushing is usually performed in one direction, targeting each hydrant in the line of sight.

For planned flushing events, the location for flushing water discharge should be determined. Contact Water Quality to determine if dechlorination is required based on the receiving water body. If water must be discharged to the sanitary sewer system, coordination with the PCRWRD through Water Quality is required. PCRWRD has specifications for large quantities of discharged flushing water that must be followed.

Note, that in emergencies, a detailed system review and route selection may not be possible.

6. Site Safety Considerations

Before beginning the hydrant flushing, it is important to inspect the site for safety. The following issues should be addressed:

- Water flow path to a nearby drain inlet should be unencumbered.
- Drain inlets should be free of debris.
- Potential flooding/damage to neighboring property should be strictly avoided.
- The flow trajectory of the water should not endanger passing vehicles or pedestrian traffic.
- Water should not cause slick or unsafe conditions in traveled areas.
- If flushing hydrants in a sensitive area (as outlined below), dechlorination is required.

Do not flush a hydrant if the above or any other conditions create an unsafe situation.

7. Sensitive Area Considerations

Sensitive areas are those that could be adversely impacted by a large influx of drinking water. Such areas might include creeks, ponds, or other water bodies. The Tucson Water Best Management Practices AZPDES Area-Wide General Permit AZG-57466 document should be reviewed before any flushing event. The 2018 AZPDES BMPs are included in Attachment A (pdf page 11 of 37).

Tucson Water chlorinates all water wells to kill existing microorganisms and protect against contamination. Chlorine present in flush water is toxic to fish and other small freshwater biota and must be removed before the water reaches any natural water bodies. In addition, extremely silty water can potentially suffocate animals living in natural ponds and streams. The following questions should be addressed before flushing a hydrant in any area suspected as sensitive:

- Where will the discharge go?
- Are the road surfaces free of significant debris that could flow into the drain inlets?
- Are curbs or ditches sufficient to handle hydrant flow without creating a buildup of silt?
- Are the surfaces over which water will flow free of possible contaminants such as oil, soil, etc.?
- Will water discharged during the flow test erode unpaved areas, etc.?

If any of the above conditions exist, steps should be taken to mitigate the situation.

As mentioned in the Tracking Water Discharges section, due to the new EPA Navigable Waters Protection Rule, Tucson Water is working with ADEQ on the dechlorination requirements for the AZPDES De Minimis permit. Further clarification is needed, and as sensitive areas are identified, they will be added to the SOP. Contact Water Quality to determine if dechlorination is required based on the receiving water body.

Dechlorination should also be done when flushing involves super-chlorinated water or if large volumes of water will be discharged to the sanitary sewer. When flushing large transmission mains, sometimes water will need to be discharged to the sanitary sewer. Clearance for discharging to the sanitary sewer must be provided by PCRWRD though coordination with Water Quality. Past requirements have included an air gap between the discharged water and the sewer and dechlorination for water over a specific quantity.

8. Equipment

This section summarizes the equipment required for flushing, including detailed descriptions of the diffuser and dechlorination equipment. A summary of the recommended equipment for flushing is as follows:

- Hydrant diffuser with hose (as needed for directing flow).
- Dechlorination equipment as needed depending on location and outfall.
- Hydrant aprons.
- Adjustable combination hydrant and spanner wrench.
- 18-inch pipe wrench.
- Adjustable 12-inch crescent wrench.
- 12-inch channellock pliers.
- 6-inch screwdriver.
- 24-foot engineers tape measure.
- Roll of 1/2-inch x 520-inch PTFE tape for thread sealing.
- Map for locating hydrants.
- Repair forms for identifying valves and hydrants that need repair.
- Cloth rags.

Flow diffuser equipment should be used during flushing if available. This equipment reduces the energy of the water as the flow from the hydrant is released to the discharge point. Even though the flushing flow rate may be high, the energy diffuser will minimize damage from erosion and allow the water to flow towards the discharge point instead of spraying across the street.

If dechlorination is required, such as discharging large amounts of water to the sanitary sewer or as determined by Water Quality based on the receiving water body, dechlorination equipment should be used. The possible two methods for dechlorination of potable water are injecting chlorine neutralizer such as sodium bisulfite or allowing the water to flow past a solid form of dechlorination chemical such as sodium bisulfite or ascorbic acid. A metering pump may inject liquid or the dechlorination equipment may have an eductor and a flow control valve that will suck in the required amount of chemical. Dry chemical tablets may be placed in the flow diffuser, or in porous bags in the gutter. The equipment selected for use by Tucson Water will have directions for the proper application of chemical. Always sample water before it flows into a storm drain inlet to ensure it is fully dechlorinated and remove all equipment, including any porous bags in the gutter.

Flushing Procedures

This section presents a general protocol for performing flushing for a well purge and a general protocol for performing hydrant flushing in other situations (e.g., a customer complaint, or a main break). The section also includes contingencies to consider during flushing and recommended data collection.

The following procedures should be used for each flush. Safety is a key issue when implementing a flushing program. As previously mentioned, while performing a flush, it is important to avoid damage to private property, to allow adequate drainage, and to use traffic control where necessary. In addition, it is important to be aware of creating erosion from the high flow rates and transporting sediment and other debris beyond Tucson Water property boundary and into MS4 permitted areas. It is important to dechlorinate the water, where required, and to ensure that excessive sediment is not discharged into a sensitive area.

Detailed Flushing Procedure for Well Purge

The following procedure should be used for each flush for a well purge:

- Assess the well to be flushed and the area surrounding the tee that will be used to discharge water to determine the safety and sensitivity of the site.
- Locate the tee to be used for discharging from the well purge. Remove the tee cap and install any necessary adaptors. Attach combination flow tester/discharge diffuser on the tee. Also, set up dechlorination, if required.
    - ***Note***: It is important to dechlorinate the discharge before it reaches any sensitive areas, as determined by Water Quality. If flushing discharge flows to a sewer, dechlorination may be required based on quantity, as determined by PCRWRD.
- Flush the well at a low flow rate (about 10 gpm) by slightly opening the valve at the discharge tee. Take total chlorine and turbidity measurements.
    - ***Note***: Verify the direction of the water flow away from the test area. Ensure that water is not causing any damage to neighboring property. Water should also discharge properly into a drain inlet, or other discharge location as previously determined. Check the path of the water and visually inspect the drain inlet for plugging or other obstructions. If water drainage is problematic, do not conduct any further testing. Shut the tee, remove all equipment, and choose another location. If the discharge caused or created movement of soil or debris, request clean-up of the area.
- Follow the flow path all the way to discharge point to make sure there are no issues downstream of the flushing site.
- Once water quality data is recorded, increase the flow rate using the following guide:
    - Approximately 200 gpm for all flushing with adjacent pipe size 6-inch diameter or larger, regardless of pipe type.
    - Approximately 100 gpm for all flushing with adjacent pipe smaller than 6-inch diameter.
    - For transmission lines larger than 12-inch diameter, the flow rate can be increased above 200 gpm, but the flushing velocity should always be kept below 2 fps.
    - ***Note***: flow meter at well should be used to measure flow.
- Purge well until approximately five times the well capacity has been flushed.
- Periodically check the chlorine and turbidity during the flush. Well Maintenance Mechanics should collect and analyze samples at least once every ten minutes. In sensitive areas, increased monitoring may be needed. The optimal frequency will depend on distance to the clean water source, pipe diameter, and the extent to which valving is used to improve process control.
- Continue the flush until the established water quality goals have been met.
- Once the flush is completed, slowly close the valve at the discharge tee. If the valve is closed too quickly, a water hammer (pressure surge) may occur.
- After discharge tee is closed, remove equipment from tee.
- If multiple wells need to be purged, continue to next designated well.

Detailed Procedure for Other Circumstances

The following procedure should be used for each hydrant flush for other situations, such as a main break, customer complaint, or after a known contamination event:

- Assess the hydrant to be flushed and the area surrounding the hydrant to determine the safety and sensitivity of the site. Verify the following information in the field:
  - Hydrant ID number.
  - Street/Address.
  - Other location notes.
  - Hydrant source main size.
  - Map discrepancies (if applicable).
- Locate the hose outlet on the flush hydrant. Remove the outlet cap and install any necessary adaptors. Attach combination flow tester/discharge diffuser on the hydrant. Also, set up dechlorination, if required.
  - ***Note***: It is important to dechlorinate the discharge before it reaches any sensitive areas, as determined by Water Quality. If flushing discharge flows to a sewer, dechlorination may be required based on quantity, as determined by PCRWRD.
- Open hydrant slightly to allow low flow from the hydrant. Take total chlorine measurement.
  - ***Note***: Verify the direction of the water flow away from the test area. Ensure that water is not causing any damage to neighboring property. Water should also discharge properly into a drain inlet, or other discharge location as previously determined. Check the path of the water and visually inspect the drain inlet for plugging or other obstructions. If water drainage is problematic, do not conduct any further testing. Shut off the hydrant, remove all equipment, and choose another hydrant.
- Follow the flow path all the way to discharge point to make sure there are no issues downstream of the flushing site.
- Increase the flow rate by opening hydrant until a reasonable flow for flushing is achieved.
- Periodically check the chlorine during the flush. Utility Technicians should collect and analyze samples at least once every ten minutes. In sensitive areas, increased monitoring may be needed. The optimal frequency will depend on distance to the clean water source, pipe diameter, and the extent to which valving is used to improve process control.
- Flush hydrant until white bucket test indicates water has cleared and chlorine goals have been met. If after 30 minutes, the water quality criteria are still not met, closing valves to isolate pipe and/or using multiple hydrants could be implemented.
- Once the flush is completed, slowly turn off the hydrant. If the hydrant is closed too quickly, a water hammer (pressure surge) may occur.
  - ***Note***: Pressure regulated areas require an even slower shutdown of the hydrant. In pressure regulated areas, shut the hydrant down halfway while monitoring the pressure gauge and let the water flow for 30 to 45 seconds. This allows the distribution system to recover and permits water pressures to level off. Then, partially close the hydrant and again allow the system to recover. After the short wait, shut down the hydrant slowly until fully closed.
- After hydrant is closed, remove equipment from hydrant, and close all nozzle caps.
- If multiple hydrants need to be flushed, continue to next designated hydrant. Continue through each area from the clean water source, moving out by decreasing pipe size

Contingencies

It is important to be prepared for unplanned events prior to commencing the hydrant flushing. Some of the following issues may arise during hydrant flushing:

- Loss of system pressure or water supply to a specific area.

- The hydrant may continue to leak after shut down.
- Customer complaints may arise after flushing a particularly sensitive area.
- Complaints from other government agencies.
- Erosion (review of BMP for water discharge should be done before performing any flushing event).
- Damage to roadways.

If there is a significant loss of pressure during the hydrant flushing, it could be an indication that there are valves in the system that are closed but should not be. Review the system maps to find valves that may be causing the low-pressure issue. Verify that they are open and repeat the flushing procedure.

Once a flush is complete, the operations staff will close the flowing hydrant. If any of these facilities are not functioning properly, i.e. the hydrant continues to leak, a report should be made to repair the equipment.

Customer complaints that could arise during the hydrant flushing include low water pressure, discolored water, odor, damaged laundry, etc. Both the crew working in the field, as well as staff answering the phones at the utility office should be sensitive to these issues and be prepared to answer any questions. Low water pressure will be corrected when the flow tests are complete. Customer water that is discolored or has an odor should be flushed from the plumbing by allowing the water to run until it is clear. A similar process can be used for complaints from other governing agencies.

Using the BMPs for water discharges should help avoid erosion during flushing events. The procedures and recommended equipment outlined in the BMP should be used to avoid erosion during the flushing event, including the use of diffusers and hydrant aprons, but if erosion does occur, repairs may be necessary. If erosion occurs on private property, the property owner should be notified. If erosion occurs in the public right-of-way, the appropriate governing agency should be notified.

If damage to roadway occurs, the appropriate department of transportation should be notified. Traffic control devices and signage should remain in place and a ROW permit should be obtained, as needed.

Note, Tucson Water PIO will manage public notifications for contingencies.

Data Collection

Notes from the flushing activity should be recorded and kept in the system records. Currently, data from the flushing event is documented in a discharge permit in Work Asset Management (WAM). Attachment B (pdf page 31 of 37) includes documentation of the WAM entry process and instructions for filling out the discharge permit form.

The discharge permit requires the date and time of flushing, the flow rates, and the flushing duration be recorded. In addition, the hydrants and valves used, water quality results, and who performed the flushing should be noted.

The NRW/AZPDES Dual Discharge Paper Form, which can be found in Attachment C, must also be completed after a flushing event.

Additional important data should be noted if applicable, including the following:

- Inoperable hydrants.
- Broken valves.
- Low flows.
- Customer complaints.
- Water quality issues.
- Inaccurate GIS data.

Note, all follow-up work from the flushing activity should have a work request created.

References

AWWA Standard G200-09 Distribution Systems Operations and Management.

https://www.michigan.gov/documents/flintwater/SOP431_Conventional_Flushing_for_Water_Turnover_FINAL_613074_7.pdf

TUCSON WATER

BEST MANAGEMENT PRACTICES
AZPDES AREA-WIDE GENERAL PERMIT
AZG-57466

CITY OF TUCSON

TUCSON WATER

2018

Signatory Requirements

In accordance with the ADEQ De Minimus permit guidelines, AZG-57466, Part V., K.2, this Best Management Plan is certified.

"I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. In addition, I certify that the operator will comply with all terms and conditions stipulated in General Permit No. AZG2010-001 issued by the Director."

Albert Avila

Printed Name of Contact

Albert Avila 10/8/2018

Signature Date

Tucson Water, Water Quality Administrator

Business/Agency

Table of Contents

Introduction:

Tucson Water Department of the City of Tucson is the largest municipal and industrial water provider in southeast Arizona, serving over 710,000 people. The Tucson Water Service area encompasses about 325 square miles within a 30 mile radius from downtown Tucson. This document contains a variety of potential Best Management Practices (BMPs) Tucson Water will use for water discharges associated with the operation of a water utility.

Climate:

The Tucson Water service area climate is characterized by hot summers and mild winters. The majority of precipitation occurs from winter rains and during the "monsoon season". The Monsoon season usually begins in July and lasts through early September. The winter storms usually occur between late November through early March. The average rainfall between 1986 and 2015 was about 11.3 inches (NOAA, 2015).

Topography:

The Tucson Water service area lies in the southern Basin and Range geologic province of western North America. It is characterized by elongate and generally northwest-trending narrow mountain ranges separated by broad alluvial valleys. Regional topography is dominated by basin-margin mountains and alluvial fans which have developed along their flanks. These mountains grade into flatland toward the middle of the basins. Tucson Water's service area is within two distinct valleys known as the Tucson Valley and adjacent Avra Valley. Surface runoff from the Tucson Water service area will drain into one of two major watercourses; the Santa Cruz River or the Brawley Wash. Major tributaries of the Santa Cruz River are the Canada del Oro Wash and Rillito Creek. Major tributaries of the Rillito Creek are the Tanque Verde Creek and the Pantano Wash. The Black Wash is the only major tributary of the Brawley Wash within the service area of Tucson Water. All the major tributaries of the Santa Cruz River and Brawley Wash are for the most part ephemeral. The Brawley Wash is also ephemeral. A segment of the Santa Cruz River is considered effluent dependent down gradient from the Pima County Agua Nueva Treatment Facility as defined by A.A.C. R-18-11-113.

Adjacent Land Uses and Downstream Uses

The adjacent land uses and downstream uses are primarily municipal and agricultural. Most De Minimus discharges by Tucson Water will never reach a major tributary, waterway or effluent dependent waterway. In addition most of the discharges are either potable or groundwater and should have minimal impact or potential impact to adjacent land uses or downstream uses.

Potential Flow Paths

Most De Minimus discharges evaporate or percolate on the ground immediately adjacent to the discharge location and may never reach a designated drainage. Other De Minimus discharges are directed to streets or small local drainage channels. In these cases discharges are conveyed to a major tributary via a storm sewer or drainage channel. Discharges in the Tucson Valley usually drain into the Santa Cruz River directly or from one of its tributaries. Discharges in Avra Valley typically drain into the Brawley Wash which eventually drains into the Santa Cruz River. The Santa Cruz River eventually drains into the Gila River which is the nearest downstream perennial/intermittent waterbody located over 75 miles from the nearest upstream De Minimus discharge from Tucson Water.

Best Management Plan

Purpose

The purpose of Best Management Practices (BMPs) for discharges is to minimize pollutants, sediment erosion and/or deposition of sediments resulting from discharge activities. Well purging, pump testing, reservoir and storage tank maintenance, hydrant flushing, water main flushing, and water quality sampling are the most common source activities resulting in discharges by Tucson Water. The following contains a variety of potential BMPs to be used by Tucson Water during AZPDES De Minimis discharge activities. The BMPs that may be employed include but are not limited to: the installation of straw wattles, wetland filter bags, tarpoline covers, geotextile sediment traps, sand bags, de-chlorination equipment, air strippers, and carbon filtration systems. The area supervisors, or other defined on-site supervisors, will have the option of selecting the sediment or contaminant control protocols for the BMP that is appropriate for the project. If the BMPs fail to perform as expected, replacement BMPs or modifications of those installed may be required. The area supervisors, or other defined on-site supervisors, will be responsible for the following:

- Selecting the appropriate BMPs
- Overseeing the installation of the selected BMPs
- Modifications/Replacements if BMPs are not performing as intended.
- Collection of field notes will be maintained for every discharge. Photographic documentation of pre-discharge and post-discharge site conditions in the area of the outfall is required for discharges lasting more than 4 continuous days and/or exceeding 0.50 million gallons in any one day. The photographs shall include areas potentially affected by erosion, streambed scour, or sedimentation resulting from the discharge. Post-discharge photographs shall be taken from the same vantage point(s) as pre-discharge photographs. (DMGP Appendix A, Section 5.)
- Potable water discharges shall have data collected on a routine basis during activities.
- Field notes shall include date and time of discharge, the names of the individuals on site, duration of flow, volume of discharge, average rate of discharge, maximum rate of discharge, visual observations,

sampling equipment, sample results; BMPs or treatment technologies in use and other factors as necessary.

- Collection of additional data if necessary.

Staff shall contact the Water Quality Division for assistance if any of the following conditions are near, or expected to potentially exceed, any of the parameters listed below. The following information may be collected on a daily basis, depending on the type of discharge:

- Oil and grease (visual inspection)
- Turbidity
- Constituent of concern
- Total/Free Residual chlorine
- Chlorine residual at the end of the discharge hose (<1.2ppm) when de-chlorinating
- E. coli if expected to exceed 576 cfu
- pH if expected to fall below 6.5 or above 9.0 NTU
- Methyl tert-butal ether (MTBE) if expected to occur above 20 ug/L
- Other constituents which may be present.

Responsible Personnel

Supervisors, or other defined on-site supervisors, will be responsible for ensuring all documentation of the discharge is collected and reported in the Tucson Water Maintenance Management Database (WAM). They are also responsible for ensuring the above mentioned BMPs are adhered to. These records will be maintained in accordance with the General Permit time frames.

ADEQ Reporting

In accordance with the requirements under the Areawide authorization (per DMGP Appendix A, Section B.1.b): For discharges lasting more than four continuous days or exceeding 0.5 million gallons in any one day, and conducted prior to January 1, 2018, documentation and results of all monitoring required by the DMGP must be submitted as required by ADEQ no later than February 28, 2018.

Sediment and Erosion Control

To reduce the amount of erosion, discharges should be directed to hard flat stable surfaces whenever possible such as pavement or concrete. Areas where high velocity and volume discharges could result in erosion the following specific BMPs should be utilized to reduce erosion, turbidity and sedimentation.

Straw Wattles

Manufactured from rice straw and wrapped in tubular plastic netting.

Common wattle types are 9 inches in diameter and 25 feet long and weigh 35 pounds. Wattles may be purchased in a variety of sizes. Wattles shall be placed on contour and staked with 18 or 24-inch stakes at 4 foot intervals from center. The ends will overlap each other. For discharges at a well head, wattles shall be placed at the end of the discharge lay flat to prevent soil from migrating off site.

Images from http://www.strawwattles.com/gallery.html on 9/22/2005

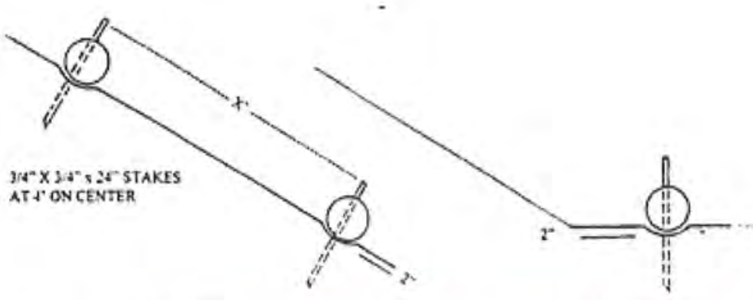


Image taken from http://www.strawwattles.com/graphics/drawing.jpg on 9/22/2005

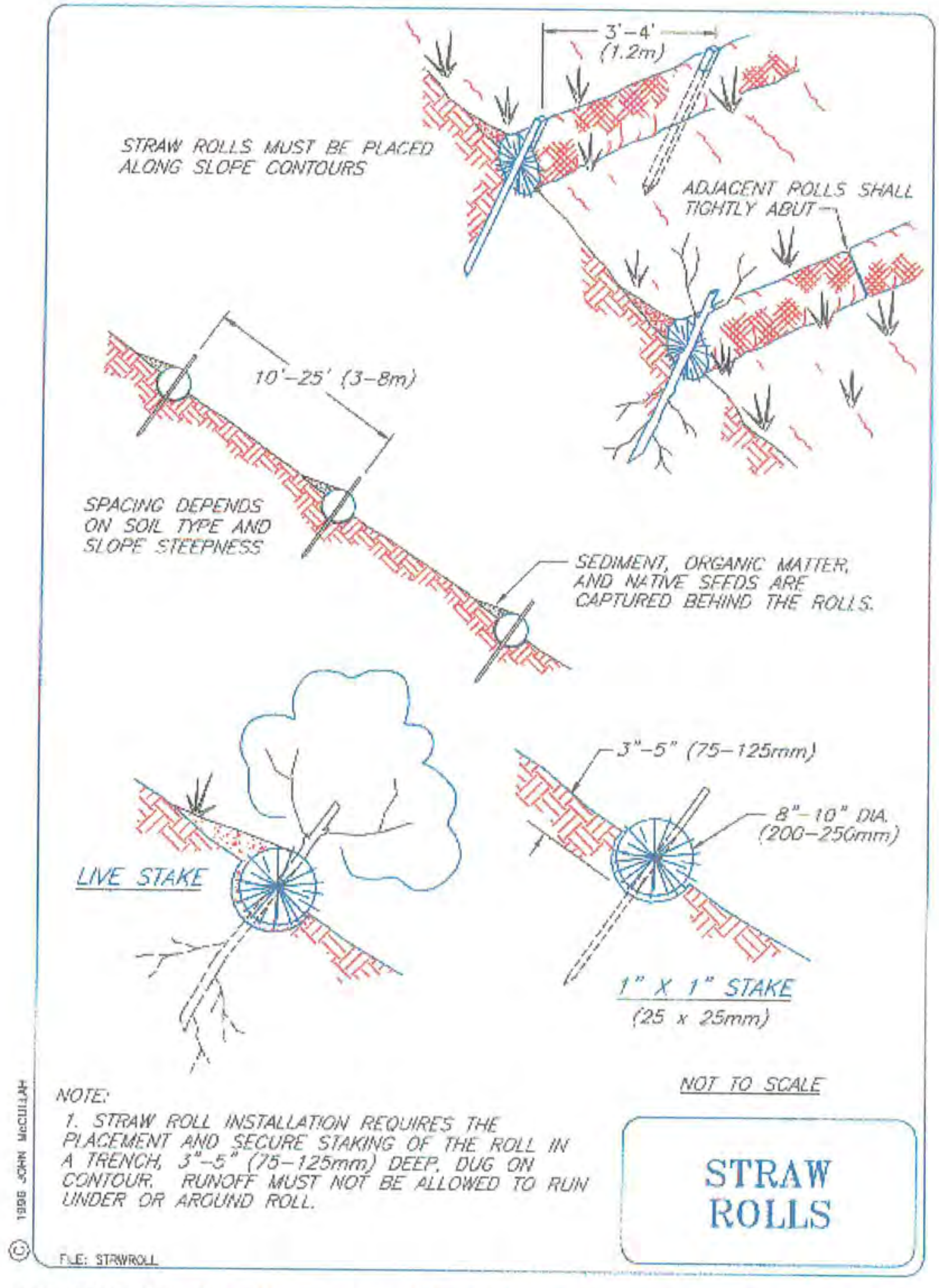


Image taken from http://www.strawwattles.com/erosiondraw/STRWROLL.GIF on 9/22/2005

Straw Wattles and the discharge lay flat at the 36 inch main dewatering.

Reservoir out fall with absorbent socks. Installed to perform similar to straw wattles to capture any oil sheen.
Image from Andy Vanover, Tucson Water (January 2008)

Wetland Filter Bags

Bags are used to contain sand, silt, and fines.

Installation requires a cut in the corner of the bag, inserting the pump discharge hose and firmly clamping the hose to the bag. Filter bags can handle up to an 8 inch discharge hose. The bags discharge capacity should not exceed 1,600 gallons per minute.

After completion of work slit the bag, remove sediment and smoothly grade into the existing topography. Store the bag for future reuse or dispose of at a suitable disposal site.

Image taken from http://www.jmdcompany.com/Enviro-Protection Bag.htm on 9/22/2005

Tarpoline

Tarpoline is used to protect part of the wash at the piping outfall when no overland flow will occur. This will assist in minimizing the turbidity of the flow as it exits the discharge piping. Flow will be allowed to travel the ephemeral wash.

Geotextile Sediment Trap

Geotextile Sediment Trap is used to capture sediment from discharge flows.

The containment system should provide sufficient volume for capturing sediment and still be able to drain. It consists of a framework which supports a geotextile filter fabric or filter bag placed on top of the framework.

Sediment collected in the trap is removed and disposed of properly and the filter bag is then ready for reuse.

Image from Chuck Faas Tucson Water on 10/05/2005

Other Pollutants

Other common potential pollutants from Tucson Water discharges include chlorine and Volatile Organic Compounds (VOC's). See Appendix A.

Chlorine

Sodium Hypochlorite (NaOCl) is used for disinfection purposes. On average 50-100 ppm is the typical level of NaOCl in water used for the disinfection of wells, pipelines, reservoirs and storage tanks. Most water distribution maintenance activities do not involve disinfection so the NaOCl concentrations are at normal potable levels, averaging between 08-1.2 ppm. Some De Minimus discharges by Tucson Water will never reach a major tributary, waterway or effluent dependent waterway.

For discharges of super chlorinated water (> 4 ppm), Tucson Water retains water on-site or uses a method to de-chlorinate the water before it enters the environment. Test strips are used to confirm the de-chlorination method is successful.

The preferred method of de-chlorination for concentrations below 200 ppm utilizes ascorbic acid and has proven to be safe and effective. The preferred method of de-chlorination for concentrations above 200 ppm is Sodium BiSulfite.

Romac Venturi Device to feed ascorbic acid for de-chlorination. (0-200 ppm)

De Chlorinator used with 3" Ascorbic Acid Tablets
Image from David Marquez , Tucson Water.

Two Venturi Manifold for flows greater than 1800 GPM – CA-009A De Chlorination
Image from Andrew Vanover , Tucson Water.

Sodium Bisulfite is used to de-chlorinate discharges over 200 ppm
Image from Laura Macklin, Tucson Water.

VOC's

VOC's are present in some of the water production and monitor wells that Tucson Water operates. When discharges from wells with known or expected VOC's are near or above the Maximum Contaminate Limit (MCL) for potable water, the following specific BMPs should be utilized to eliminate or reduce the amount of VOC's to below the MCL.

Air Stripper

Image from Chuck Faas Tucson Water on 02/02/2001

Air strippers are used to remove VOC's from water by aerating the water as it drains and is dispersed through the structure. Air strippers should be considered when VOC's are known or expected to be present in discharge waters.

Advantages over a carbon filtration system include its ability to handle much higher discharge rates than a carbon filtration system and cost effectiveness for high volume discharges.

Carbon Filtration System

Carbon filtration systems are used to remove VOCs from water through adsorption from contaminated water. Carbon filtration systems should be considered when VOC's are known or expected to be present in discharge waters.

Carbon filtration systems are ideal for low discharge rates and volumes.

Advantages over an air stripper system include its maneuverability and ease of transport.

Image from Chuck Faas Tucson Water 2012

Spill Prevention and Contaminate Reduction

Most spills can be prevented if material handling practice controls are followed and enforced. Frequent inspection and monitoring of potential sources of contamination should be performed on a routine basis. In the event of a small spill, the City of Tucson Small Spill Response Management Plan should be followed. In the event of large spill 911 is called.

With effective BMPs, contaminates can be reduced or removed from discharges. Where pre-existing contamination exists, measures will be taken to prevent further spreading of contaminates from discharge activities.

References and Additional Information

National Oceanic and Atmospheric Administration, (2015) web page.

http://www.franklin-gov.com/engineering/STORMWATER/tcp.htm
http://www.abe.msstate.edu/csd/p-dm/chapter3.html
http://www.azdeq.gov/environ/water/permits/azpdes.html
http://www.epa.gov/OST/stormwater/
http://www.mtas.utk.edu/bmptoolkit.htm

WAM Entry Process

Planner Scheduler

Add when requesting a WO or SR	Add to WO or SR when in "Active" status	Create a stand alone permit and associate with WO or SR

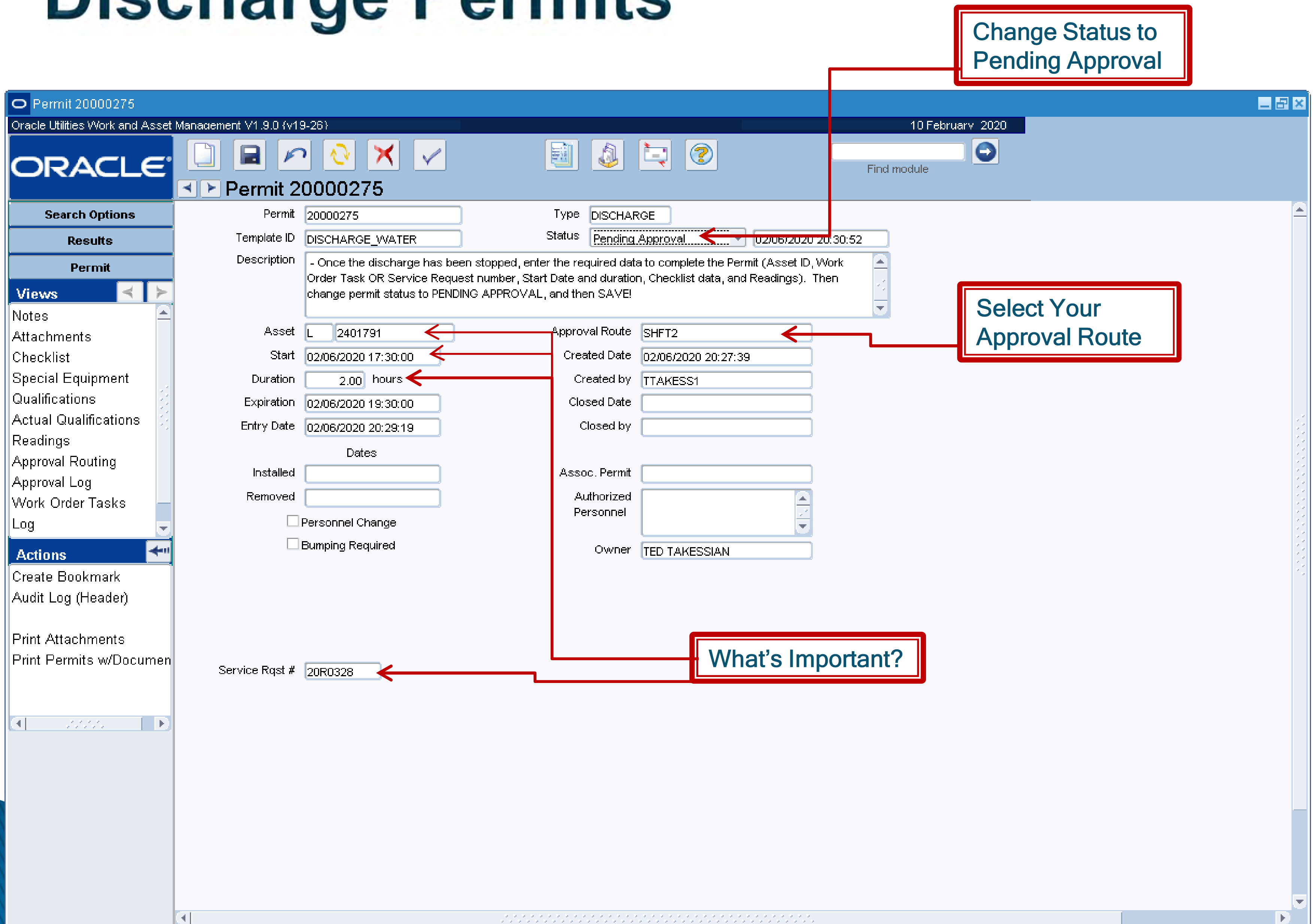
Assigned crew responsible for entering data into WAM

Place in "Pending Approval" status

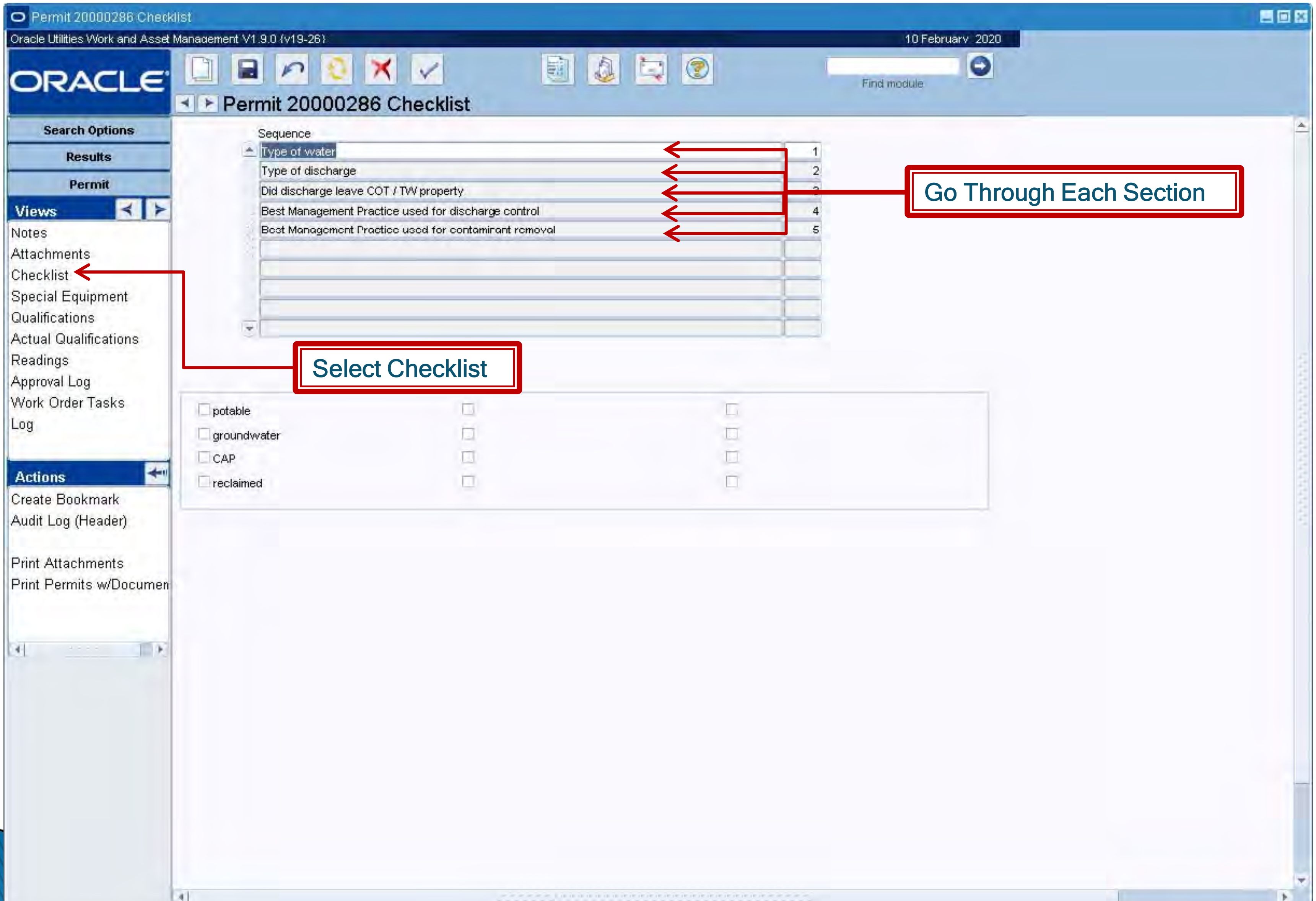
Supervisor Approves Permit or TW_D_PRMT

Planner Scheduler or TW_D_PRMT closes out completed permit with completed WO or SR

Discharge Permits

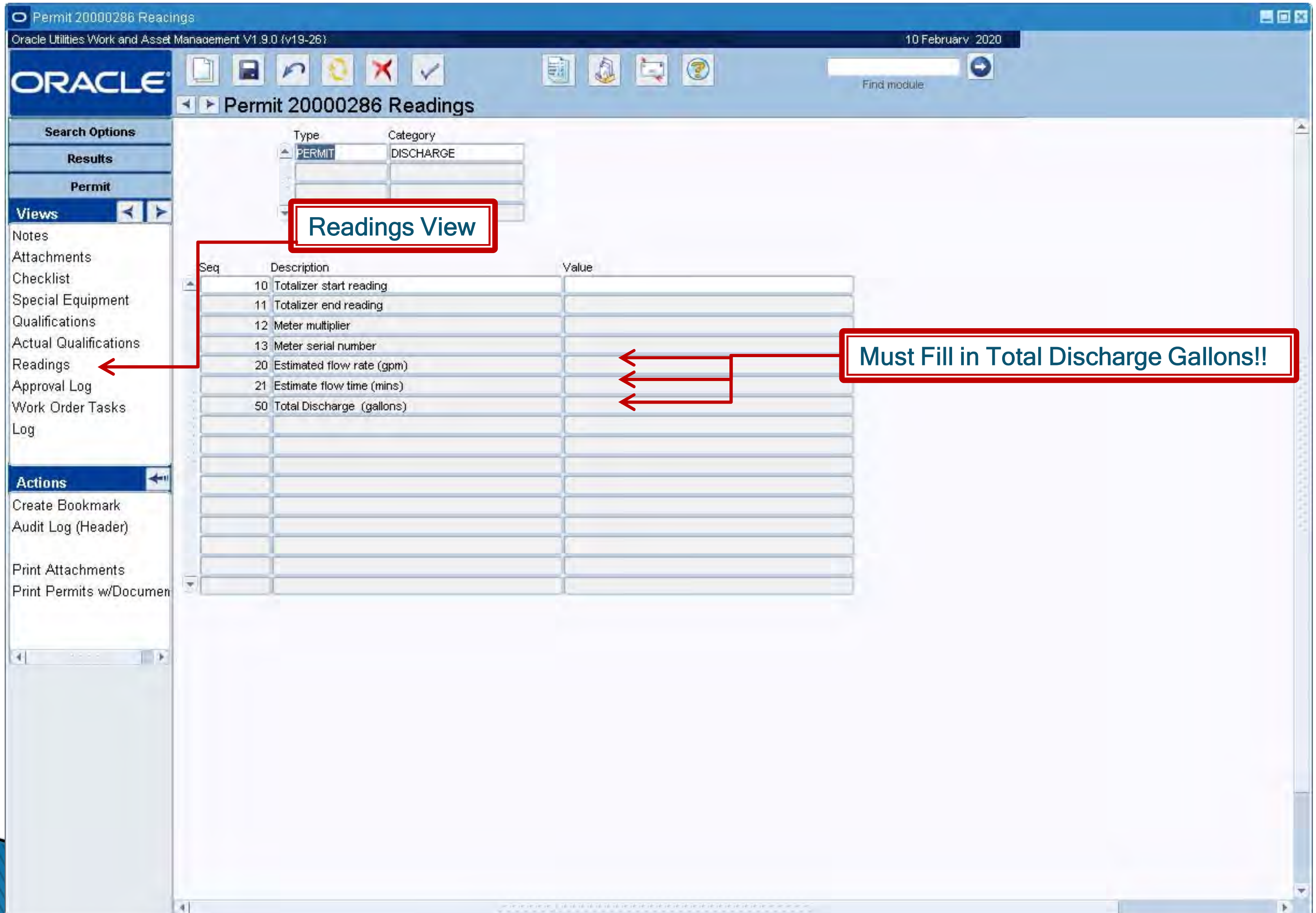


Checklist



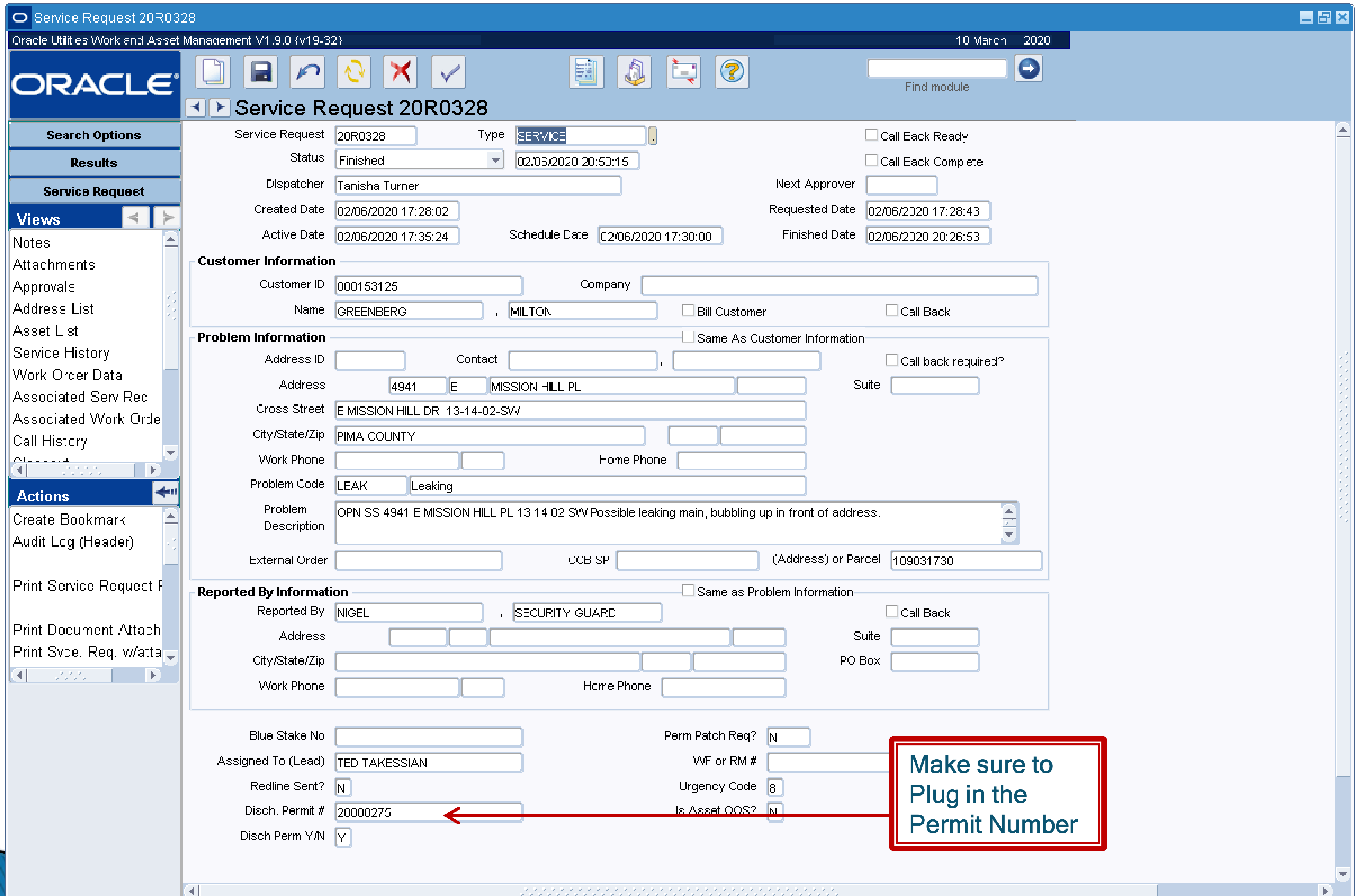
Permit 20000286 Checklist
Oracle Utilities Work and Asset Management V1.9.0 (v19-26)
10 February 2020
Find module
Permit 20000286 Checklist
Search Options
Results
Permit
Views
Notes
Attachments
Checklist
Special Equipment
Qualifications
Actual Qualifications
Readings
Approval Log
Work Order Tasks
Log
Actions
Create Bookmark
Audit Log (Header)
Print Attachments
Print Permits w/Documen
Sequence
Type of water 1
Type of discharge 2
Did discharge leave COT / TW property
Best Management Practice used for discharge control 4
Best Management Practice used for contaminant removal 5
Go Through Each Section
Select Checklist
potable
groundwater
CAP
reclaimed

Readings



Permit 20000286 Readings
Oracle Utilities Work and Asset Management V1.9.0 (v19-26)
10 February 2020
ORACLE
Find module
Permit 20000286 Readings
Search Options
Results
Permit
Views
Notes
Attachments
Checklist
Special Equipment
Qualifications
Actual Qualifications
Readings
Approval Log
Work Order Tasks
Log
Actions
Create Bookmark
Audit Log (Header)
Print Attachments
Print Permits w/Documen
Type
Category
PERMIT
DISCHARGE
Readings View
Seq
Description
Value
10 Totalizer start reading
11 Totalizer end reading
12 Meter multiplier
13 Meter serial number
20 Estimated flow rate (gpm)
21 Estimate flow time (mins)
50 Total Discharge (gallons)
Must Fill in Total Discharge Gallons!!

Service Request - Discharge Permits



NRW/AZPDES Dual Discharge Paper Form

NRW or AZPDES DISCHARGE FORM

Provide text and/or ✔ applicable boxes

1. LOCATION **Asset ID, WO# or SR#** ______________________________

Location Description: ____

____

2. TYPE OF WATER

- ☐ potable
- ☐ groundwater/well purging
- ☐ CAP

3. TYPE OF DISCHARGE

- ☐ fire hydrant / fire service
- ☐ well
- ☐ reservoir
- ☐ booster(s)
- ☐ PRV
- ☐ tank, hydro-tank
- ☐ water quality sampling
- ☐ curbstop / meter
- ☐ line break
- ☐ other (description) ____________

4. DATE / TIME of DISCHARGE ____/____/20__ **Time:** ____________

5. Did the discharge leave COT/Tucson Water property? ☐ YES ☐ NO

6. VOLUME of DISCHARGE *Use any of these 3 options to give a Total Discharge*

Totalizer start ________ end ________ Estimated flowrate ________ gpm

Total Discharge:

Meter multiplier ____________ and time ________ min ____________ gallons

Meter serial number ____________

(continue on reverse side)

NRW/AZPDES Dual Discharge Form

7. Best Management Practice (BMP) used:

☐ street / hard surface ☐ straw wattles ☐ filter bags ☐ woven sack / tarpoline

☐ geotextile sediment trap ☐ straw bale / check dam ☐ other ______________________

8. Contaminant removal BMP (if necessary):

☐ air stripper ☐ carbon filtration ☐ dechlorination

☐ other __________________________

9. Description of activity – time and comment (include samples taken and field measurements)

____

____

____

10. On-Site Supervisor

Name ________________________________ **Date:** __/___ / _____

____

OFFICE USE: Input Date ______________________________ Initials: ______________________

Appendix E

TUCSON WATER SENTRY PROGRAM RESULTS

CONTAMINANTS OF EMERGING CONCERN SENTRY PROGRAM

March 22, 2021

2020 RESULTS SUMMARY

Tucson Water Quality and Operations Division ● P.O. Box 27210 ● Tucson, AZ 85726

CONTAMINANTS OF EMERGING CONCERN SENTRY PROGRAM

2020 RESULTS SUMMARY

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1.0 EXECUTIVE SUMMARY

Recent scientific research has indicated that exposure to contaminants of emerging concern (CECs) may pose risks to human health. To respond to these potential health concerns, Tucson Water established the "Sentry Program" in 2008 under the direction of the City Manager. The Sentry Program has detected trace levels of CECs in the drinking water system and Tucson Water has been tracking the annual sampling results to proactively identify and address potential CECs contamination issues. The Sentry Program is a proactive, voluntary monitoring component of the routine water quality management program. Results of the 2020 Sentry Program are summarized in this report and are largely consistent with historical CECs data.

Tucson Water has expanded its Sentry Program to keep its water supplies safe and protect public health. The following Sentry Program enhancements were implemented:

- Expanded the CECs investigation by increasing the number of both potable and nonpotable from 9 to 18 sampling locations.
- Accelerated CECs data collection by increasing the sampling frequency from an annual to a semi-annual basis; sampling performed in the months of June-July and December 2020.
- Collaborated with other local water utilities, stakeholders, and partners to set priorities, direct resource uses, and develop projects, programs, and policies concerning CECs issues.
- Shared information on the City of Tucson Internet to improve our Sentry Program and maintain our reputation as a trusted source of drinking water.

2.0 BACKGROUND

CECs can best be described as newly identified or emerging manufactured or naturally occurring compounds that may have lacked public health impact data or may not have an applicable regulatory maximum contaminant level (MCL) or health advisory (HA) established for drinking water by federal and state regulatory agencies. The lack of regulatory drinking water standards is driven by a cumbersome regulatory rule making process and critical research gaps in toxicity information associated with individual CECs, mixtures of CECs, and cumulative exposure over time. Typically, CECs are categorized by their type and source, and the most common categories are fire retardants and other per- and polyfluoroalkyl substances (PFAS), industrial chemicals, personal care products, pesticides, and pharmaceuticals. State-of-the-art advances in analytical technologies and instrumentation have made it possible to identify trace concentrations of CECs measured in parts per trillion (ppt). A list of all 114 CECs analyzed under the 2020 Sentry Program is provided (**Table 1**).

3.0 SAMPLING SITES

As part of the 2020 Sentry Program, water samples were collected at single entry points to the distribution system (EPDS) representing native groundwater wells and at combined entry points to the distribution system (CEPDS) that represent combined groundwater well flows from blended groundwater sources. Water samples were collected in June-July and December 2020 from a total of 18 sample locations as follows (**Figure 1**).

Samples were collected at four EPDS sampling sites located at native groundwater wells located in close proximity to the Santa Cruz River, downstream of Pima County's Agua Nueva Water Reclamation and Tres Rios Water Reclamation facilities. These four samples represent drinking water wells impacted by treated wastewater.

1. EPDS 109 (Z-013A) represents an out of service potable well – inactive
2. EPDS 166 (Y-001B) represents an out of service potable well – inactive
3. EPDS 160 (Y-004A) represents a standby emergency use only potable well
4. EPDS 232 (W-001C) represents an active potable well

Samples were collected at four CEPDS sampling sites comprised of combined flow of groundwater wells that represent the blended drinking water supply entering the distribution system at different locations.

5. CEPDS 124 (167R) represents the Southern Avra Valley Storage and Recovery Project (SAVSARP) wellfield
6. CEPDS 125 (310) represents the Santa Cruz wellfield
7. CEPDS 159 (EP1) represents the Central Avra Valley Storage and Recovery Project (CAVSARP) and SAVSARP wellfields
8. CEPDS 171 (198R) represents the Tucson Airport Remediation Project/Advanced Oxidation Process (TARP/AOP) Water Treatment Plant wellfield

Samples were collected at four EPDS and one reservoir sampling sites that represent the drinking water supply entering the distribution system at different locations.

9. EPDS 013 (A-055A) represents a standby emergency use only potable well
10. EPDS 054 (C-046B) represents an active potable well
11. EPDS 147 (B-110A) represents an active potable well
12. EPDS 245 (F-006A) represents an active potable well
13. Escalante Reservoir (EP21) represents an active potable reservoir

Samples were collected at two locations at the Tucson Airport Remediation Project/Advanced Oxidation Process (TARP/AOP) Water Treatment Plant. Tucson Water's AOP Water Treatment Facility uses state-of-the-art technology to effectively remove trichloroethylene (TCE), 1,4-dioxane, and PFAS from water.

The facility operates in conjunction with the adjacent TARP facility to produce up to seven million gallons of purified water a day. The two samples represent groundwater before and after treatment prior to entering the distribution system.

14. TA-030A (influent) represents untreated groundwater collected at the influent booster station
15. TP-021T (effluent) represents treated groundwater collected after the granular activated carbon (GAC) vessels prior to the packed column aeration system

Tucson Water uses some of its recycled water to produce reclaimed water, which is specially treated for applications such as irrigation, dust control, firefighting, and industrial uses. Reclaimed water is not treated for use in drinking or bathing. Three samples were collected at locations that represent reclaimed water before and after treatment prior to entering the Sweetwater wetlands and/or the reclaimed water distribution system.

16. 510 (influent) represents untreated reclaimed water
17. 522 (effluent) represents treated reclaimed water
18. EW-007A (influent) represents untreated groundwater from an extraction well

4.0 DETECTED CECs

Trace levels of CECs were detected in all 36 samples collected in the June-July and December 2020 sampling events (**Table 2**).

- Within active wells serving Tucson Water customers, all 2020 trace detections were well below any established health-based MCLs or HAs, if applicable **(Table 2 - Potable)**.
- Within water sources not serving Tucson Water customers, 2020 trace detections were above the HA of 0.35 part per billion (ppb) for 1,4-dioxane at the following sample locations: 510, 522, EW-007A, TA-030A, Y-001B, Y-004A, and Z-013A **(Table 2 - Nonpotable)**.
- Within water sources not serving Tucson Water customers, 2020 trace detections were above the HA of 70 ppt for PFOS and PFOA at the following sample locations: 522, EW-007A, TA-030A, Y-001B, Y-004A, and Z-013A **(Table 2 - Nonpotable)**.

The types of CECs and concentrations detected in the 2020 Sentry Program were generally consistent with historical data, with no CECs showing discernable trends.

5.0 REGULATORY OUTLOOK

Tucson Water takes seriously the detection of CECs in its drinking water. However, it is important to put their presence into context. The EPA has not determined whether standards are necessary for many CECs. EPA uses the Unregulated Contaminant Monitoring Rule (UCMR) to collect data for contaminants that are suspected to be present in drinking water and do not have health-based standards set under the Safe Drinking Water Act (SDWA). The UCMR program was developed in coordination with the Contaminant Candidate List (CCL). The CCL is a list of contaminants that:

- Are not regulated by the National Primary Drinking Water Regulations
- Are known or anticipated to occur at public water systems
- May warrant regulation under the SDWA

Tucson Water completed the fourth Unregulated Contaminant Monitoring Rule (UCMR4) sampling in 2020 and some of the Sentry Program CECs are listed on the UCMR4 CCL. The UCMR program provides a basis for future EPA regulatory actions to protect public health. The previous and current UCMR CCL results are being and will be reviewed by EPA. Depending on the outcome of the EPA review, some of the Sentry Program CECs may or may not be considered for regulation in the future. On February 14, 2019, EPA announced a Nationwide PFAS Action Plan and stated plans to move ahead with establishing an MCL for PFOS and PFOA, two of the most well-known and prevalent PFAS chemicals. In March 2020, EPA proposed a positive determination for PFOA and PFOS and released a pre-publication version of the final determination on January 19, 2021. This 2021 notice indicates the EPA will be initiating evaluation of regulations for PFOA and PFOS only.

6.0 CONTINUED ACTION PLAN

As previously stated, Tucson Water will continue to enhance the Sentry Program. CECs monitoring frequency is currently performed twice per year at total of 18 selected sampling locations. These semi-annual sampling events will continue to be conducted in the summer months and then repeated in the winter months. Both potable and nonpotable sample locations will continue to be sampled in 2021. In addition, Tucson Water plans to actively engage local utilities and other key partners in investigation programs that focus on monitoring and treatment of CECs and any potential health impacts that may be associated with the presence of these contaminants in source water and drinking water.

Figure 1. CECs Sentry Program Sampling Plan - 2020

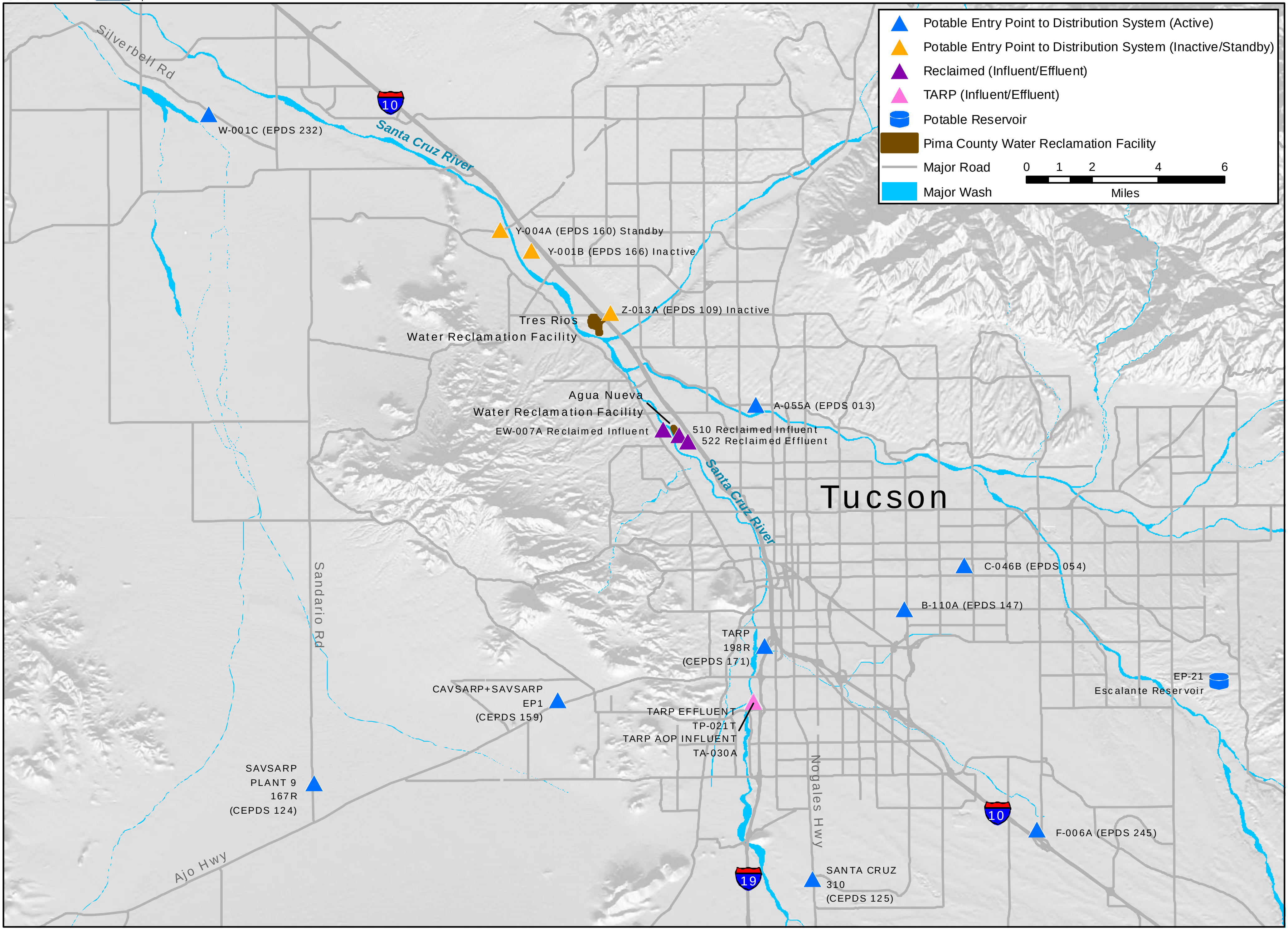

TABLE 1. 2020 SENTRY PROGRAM - CECs ANALYZED

No.	Contaminant of Emerging Concern (CEC) Parameter Name	General Category
1	N-ETHYL PERFLUOROOCTANESULFONAMIDOACETIC	Fire Retardant and Other PFAS
2	N-METHYL PERFLUOROOCTANESULFONAMIDOACETIC	
3	PERFLUORO OCTANESULFONIC ACID - PFOS	
4	PERFLUORO OCTANOIC ACID - PFOA	
5	PERFLUORO-1-BUTANESULFONIC ACID - PFBS	
6	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS	
7	PERFLUORODODECANOIC ACID	
8	PERFLUOROHEPTANOIC ACID - PFHpA	
9	PERFLUORO-N-DECANOIC ACID	
10	PERFLUORO-N-HEXANOIC ACID	
11	PERFLUORO-N-NONANOIC ACID - PFNA	
12	PERFLUOROTETRADECANOIC ACID	
13	PERFLUOROTRIDECANOIC ACID	
14	PERFLUOROUNDECANOIC ACID	
15	ACESULFAME-K	Food Additive
16	SUCRALOSE	
17	1,4-DIOXANE	Industrial Chemical
18	4-TERT-OCTYLPHENOL	
19	BIS PHENOL A (BPA)	
20	CHROMIUM, HEXAVALENT	
21	QUINOLINE	
22	TCEP	
23	TCPP	
24	TDCPP	
25	BUTYLPARABEN	Personal Care Product
26	ETHYLPARABEN	
27	ISOBUTYLPARABEN	
28	PROPYLPARABEN	
29	TRICLOSAN	
30	2,4-D	Pesticide
31	4-NONYLPHENOL	
32	ATRAZINE	
33	BROMACIL	
34	CHLORIDAZON	
35	CHLOROTOLURON	
36	CLOFIBRIC ACID	
37	CYANAZINE	
38	DACT	
39	DEA	
40	DEET	
41	DIA	
42	DIURON	
43	ISOPROTURON	
44	LINURON	
45	METAZACHLOR	
46	METOLACHLOR	
47	PROPAZINE	
48	SIMAZINE	
49	SULFOMETURON METHYL	
50	THIABENDAZOLE	
51	ACETAMINOPHEN	
52	ALBUTEROL	

TABLE 1. 2020 SENTRY PROGRAM - CECs ANALYZED

No.	Contaminant of Emerging Concern (CEC) Parameter Name	General Category
53	AMOXICILLIN	Pharmaceutical
54	ANDROSTENEDIONE	
55	ATENOLOL	
56	BENDROFLUMETHIAZIDE	
57	BEZAFIBRATE	
58	BUTALBITAL	
59	CAFFEINE	
60	CARBADOX	
61	CARBAMAZEPINE	
62	CARISOPRODOL	
63	CHLORAMPHENICOL	
64	CIMETIDINE	
65	DIAZEPAM	
66	DICLOFENAC	
67	DILANTIN	
68	DILTIAZEM	
69	ERYTHROMYCIN	
70	ESTRADIOL	
71	ESTRIOL	
72	ESTRONE	
73	ETHINYL ESTRADIOL-17 ALPHA	
74	FLUMEQUINE	
75	FLUOXETINE	
76	GEMFIBROZIL	
77	IBUPROFEN	
78	IOHEXAL	
79	IOPROMIDE	
80	KETOPROFEN	
81	KETOROLAC	
82	LIDOCAINE	
83	LINCOMYCIN	
84	LOPRESSOR	
85	MECLOFENAMIC ACID	
86	MEPROBAMATE	
87	METFORMIN	
88	METHYLPARABEN	
89	NAPROXEN	
90	NIFEDIPINE	
91	NORETHISTERONE	
92	OXOLINIC ACID	
93	PENTOXIFYLLINE	
94	PHENAZONE	
95	PRIMIDONE	
96	PROGESTERONE	
97	SALICYLIC ACID	
98	SULFACHLOROPYRIDAZINE	
99	SULFADIAZINE	
100	SULFADIMETHOXINE	
101	SULFAMERAZINE	
102	SULFAMETHAZINE	
103	SULFAMETHIZOLE	
104	SULFAMETHOXAZOLE	
105	SULFATHIAZOLE	

TABLE 1. 2020 SENTRY PROGRAM - CECs ANALYZED

No.	Contaminant of Emerging Concern (CEC) Parameter Name	General Category
106	TESTOSTERONE	
107	THEOBROMINE	
108	THEOPHYLLINE	
109	TRICLOCARBAN	
110	TRIMETHOPRIM	
111	WARFARIN	
112	1,7-DIMETHYLXANTHINE	**Pharmaceutical (Metabolite of Caffeine)**
113	COTININE	**Pharmaceutical (Metabolite of Nicotine)**
114	DEHYDRONIFEDIPINE	**Pharmaceutical (Metabolite of Nifedipene)**

Acronym/Abbreviations:
PFAS = Perfluorinated alkylated substances

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
POTABLE						
310	12/28/2020	1,7-DIMETHYLXANTHINE		8.3	5	ppt
310	7/6/2020	ACESULFAME-K		20	20	ppt
310	12/28/2020	CAFFEINE		20	10	ppt
310	7/6/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.29	0.02	ppb
310	12/28/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.46	0.02	ppb
310	12/28/2020	METHYLPARABEN		67	20	ppt
310	12/28/2020	PROPYLPARABEN		35	5	ppt
167R	6/29/2020	ACESULFAME-K		65	20	ppt
167R	12/28/2020	ACESULFAME-K		21	20	ppt
167R	12/28/2020	CAFFEINE		16	10	ppt
167R	6/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.72	0.02	ppb
167R	12/28/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.53	0.02	ppb
167R	12/28/2020	METHYLPARABEN		31	20	ppt
167R	12/28/2020	PROPYLPARABEN		19	5	ppt
167R	6/29/2020	SUCRALOSE		190	100	ppt
167R	12/28/2020	SUCRALOSE		130	100	ppt
198R	6/30/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	2.6	0.02	ppb
198R	12/24/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	2.6	0.02	ppb
198R	6/30/2020	PERFLUORO-N-HEXANOIC ACID		3	2	ppt
B-110A	6/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	7	0.02	ppb
B-110A	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	7	0.02	ppb
C-046B	6/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.084	0.02	ppb
C-046B	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.13	0.02	ppb
C-046B	12/18/2020	PROPYLPARABEN		7.3	5	ppt
EP1	12/29/2020	4-NONYLPHENOL		520	400	ppt
EP1	6/29/2020	ACESULFAME-K		100	20	ppt
EP1	6/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.49	0.02	ppb
EP1	12/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.42	0.02	ppb
EP21	6/30/2020	ACESULFAME-K		27	20	ppt
EP21	12/29/2020	ACESULFAME-K		28	20	ppt
EP21	6/30/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.46	0.02	ppb
EP21	12/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.42	0.02	ppb
EP21	6/30/2020	DEET		11	10	ppt
F-006A	12/29/2020	CAFFEINE		140	10	ppt
F-006A	6/30/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.47	0.02	ppb
F-006A	12/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.4	0.02	ppb
F-006A	7/28/2020	METHYLPARABEN		220	20	ppt
F-006A	7/28/2020	PROPYLPARABEN		150	5	ppt
F-006A	7/28/2020	SALICYLIC ACID		270	200	ppt
TP-021T	6/30/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	3.5	0.02	ppb
TP-021T	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	3.3	0.02	ppb
TP-021T	12/18/2020	ERYTHROMYCIN		20	10	ppt
TP-021T	6/30/2020	PERFLUORO-N-HEXANOIC ACID		4.7	2	ppt
TP-021T	12/18/2020	PROPYLPARABEN		7.3	5	ppt
W-001C	12/18/2020	1,4-DIOXANE	HA 0.35	0.13	0.1	ppb
W-001C	6/29/2020	ACESULFAME-K		48	20	ppt
W-001C	12/18/2020	ACESULFAME-K		640	200	ppt
W-001C	6/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.13	0.02	ppb
W-001C	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.1	0.02	ppb
W-001C	6/29/2020	DACT		72	20	ppt

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
W-001C	12/18/2020	DACT		29	20	ppt
W-001C	6/29/2020	DIA		12	5	ppt
W-001C	12/18/2020	DIA		8.5	5	ppt
W-001C	6/29/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	2.8	2	ppt
W-001C	12/18/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	2.38	2	ppt
W-001C	12/18/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		2.1	2	ppt
W-001C	12/18/2020	PRIMIDONE		9	5	ppt
W-001C	6/29/2020	PROPYLPARABEN		6.4	5	ppt
W-001C	12/18/2020	PROPYLPARABEN		13	5	ppt
W-001C	6/29/2020	SIMAZINE	MCL 4,000	9.7	5	ppt
W-001C	12/18/2020	SIMAZINE	MCL 4,000	9.4	5	ppt
NONPOTABLE						
510	7/2/2020	1,4-DIOXANE	HA 0.35	**0.64**	0.1	ppb
510	12/23/2020	1,4-DIOXANE	HA 0.35	**0.77**	0.1	ppb
510	7/2/2020	1,7-DIMETHYLXANTHINE		22	5	ppt
510	12/23/2020	1,7-DIMETHYLXANTHINE		43	5	ppt
510	7/2/2020	4-NONYLPHENOL		2,600	400	ppt
510	12/23/2020	4-NONYLPHENOL		1,500	400	ppt
510	7/2/2020	4-TERT-OCTYLPHENOL		91	25	ppt
510	12/23/2020	4-TERT-OCTYLPHENOL		92	25	ppt
510	7/2/2020	ACESULFAME-K		78	20	ppt
510	7/2/2020	ALBUTEROL		10	5	ppt
510	7/2/2020	ATENOLOL		270	5	ppt
510	12/23/2020	ATENOLOL		240	5	ppt
510	7/2/2020	BEZAFIBRATE		5.4	5	ppt
510	7/2/2020	BUTALBITAL		69	10	ppt
510	12/23/2020	BUTALBITAL		79	10	ppt
510	7/2/2020	CARBAMAZEPINE		360	50	ppt
510	12/23/2020	CARBAMAZEPINE		270	5	ppt
510	7/2/2020	CARISOPRODOL		19	5	ppt
510	12/23/2020	CARISOPRODOL		20	5	ppt
510	7/2/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.023	0.02	ppb
510	12/23/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.064	0.02	ppb
510	7/2/2020	COTININE		37	10	ppt
510	12/23/2020	COTININE		36	10	ppt
510	7/2/2020	DEET		53	10	ppt
510	12/23/2020	DEET		58	10	ppt
510	12/23/2020	DEHYDRONIFEDIPINE		5	5	ppt
510	7/2/2020	DIA		11	5	ppt
510	7/2/2020	DICLOFENAC		590	125	ppt
510	12/23/2020	DICLOFENAC		250	5	ppt
510	7/2/2020	DILANTIN		65	20	ppt
510	12/23/2020	DILANTIN		81	20	ppt
510	7/2/2020	DILTIAZEM		110	5	ppt
510	12/23/2020	DILTIAZEM		100	50	ppt
510	7/2/2020	DIURON		89	5	ppt
510	12/23/2020	DIURON		1,200	50	ppt
510	7/2/2020	ERYTHROMYCIN		22	10	ppt
510	12/23/2020	ERYTHROMYCIN		240	10	ppt
510	7/2/2020	ESTRONE		13	10	ppt
510	12/23/2020	ESTRONE		31	10	ppt
510	7/2/2020	FLUOXETINE		86	10	ppt
510	7/2/2020	GEMFIBROZIL		46	5	ppt

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
510	12/23/2020	GEMFIBROZIL		26	5	ppt
510	7/2/2020	IOHEXOL		3,600	500	ppt
510	12/23/2020	IOHEXOL		15,000	2000	ppt
510	12/23/2020	IOPROMIDE		16	10	ppt
510	7/2/2020	KETOROLAC		7.9	5	ppt
510	7/2/2020	LIDOCAINE		1,600	50	ppt
510	12/23/2020	LIDOCAINE		1,200	50	ppt
510	7/2/2020	LOPRESSOR		330	20	ppt
510	12/23/2020	LOPRESSOR		1,000	20	ppt
510	7/2/2020	MEPROBAMATE		68	5	ppt
510	12/23/2020	MEPROBAMATE		73	5	ppt
510	7/2/2020	NAPROXEN		72	20	ppt
510	12/23/2020	NAPROXEN		31	20	ppt
510	7/2/2020	OXOLINIC ACID		12	10	ppt
510	7/2/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	3	2	ppt
510	12/23/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	2.11	2	ppt
510	7/2/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	8.6	2	ppt
510	12/23/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	6.78	2	ppt
510	7/2/2020	PERFLUORO-N-HEXANOIC ACID		26	2	ppt
510	12/23/2020	PERFLUORO-N-HEXANOIC ACID		12.7	2	ppt
510	7/2/2020	PRIMIDONE		240	5	ppt
510	12/23/2020	PRIMIDONE		260	5	ppt
510	7/2/2020	SALICYLIC ACID		580	200	ppt
510	12/23/2020	SALICYLIC ACID		210	200	ppt
510	7/2/2020	SIMAZINE	MCL 4,000	440	50	ppt
510	12/23/2020	SIMAZINE	MCL 4,000	14	5	ppt
510	7/2/2020	SUCRALOSE		69,000	2500	ppt
510	12/23/2020	SUCRALOSE		58,000	1000	ppt
510	12/23/2020	SULFADIAZINE		44	5	ppt
510	7/2/2020	SULFAMETHOXAZOLE		1,400	50	ppt
510	12/23/2020	SULFAMETHOXAZOLE		790	50	ppt
510	7/2/2020	TCEP		120	10	ppt
510	12/23/2020	TCEP		160	10	ppt
510	7/2/2020	TCPP		1,100	200	ppt
510	12/23/2020	TCPP		860	200	ppt
510	7/2/2020	TDCPP		830	100	ppt
510	12/23/2020	TDCPP		360	100	ppt
510	7/2/2020	THEOPHYLLINE		20	10	ppt
510	12/23/2020	THEOPHYLLINE		88	10	ppt
510	7/2/2020	THIABENDAZOLE		9.7	5	ppt
510	12/23/2020	THIABENDAZOLE		22	5	ppt
510	7/2/2020	TRIMETHOPRIM		36	5	ppt
510	12/23/2020	TRIMETHOPRIM		48	5	ppt
522	7/2/2020	1,4-DIOXANE	HA 0.35	**0.75**	0.1	ppb
522	12/23/2020	1,4-DIOXANE	HA 0.35	**0.73**	0.1	ppb
522	7/2/2020	ACESULFAME-K		140	20	ppt
522	12/23/2020	ACESULFAME-K		74	20	ppt
522	7/2/2020	ATENOLOL		71	5	ppt
522	7/2/2020	BUTALBITAL		25	10	ppt
522	7/2/2020	CARBAMAZEPINE		280	5	ppt
522	7/2/2020	CARISOPRODOL		13	5	ppt
522	12/23/2020	CARISOPRODOL		16	5	ppt
522	7/2/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.057	0.02	ppb

TUCSON WATER
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TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
522	12/23/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.092	0.02	ppb
522	7/2/2020	DEET		20	10	ppt
522	7/2/2020	DIA		5.3	5	ppt
522	7/2/2020	DICLOFENAC		110	5	ppt
522	7/2/2020	DILANTIN		27	20	ppt
522	7/2/2020	DILTIAZEM		10	5	ppt
522	7/2/2020	DIURON		32	5	ppt
522	12/23/2020	DIURON		9.5	5	ppt
522	7/2/2020	FLUOXETINE		20	10	ppt
522	7/2/2020	GEMFIBROZIL		10	5	ppt
522	12/23/2020	IOHEXOL		49	20	ppt
522	7/2/2020	LIDOCAINE		200	5	ppt
522	7/2/2020	LOPRESSOR		95	20	ppt
522	7/2/2020	MEPROBAMATE		53	5	ppt
522	12/23/2020	MEPROBAMATE		16	5	ppt
522	7/2/2020	NAPROXEN		22	20	ppt
522	7/2/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**67**	2	ppt
522	12/23/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**70.6**	2	ppt
522	7/2/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**17**	2	ppt
522	12/23/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**17.8**	2	ppt
522	7/2/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		6.5	2	ppt
522	12/23/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		11.8	2	ppt
522	7/2/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		17	2	ppt
522	12/23/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		21.6	2	ppt
522	7/2/2020	PERFLUOROHEPTANOIC ACID - PFHpA		6.5	2	ppt
522	12/23/2020	PERFLUOROHEPTANOIC ACID - PFHpA		8.2	2	ppt
522	7/2/2020	PERFLUORO-N-DECANOIC ACID		2.3	2	ppt
522	12/23/2020	PERFLUORO-N-DECANOIC ACID		2.27	2	ppt
522	7/2/2020	PERFLUORO-N-HEXANOIC ACID		22	2	ppt
522	12/23/2020	PERFLUORO-N-HEXANOIC ACID		21.2	2	ppt
522	7/2/2020	PERFLUORO-N-NONANOIC ACID - PFNA		3.7	2	ppt
522	12/23/2020	PERFLUORO-N-NONANOIC ACID - PFNA		3.92	2	ppt
522	7/2/2020	PRIMIDONE		160	5	ppt
522	12/23/2020	PRIMIDONE		110	5	ppt
522	7/2/2020	SALICYLIC ACID		200	200	ppt
522	7/2/2020	SIMAZINE	MCL 4,000	120	5	ppt
522	7/2/2020	SUCRALOSE		22,000	1000	ppt
522	12/23/2020	SUCRALOSE		7,200	100	ppt
522	7/2/2020	SULFAMETHOXAZOLE		7.2	5	ppt
522	7/2/2020	TCEP		52	10	ppt
522	12/23/2020	TCEP		33	10	ppt
522	7/2/2020	TCPP		400	200	ppt
522	7/2/2020	TDCPP		220	100	ppt
522	7/2/2020	THIABENDAZOLE		7.3	5	ppt
A-055A	7/2/2020	1,7-DIMETHYLXANTHINE		5.3	5	ppt
A-055A	7/2/2020	ATRAZINE	MCL 3,000	18	5	ppt
A-055A	12/29/2020	ATRAZINE	MCL 3,000	17	5	ppt
A-055A	7/2/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.026	0.02	ppb
A-055A	12/29/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.046	0.02	ppb
A-055A	12/29/2020	DACT		21	20	ppt
A-055A	7/2/2020	DEA		9.5	5	ppt
A-055A	12/29/2020	DEA		16	5	ppt

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
A-055A	7/2/2020	DIA		69	5	ppt
A-055A	12/29/2020	DIA		76	5	ppt
A-055A	7/2/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	3.8	2	ppt
A-055A	12/29/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	4.54	2	ppt
A-055A	7/2/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	5.6	2	ppt
A-055A	12/29/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	6.32	2	ppt
A-055A	7/2/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		4.8	2	ppt
A-055A	12/29/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		6.48	2	ppt
A-055A	7/2/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		5.2	2	ppt
A-055A	12/29/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		7.04	2	ppt
A-055A	7/2/2020	PERFLUOROHEPTANOIC ACID - PFHpA		2.3	2	ppt
A-055A	12/29/2020	PERFLUOROHEPTANOIC ACID - PFHpA		2.76	2	ppt
A-055A	7/2/2020	PERFLUORO-N-HEXANOIC ACID		2	2	ppt
A-055A	12/29/2020	PERFLUORO-N-HEXANOIC ACID		2.25	2	ppt
A-055A	7/2/2020	SIMAZINE	MCL 4,000	6.7	5	ppt
A-055A	12/29/2020	SIMAZINE	MCL 4,000	7.5	5	ppt
A-055A	7/2/2020	THEOPHYLLINE		10	10	ppt
EW-007A	7/2/2020	1,4-DIOXANE	HA 0.35	**0.72**	0.1	ppb
EW-007A	12/23/2020	1,4-DIOXANE	HA 0.35	**0.81**	0.1	ppb
EW-007A	7/2/2020	ACESULFAME-K		170	20	ppt
EW-007A	7/2/2020	ATRAZINE	MCL 3,000	5.2	5	ppt
EW-007A	12/23/2020	ATRAZINE	MCL 3,000	6.1	5	ppt
EW-007A	7/2/2020	BIS PHENOL A (BPA)		18	10	ppt
EW-007A	7/2/2020	BUTALBITAL		13	10	ppt
EW-007A	12/23/2020	BUTALBITAL		25	10	ppt
EW-007A	7/2/2020	CARBAMAZEPINE		240	5	ppt
EW-007A	12/23/2020	CARBAMAZEPINE		150	5	ppt
EW-007A	7/2/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.2	0.02	ppb
EW-007A	12/23/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.17	0.02	ppb
EW-007A	7/2/2020	DEA		5.2	5	ppt
EW-007A	12/23/2020	DEA		5.2	5	ppt
EW-007A	12/23/2020	DEET		11	10	ppt
EW-007A	12/23/2020	DIA		6.3	5	ppt
EW-007A	7/2/2020	DIURON		5.7	5	ppt
EW-007A	12/23/2020	DIURON		11	5	ppt
EW-007A	12/23/2020	ERYTHROMYCIN		14	10	ppt
EW-007A	7/2/2020	IOHEXOL		23	20	ppt
EW-007A	7/2/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	43	2	ppt
EW-007A	12/23/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**51.7**	2	ppt
EW-007A	7/2/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	24	2	ppt
EW-007A	12/23/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**19.7**	2	ppt
EW-007A	7/2/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		12	2	ppt
EW-007A	12/23/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		14.1	2	ppt
EW-007A	7/2/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		49	2	ppt
EW-007A	12/23/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		47.6	2	ppt
EW-007A	7/2/2020	PERFLUOROHEPTANOIC ACID - PFHpA		9.2	2	ppt
EW-007A	12/23/2020	PERFLUOROHEPTANOIC ACID - PFHpA		7.86	2	ppt
EW-007A	7/2/2020	PERFLUORO-N-HEXANOIC ACID		22	2	ppt
EW-007A	12/23/2020	PERFLUORO-N-HEXANOIC ACID		22.5	2	ppt
EW-007A	7/2/2020	PRIMIDONE		81	5	ppt
EW-007A	12/23/2020	PRIMIDONE		100	5	ppt
EW-007A	12/23/2020	SIMAZINE	MCL 4,000	5.4	5	ppt

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
EW-007A	7/2/2020	SUCRALOSE		2,800	100	ppt
EW-007A	12/23/2020	SUCRALOSE		2,900	100	ppt
EW-007A	7/2/2020	SULFAMETHOXAZOLE		27	5	ppt
EW-007A	12/23/2020	SULFAMETHOXAZOLE		32	5	ppt
EW-007A	12/23/2020	TCEP		12	10	ppt
TA-030A	6/30/2020	1,4-DIOXANE	HA 0.35	**1.13**	0.1	ppb
TA-030A	12/18/2020	1,4-DIOXANE	HA 0.35	**1.13**	0.1	ppb
TA-030A	6/30/2020	BROMACIL		7.9	5	ppt
TA-030A	12/18/2020	BROMACIL		9.8	5	ppt
TA-030A	6/30/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	3.1	0.02	ppb
TA-030A	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	3.2	0.02	ppb
TA-030A	6/30/2020	DEA		8.5	5	ppt
TA-030A	12/18/2020	DEA		12	5	ppt
TA-030A	12/18/2020	DILTIAZEM		5.3	5	ppt
TA-030A	12/18/2020	ERYTHROMYCIN		25	10	ppt
TA-030A	6/30/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	9.8	2	ppt
TA-030A	12/18/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	11.7	2	ppt
TA-030A	12/24/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	13.2	2	ppt
TA-030A	6/30/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	3.3	2	ppt
TA-030A	12/18/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	4.34	2	ppt
TA-030A	12/24/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	4.57	2	ppt
TA-030A	6/30/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		7.4	2	ppt
TA-030A	12/18/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		10.5	2	ppt
TA-030A	12/24/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		10.6	2	ppt
TA-030A	6/30/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		43	2	ppt
TA-030A	12/18/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		58.4	2	ppt
TA-030A	12/24/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		63	2	ppt
TA-030A	6/30/2020	PERFLUOROHEPTANOIC ACID - PFHpA		2.8	2	ppt
TA-030A	12/18/2020	PERFLUOROHEPTANOIC ACID - PFHpA		3.45	2	ppt
TA-030A	12/24/2020	PERFLUOROHEPTANOIC ACID - PFHpA		3.54	2	ppt
TA-030A	6/30/2020	PERFLUORO-N-HEXANOIC ACID		10	2	ppt
TA-030A	12/18/2020	PERFLUORO-N-HEXANOIC ACID		12.2	2	ppt
TA-030A	12/24/2020	PERFLUORO-N-HEXANOIC ACID		12.3	2	ppt
TA-030A	12/18/2020	PROPYLPARABEN		8.6	5	ppt
Y-001B	7/1/2020	1,4-DIOXANE	HA 0.35	**0.76**	0.1	ppb
Y-001B	12/18/2020	1,4-DIOXANE	HA 0.35	**0.77**	0.1	ppb
Y-001B	7/1/2020	ACESULFAME-K		67	20	ppt
Y-001B	12/18/2020	ACESULFAME-K		150	20	ppt
Y-001B	7/1/2020	ATRAZINE	MCL 3,000	7.2	5	ppt
Y-001B	12/18/2020	ATRAZINE	MCL 3,000	6.4	5	ppt
Y-001B	7/1/2020	CARBAMAZEPINE		140	5	ppt
Y-001B	12/18/2020	CARBAMAZEPINE		95	5	ppt
Y-001B	7/1/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.099	0.02	ppb
Y-001B	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.14	0.02	ppb
Y-001B	7/1/2020	DEA		5	5	ppt
Y-001B	12/18/2020	DIA		6.3	5	ppt
Y-001B	7/1/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**81**	20	ppt
Y-001B	12/18/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**72**	2	ppt
Y-001B	7/1/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**18**	2	ppt
Y-001B	12/18/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**12**	2	ppt
Y-001B	7/1/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		5.6	2	ppt

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
Y-001B	12/18/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		5.09	2	ppt
Y-001B	7/1/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		51	2	ppt
Y-001B	12/18/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		44.8	2	ppt
Y-001B	7/1/2020	PERFLUOROHEPTANOIC ACID - PFHpA		5.5	2	ppt
Y-001B	12/18/2020	PERFLUOROHEPTANOIC ACID - PFHpA		3.81	2	ppt
Y-001B	7/1/2020	PERFLUORO-N-HEXANOIC ACID		11	2	ppt
Y-001B	12/18/2020	PERFLUORO-N-HEXANOIC ACID		6.93	2	ppt
Y-001B	7/1/2020	PERFLUORO-N-NONANOIC ACID - PFNA		2.2	2	ppt
Y-001B	7/1/2020	PRIMIDONE		32	5	ppt
Y-001B	12/18/2020	PRIMIDONE		27	5	ppt
Y-001B	7/1/2020	SIMAZINE	MCL 4,000	8.2	5	ppt
Y-001B	12/18/2020	SIMAZINE	MCL 4,000	6.1	5	ppt
Y-001B	7/1/2020	SULFAMETHOXAZOLE		10	5	ppt
Y-001B	12/18/2020	SULFAMETHOXAZOLE		6.6	5	ppt
Y-004A	7/1/2020	1,4-DIOXANE	HA 0.35	**0.75**	0.1	ppb
Y-004A	12/18/2020	1,4-DIOXANE	HA 0.35	**1.04**	0.1	ppb
Y-004A	7/1/2020	ACESULFAME-K		130	20	ppt
Y-004A	7/1/2020	CARBAMAZEPINE		210	5	ppt
Y-004A	12/18/2020	CARBAMAZEPINE		160	5	ppt
Y-004A	7/1/2020	CARISOPRODOL		5.3	5	ppt
Y-004A	12/18/2020	CARISOPRODOL		9.4	5	ppt
Y-004A	7/1/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.08	0.02	ppb
Y-004A	12/18/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.18	0.02	ppb
Y-004A	7/1/2020	DIA		7.4	5	ppt
Y-004A	12/18/2020	DIA		8.7	5	ppt
Y-004A	7/1/2020	DILANTIN		21	20	ppt
Y-004A	12/18/2020	DILANTIN		31	20	ppt
Y-004A	7/1/2020	DIURON		11	5	ppt
Y-004A	7/1/2020	MEPROBAMATE		12	5	ppt
Y-004A	12/18/2020	MEPROBAMATE		13	5	ppt
Y-004A	7/1/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**55**	2	ppt
Y-004A	12/18/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	47.5	2	ppt
Y-004A	7/1/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**19**	2	ppt
Y-004A	12/18/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	14.3	2	ppt
Y-004A	7/1/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		8.8	2	ppt
Y-004A	12/18/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		8.12	2	ppt
Y-004A	7/1/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		25	2	ppt
Y-004A	12/18/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		24.7	2	ppt
Y-004A	7/1/2020	PERFLUOROHEPTANOIC ACID - PFHpA		5.2	2	ppt
Y-004A	12/18/2020	PERFLUOROHEPTANOIC ACID - PFHpA		3.81	2	ppt
Y-004A	7/1/2020	PERFLUORO-N-DECANOIC ACID		2	2	ppt
Y-004A	7/1/2020	PERFLUORO-N-HEXANOIC ACID		14	2	ppt
Y-004A	12/18/2020	PERFLUORO-N-HEXANOIC ACID		9.34	2	ppt
Y-004A	7/1/2020	PERFLUORO-N-NONANOIC ACID - PFNA		2.7	2	ppt
Y-004A	7/1/2020	PRIMIDONE		64	5	ppt
Y-004A	12/18/2020	PRIMIDONE		50	5	ppt
Y-004A	7/1/2020	SIMAZINE	MCL 4,000	34	5	ppt
Y-004A	12/18/2020	SIMAZINE	MCL 4,000	32	5	ppt
Y-004A	7/1/2020	SUCRALOSE		4,400	100	ppt
Y-004A	12/18/2020	SUCRALOSE		1,700	100	ppt
Y-004A	7/1/2020	SULFAMETHOXAZOLE		57	5	ppt
Y-004A	12/18/2020	SULFAMETHOXAZOLE		57	5	ppt
Z-013A	7/1/2020	1,4-DIOXANE	HA 0.35	**1.31**	0.1	ppb

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units
Z-013A	12/28/2020	1,4-DIOXANE	HA 0.35	**1.39**	0.1	ppb
Z-013A	7/1/2020	4-NONYLPHENOL		4,500	400	ppt
Z-013A	7/1/2020	4-TERT-OCTYLPHENOL		140	25	ppt
Z-013A	12/28/2020	4-TERT-OCTYLPHENOL		36	25	ppt
Z-013A	7/1/2020	ACESULFAME-K		3,200	200	ppt
Z-013A	12/28/2020	ACESULFAME-K		2,700	200	ppt
Z-013A	7/1/2020	ATRAZINE	MCL 3,000	11	5	ppt
Z-013A	12/28/2020	ATRAZINE	MCL 3,000	12	5	ppt
Z-013A	7/1/2020	CARBAMAZEPINE		180	5	ppt
Z-013A	12/28/2020	CARBAMAZEPINE		120	5	ppt
Z-013A	7/1/2020	CARISOPRODOL		64	5	ppt
Z-013A	12/28/2020	CARISOPRODOL		62	5	ppt
Z-013A	12/28/2020	CHROMIUM, HEXAVALENT	[1]MCL 100	0.038	0.02	ppb
Z-013A	7/1/2020	DEA		6.6	5	ppt
Z-013A	12/28/2020	DEA		7.5	5	ppt
Z-013A	7/1/2020	DILANTIN		53	20	ppt
Z-013A	12/28/2020	DILANTIN		65	20	ppt
Z-013A	7/1/2020	MEPROBAMATE		220	5	ppt
Z-013A	12/28/2020	MEPROBAMATE		250	5	ppt
Z-013A	7/1/2020	N-ETHYL PERFLUOROOCTANESULFONAMIDOACETIC		7.3	2	ppt
Z-013A	12/28/2020	N-ETHYL PERFLUOROOCTANESULFONAMIDOACETIC		7.83	2	ppt
Z-013A	7/1/2020	N-METHYL PERFLUOROOCTANESULFONAMIDOACETIC		2.7	2	ppt
Z-013A	12/28/2020	N-METHYL PERFLUOROOCTANESULFONAMIDOACETIC		3.05	2	ppt
Z-013A	7/1/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**120**	20	ppt
Z-013A	12/28/2020	PERFLUORO OCTANESULFONIC ACID - PFOS	[2]HA 70	**146**	2	ppt
Z-013A	7/1/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**27**	2	ppt
Z-013A	12/28/2020	PERFLUORO OCTANOIC ACID - PFOA	[2]HA 70	**28.2**	2	ppt
Z-013A	7/1/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		10	2	ppt
Z-013A	12/28/2020	PERFLUORO-1-BUTANESULFONIC ACID - PFBS		11.4	2	ppt
Z-013A	7/1/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		53	2	ppt
Z-013A	12/28/2020	PERFLUORO-1-HEXANESULFONIC ACID - PFHxS		67.5	2	ppt
Z-013A	7/1/2020	PERFLUOROHEPTANOIC ACID - PFHpA		6.8	2	ppt
Z-013A	12/28/2020	PERFLUOROHEPTANOIC ACID - PFHpA		6.79	2	ppt
Z-013A	7/1/2020	PERFLUORO-N-HEXANOIC ACID		13	2	ppt
Z-013A	12/28/2020	PERFLUORO-N-HEXANOIC ACID		11.5	2	ppt
Z-013A	7/1/2020	PERFLUORO-N-NONANOIC ACID - PFNA		2.8	2	ppt
Z-013A	12/28/2020	PERFLUORO-N-NONANOIC ACID - PFNA		2.95	2	ppt
Z-013A	7/1/2020	PRIMIDONE		80	5	ppt
Z-013A	12/28/2020	PRIMIDONE		86	5	ppt
Z-013A	7/1/2020	SULFAMETHOXAZOLE		52	5	ppt
Z-013A	12/28/2020	SULFAMETHOXAZOLE		39	5	ppt

Footnotes, Acronyms, and Abbreviations:

Bold Font indicates the sample result exceeds the HA

[1]Total Chromium MCL =100 ppb; There is no MCL for Hexavalent Chromium

[2]HA 70 ppt combined PFOS + PFOA

CEC = Contaminant of Emerging Concern

HA = Health Advisory

MCL = Maximum Contaminant Level

Nonpotable: Drinking water **NOT** being served to Tucson Water customers; Inactive well or emergency use only

Potable: Drinking water being served to Tucson Water customers; Active well

ppb = parts per billion

ppt = parts per trillion

TABLE 2. 2020 SENTRY PROGRAM - CECs DETECTED

Sample Point	Sample Date	CEC Parameter Name	Water Quality Standard	Result	Detection Limit	Units

Nonpotable Sources:

510, 522, EW-007A Reclaimed Water

A-055A Standby Emergency Use Only 1/16/2020

TA-030A TARP AOP Plant Influent

TP-021T TARP AOP Effluent

Y-001B Out of Service Date 9/22/2016

Y-004A Stand By Emergency Use Only 1/16/2020

Z-013A Out of Service Date 9/9/2016

Appendix F

OUT-OF-SERVICE WELLS

OUT-OF-SERVICE WELLS - LOST AND AT-RISK ASSETS

Table 1: Out of Service (OOS) Wells (as of July 2019) that are impacted by contaminants - PFAS, 1,4-dioxane, and TCE

				Most Recent Concentrations							
#	Well Name	Flow (gpm)	OOS Date	PFOA+PFOS (ppt)	Sampling Date	PFHxS+PFHxA (ppt)	Sampling Date	1,4-dioxane (ppb)	Sampling Date	TCE (ppb)	Sampling Date
1	A-009B	379	10/31/2018	2	3/6/2019	2.3	3/6/2019	-	-	-	-
2	A-036A	330	11/16/2018	2.7	3/6/2019	2	3/6/2019	-	-	-	-
3	A-057B	558	7/18/2018	15	3/6/2019	9.5	3/6/2019	-	-	-	-
4	B-048B	713	11/16/2018	5.5	3/7/2019	3.3	3/7/2019	-	-	-	-
5	C-007A	235	3/20/2018	2950	3/20/2018	-	-	-	-	-	-
6	C-008B	680	10/24/2018	195	3/4/2019	164	3/4/2019	-	-	-	-
7	C-014B	312	3/20/2018	158	3/19/2019	690	3/19/2019	-	-	-	-
8	C-036B	313	2/5/2019	131	12/27/2018	224	12/27/2018	-	-	-	-
9	SS-001A	321	7/27/2018	23	10/5/2017	-	-	-	-	-	-
10	Y-001B	740	9/22/2016	108	10/15/2018	69	10/15/2018	0.66	10/15/2018	-	-
11	Y-004A	935	NA	82	10/15/2018	43	10/15/2018	0.71	10/15/2018	-	-
12	Z-002A	389	3/9/2016	<2	10/30/2018	<2	10/30/2018	-	-	2.5	3/3/2016
13	Z-005A	315	9/19/2016	<2	3/6/2018	-	-	0.19	10/15/2018	-	-
14	Z-013A	477	9/19/2016	148	10/15/2018	73	10/15/2018	1.26	10/15/2018	-	-
15	Z-014B	814	8/22/2016	<2	10/16/2018	<2	10/16/2018	<0.1	10/16/2018	-	-
16	Z-015A	801	9/19/2016	93	10/16/2018	123	10/16/2018	0.32	10/16/2018	-	-
	Total (gpm)	8312									

Table 2: Out of Service (OOS) Wells (as of July 2019) that are impacted by PFAS and 1,4-dioxane

				Most Recent Concentrations					
#	Well Name	Flow (gpm)	OOS Date	PFOA+PFOS (ppt)	Sampling Date	PFHxS+PFHxA (ppt)	Sampling Date	1,4-dioxane (ppb)	Sampling Date
1	Y-001B	740	9/22/2016	108	10/15/2018	69	10/15/2018	0.66	10/15/2018
2	Y-004A	935	NA	82	10/15/2018	43	10/15/2018	0.71	10/15/2018
3	Z-005A	315	9/19/2016	<2	3/6/2018	-	-	0.19	10/15/2018
4	Z-013A	477	9/19/2016	148	10/15/2018	73	10/15/2018	1.26	10/15/2018
5	Z-014B	814	8/22/2016	<2	10/16/2018	<2	10/16/2018	<0.1	10/16/2018
6	Z-015A	801	9/19/2016	93	10/16/2018	123	10/16/2018	0.32	10/16/2018
	Total (gpm)	4082							

Table 3: Out of Service (OOS) Wells (as of July 2019) that are impacted by PFAS only

				Most Recent Concentrations			
#	Well Name	Flow (gpm)	OOS Date	PFOA+PFOS (ppt)	Sampling Date	PFHxS+PFHxA (ppt)	Sampling Date
1	A-009B	379	10/31/2018	2	3/6/2019	2.3	3/6/2019
2	A-036A	330	11/16/2018	2.7	3/6/2019	2	3/6/2019
3	A-057B	558	7/18/2018	15	3/6/2019	9.5	3/6/2019
4	B-048B	713	11/16/2018	5.5	3/7/2019	3.3	3/7/2019
5	C-007A	235	3/20/2018	2950	3/20/2018	-	-
6	C-008B	680	10/24/2018	195	3/4/2019	164	3/4/2019
7	C-014B	312	3/20/2018	158	3/19/2019	690	3/19/2019
8	C-036B	313	2/5/2019	131	12/27/2018	224	12/27/2018
9	SS-001A	321	7/27/2018	23	10/5/2017	-	-
	Total (gpm)	3841					

Table 4: At-Risk Wells (as of May 2019)[(1)]

				Most Recent Concentrations			
#	Well Name	Flow (gpm)	OOS Date	PFOA+PFOS (ppt)	Sampling Date	PFHxS+PFHxA (ppt)	Sampling Date
1	A-053A	243	7/18/2018	<2	3/6/2019	4	3/6/2019
2	B-026B	385	11/16/2018	<2	3/7/2019	2.1	3/7/2019
3	C-082A	289	12/14/2018	<2	3/7/2019	<2	3/7/2019
4	E-029A	1040		<2	10/17/2018	-	-
	Total (gpm)	1957					

Notes:

(1) At-Risk Wells are wells that were taken out of service but have since been returned to service

Appendix F

ONE WATER 2100 BENEFITS AND COSTS OF THE RECLAIMED SYSTEM

Tucson Water
One Water 2100 Master Plan

Technical Memorandum: The Benefits and Costs of Tucson Water's Reclaimed Water System

Final | May 2, 2022

Galardi-Rothstein Group
Raucher LLC

Tucson Water
One Water 2100 Master Plan

Technical Memorandum

The Benefits and Costs of Tucson Water's Reclaimed Water System

FINAL | May 2022

This document is released for the purpose of information exchange review and planning only.

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Commonly Used Abbreviations and Acronyms

AC	Acre
AFY	Acre-Feet Per Year
AMA	Aquifer Management Area
AWWA	American Water Works Association’s
BCA	Benefit-Cost Analysis
CAP	Central Arizona Project
CCF	Hundred Cubic Feet
COS	Cost of Service
CPI	Consumer Price Index
CWAC	Citizen Water Advisory Committee
FY	Fiscal Year
GMA	Groundwater Management Act (1980), State of Arizona
GPCD	Gallons Per Capita Per Day
IGA	Intergovernmental Agreement
IMPLAN	IMpact Analysis for PLANning model
I/O	Input-Output
M	Million
MG	Million Gallons
MGD	Million Gallons Per Day
MRIO	Multi-Regional Input-Output
MSA	Metropolitan Statistical Area
NPR	Nonpotable Reuse
O&M	Operation and Maintenance
PCRWRD	Pima County Regional Wastewater Reclamation Department
RWS	Reclaimed Water System
SHARP	Southeast Houghton Area Recharge Project
TBL	Triple Bottom Line
TM	Technical Memorandum
USD	United States Dollars

1. Executive Summary

This Technical Memorandum (TM) provides a summary of findings from our analyses of the *Benefits and Costs of the Tucson Water Reclaimed Water System*. Our study is a component of Tucson Water's broader *One Water 2100* (1W2100) master plan. This Executive Summary draws on analyses developed in the sections that follow and a set of supporting appendices describing the objectives, methods, data, and findings of our analyses.

The intent of our analyses is to provide an objective empirical basis for evaluating the benefits and costs of the Reclaimed Water System. The analysis is intended, in part, to inform an upcoming review of the reclaimed system water rates and rate structure. Portions of our analysis may also inform and guide deliberations regarding the utility's approach to recycled water resources.

1.1 Reclaimed Water System Overview

Tucson Water, a department of the City of Tucson, has successfully developed and operated the Reclaimed Water System since the mid 1980s. The framework for the reuse program was established under an Intergovernmental Agreement (IGA), signed in 1979 by the City of Tucson and Pima County (in which Tucson is located). Under the terms of the IGA, the City became the primary provider of potable and recycled water for Tucson and portions of the Tucson Water service area in Pima County that lie outside of City limits. Under the IGA, Pima County became the primary provider of wastewater management services throughout the greater Tucson region.

The Reclaimed Water System repurposes highly treated effluent derived from the Pima County Regional Wastewater Reclamation Department (PCRWRD). Tucson's mature water reuse program delivers between 14,000 and 20,000 acre feet per year (AFY) of recycled water to more than 900 sites via a network including approximately 200 miles of purple pipe. The Reclaimed Water System delivers recycled water for nonpotable applications, including turf and agricultural irrigation, groundwater recharge, and ecologic restoration. Area golf courses are the largest users of Reclaimed Water System waters, accounting for approximately 9,000 AFY.

1.2 Reclaimed Water System Costs and Cost Recovery

It is common practice across the United States (and other nations) to sell reclaimed water for nonpotable reuse at rates that recover revenues that are less than the full "cost of service" of producing and distributing high quality, fit-for-purpose product water. Pricing nonpotable reclaimed water at less than its full cost of service occurs for numerous well-established reasons, including a need to create customer demand given the relatively attractive price of available substitute water sources, such as potable supplies and self-supply (e.g., well pumping) (Cristiano and Henderson, 2009; AWWA 2017, 2019; Raucher et al., 2019).

Annualized capital and yearly operation and maintenance expenses for the Reclaimed Water System amount to $13 million per year, while annual revenues from the recycled water sales amount to about $8 million to $11 million. The resulting revenue shortfall of $2 million to $5 million per year (i.e., the annual deficit relative to the cost of service) is covered largely through cross-subsidies from potable customers.

Selling reclaimed water at a discount implies that its users are being subsidized by other parties, typically the customers of the local potable system (as is the case in Tucson) and/or wastewater systems. These "cross-subsidies" often are well justified by the benefits the various parties receive from the reclaimed water system, including avoiding the expense of expanding the potable system to meet nonpotable demands. This Technical Memorandum explores the extent to which the benefits and the associated beneficiaries compare to the Reclaimed Water System's costs and the allocation of those costs.

1.3 Reclaimed Water System Benefits and Beneficiaries

The Reclaimed Water System provides a range of valuable benefits to the residents, businesses, and other entities in the region. The Reclaimed Water System (1) facilitates regional population and economic growth by providing a reliable and locally controlled water source, (2) reduces demands on the potable water supply system, (3) contributes to stored groundwater reserves while (4) reduces groundwater depletion and subsidence, (5) restores native riparian habitat, and (6) supports green spaces that enhance the quality of life for the residents of and visitors to the City of Tucson and broader region.

Our analysis has estimated the following benefits provided by the Reclaimed Water System, as detailed in subsequent sections and appendices of this TM (all dollar amounts stated in 2021 US Dollars, unless otherwise stated):[1]

1. Avoided Costs (cost savings). With the needs of large irrigation customers being met with reclaimed water, seasonal peaks in potable water demand are significantly reduced. Absent the Reclaimed Water System, Tucson Water would have needed to expand its potable supply capacity by 35 million gallons per day (mgd) to meet total water system peak season demands. The additional cost of potable system expansion would have amounted to an estimated $181.5 million in capital outlays and $26.2 million in annual operation and maintenance expenses (Mayer, 2017). The associated benefit for a typical City of Tucson single family household is $91 per year in potable water cost savings (Mayer, 2017). Another added benefit is that certain capital improvements to the potable system may be delayed because of lower total and seasonal potable water demands (Thomure and Kmiec, 2008).

2. Water Supply Resilience. The Reclaimed Water System has helped stabilize and restore groundwater levels in the regional aquifer, through its contribution to groundwater recharge and by offsetting demands on the potable system. The source of reclaimed water (treated effluent from indoor water use) is drought-resistant, locally generated, and locally controlled, thereby enhancing the resilience and reliability of the regional water supply portfolio.

[1] Dollar values updated to 2021 values using the Consumer Price Index (per https://www.bls.gov/data/inflation_calculator.htm)

The dollar value of enhanced supply reliability and resilience is difficult to quantify, yet there is credible empirical evidence, generated by a suite of relevant economic studies, that reliability and resilience values may be substantial. Supply reliability has been shown in other locations to have considerable economic value to regional households and businesses, E.g., on the order of $45 per household per year to avoid 20% water use restrictions in one year out of the next 20 years (Raucher et al., 2013). In terms of regional economic activity, the value of reducing a potential regional water supply shortfall from 25% to 15% (i.e., reducing the shortfall from 25% to 15% of annual demand) has been shown to exceed $500,000 per AFY in terms of regional economic output in California's Bay Area (e.g., M Cubed, 2008).

3. Contributions to Banked Water Storage. Tucson Water's active groundwater storage program has been enhanced by the Reclaimed Water System. Net groundwater recharge attributable to the Reclaimed Water System averages between 8,000 and 9,000 AFY. If that net additional groundwater storage were to be replaced with Central Arizona Project (CAP) water, at an expense of $372/AF (Malcolm Pirnie/Arcadis, 2013), then the value provided by the Reclaimed Water System (expressed here as an avoided cost) would amount to between $3.0 million and $3.4 million per year. In total, one year of Tucson Water's water supply has been stored due to direct accumulated contributions by the Reclaimed Water System (Reclaimed Water Annual Report, draft, 2020).

4. Enhanced Ecosystems and Related Recreational, Aesthetic, and Quality of Life Benefits. Several important but hard-to-quantify ecosystem and social "quality-of-life" benefits for the region are derived from the Reclaimed Water System. The Sweetwater Wetlands, Santa Cruz River Heritage Project, and Southeast Houghton Area Recharge Project (SHARP) are key examples, providing high quality recreational, aesthetic, educational, cultural, wildlife and ecosystem restoration values to the community.

As one example, Audubon Society-led weekly bird watching tours at the Sweetwater Wetlands generate a nonmarket benefit of more than $110,000 per year for an estimated 1,500 annual participants. And, by helping to "green" portions of the community, the Reclaimed Water System is likely to alleviate some urban heat island impacts which may pose significant adverse health risks and discomfort, and higher energy use, especially under climate change.

The Santa Cruz River Heritage Project provides another important Reclaimed Water System-enhanced environmental and community asset. Reclaimed Water System discharge to the dry riverbed, beginning in 2019, has brought a surprising diversity and abundance of riparian life to the otherwise dry channel. This flowing stretch of river is located in the heart of Tucson and runs alongside a popular bike and walking trail. The Reclaimed Water System-based enhancements to the Santa Cruz River provide aesthetic, ecologic, cultural, and educational value to many residents as well as visitors to the region.

5. Regional Economic Impact Benefits. The Reclaimed Water System supports many economic activities and sectors, including the destination golf sector in the Tucson service area. Expenditures made by golfers traveling to the Tucson metro area provide significant revenues for golf courses and associated resorts, and their spending also generates an appreciable economic stimulus for the City and the rest of the Tucson Water service area.

Golf course and related resort owners and investors, as well as the local government entities that host them, realize large financial gains generated by access to Reclaimed Water System water for golf course turf irrigation. For example, the Ritz-Carlton resort and golf courses at Dove Mountain had revenue projections that indicated that the capital investment in the resort could be recovered in fewer than five years (Thomure and Kmiec, 2008)

Economic benefits also extend more widely across the region's sectors. Our regional economic impact analysis[2] estimates that golfers traveling to the region contribute an average of $2,805 per trip, and $49.4 Million per year in total, to metro area goods and services. The associated stimulus to the regional economy – consisting of direct, indirect, and induced impacts – includes an estimated 550 jobs added in the Tucson Water service area (144 of these added jobs are within the City of Tucson), labor income gains of $16.5 million annually ($5.2 million within the City), overall economic output gains of $48.4 million annually ($16.1 million within the City), and tax revenue enhancements of $7.1 million ($1.9 million for the City).

The portion of the annual economic stimulus benefits realized by and within the City of Tucson, derived solely from subsidized Reclaimed Water System use at golf courses located *outside* of City limits, amounts to an estimated 55 added jobs, $2.5 million in added labor income, $8.5 million annually in economic output, and $46,000 in added tax revenues.

In addition, local residents also enjoy the "nonmarket benefits" of irrigated golf courses (i.e., for recreational user days that are highly valued, and for aesthetic purposes). And the spending locals make related to their golf course activities also helps sustain and stimulate the City and regional economies. These local golfer benefits are not included in the empirical values provided above.

6. Additional Benefits Provided by the Reclaimed Water System. In addition to the benefits described above, the Reclaimed Water System provides other beneficial values to the region. For example, by wheeling recycled water to other users and their beneficial uses, Tucson Water enables recycled water benefits to be realized in the Town of Oro Valley and served Pima County facilities.

The benefits derived from the Reclaimed Water System are summarized in the following Tables ES-1 and ES-2 (next page).

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[2] The regional economic impact analysis applied here applies the IMPLAN model, which is widely used and accepted across the U.S. Additional detail is provided in Appendix C.

Table ES-1 Key Benefits provided by the Tucson Reclaimed Water System

Type of Benefit	Description	Level and Value	Beneficiaries
Avoided costs (cost savings) from not needing to expand or upgrade the Tucson Water potable water system to meet peak season system demands.	Reduced potable water bills for residential customers.	$91 annual savings on potable water bills per average single-family household in the City of Tucson. (Presumably similar benefits to other potable customers)	Potable water system customers in City of Tucson, and potable customers in the rest of Tucson Water's service area
Recreational opportunities and aesthetic values at Sweetwater Wetlands, Santa Cruz River Heritage, and other sites using reclaimed water to create, restore, and/or enhance riparian and other natural habitats and public greenspace.	Walking, biking, birding and wildlife observation, school field trips, and other activities enabled and/or enhanced by reclaimed water use at local sites.	1500+ user days annually for Audubon-sponsored weekly Sweetwater birdwatching tours, with an approximate nonmarket value of $110,000 to participants. Additional recreational and related benefits for other users of sites created or enhanced by provisions of reclaimed waters.	All recreational users of Reclaimed Water System-supported amenities and resources, including City and Pima County residents, as well as visitors and tourists from outside the region.
Contributed to reduced risk of subsidence-related damages to City/public infrastructure (e.g., roads, bridges, water, and sewer lines) and private property	Avoided expense of disruption and repair costs from damage to roads, bridges, buildings, etc.	Monetary estimates are not available, however, subsidence-related damages can be very expensive to repair	Municipal entities and taxpayers, businesses, households, and other entities across the region
Enhanced water system reliability, resilience, and sustainability	Increased ability of total water supply system to meet demands in times of drought or other risks	Monetary estimates are not available for Tucson region, however studies elsewhere in the western U.S. indicate a high value of avoiding water shortages > 15% of demand	All households, businesses, municipal and other entities relying on Tucson Water-provided water.
Local and regional economic stimulus (golf course-related)	Reclaimed Water System supports golf-related tourism sectors, with beneficial economic impacts to the City of Tucson and region.	Local spending by visiting out-of-region golfers generates: $49 million in additional revenues for regional businesses $16.5 million in added regional employment income $48.4 million in added regional economic output $7.1 million in added tax revenues.	City of Tucson economic benefits amount to: 144 added jobs (26% of total job gains) $5.2 million in labor income (32% of total) $16.1 million in added economic output (33% of total) $1.9 million added tax revenue (27% of total)
Ecosystem and related other "greening" benefits	Riparian habitat restoration	Monetary nonmarket value estimates not available	Flora and fauna, and human residents

Table ES-2 Overview of Key Benefits and Costs for the Reclaimed Water System (Annualized 2021 US Dollars)

Benefits		
Benefits: Monetized	**Estimated Value**	**Comments**
Avoided Costs for Potable System	$37 Million per year ($11M in annualized capital outlays, plus $26M in annual O&M expenses)	Approximately $91 per year savings for a single-family residential household in City
Banked storage in groundwater (average of about 9000 AFY)	$3.0 to $3.4 M/year (on average)	Based on cost of acquiring and groundwater storage of CAP water
Audubon-led birding outings at Sweetwater facility	$0.1 M/year	Does not include other birding, wildlife observation, or other recreational or educational activities at Sweetwater
Revenues for Reclaimed Water Sales	$9 Million per year	Based on 2019-2020 rates
Regional economic impacts from nonlocal golf course visitors (associated with Reclaimed Water System-enabled golf course turf irrigation)	$8.5 million in added regional economic output (as well as 550 added jobs and $7.1 M in added tax revenues)[3]	Based solely on economic impact of nonlocal visitors to region with express purpose of trip being golf
Benefits: Not Quantified	**Description**	**Comments**
Enhanced diversification and sustainability of water portfolio	More reliable and resilient supply portfolio for the served region	Also aids in restoring groundwater levels
Enhanced ecosystems and related recreational, aesthetic, and quality of life benefits.	Sweetwater Wetlands, Santa Cruz River Heritage Project, and Southeast Houghton Area Recharge Project as examples	Providing recreational, aesthetic, educational, cultural, wildlife and ecosystem restoration values to the community.
Total Benefits	**>$48 million per year [3]**	Does not include nonmonetized and regional economic impact benefits
Costs		
Total Costs (Combined annualized capital and yearly O&M expense)	**$13 Million per Year** ($4 Million per year revenue shortfall)	Revenues from RWS Customers: $9 million/year based on 2019-2020 Reclaimed Water System rates and sales.

[3] Regional economic stimulus values are not appropriate to include in the monetized benefits total, as they may be diverting economic activity from other regions (e.g., Phoenix). However, these values are important for the City of Tucson and Pima County.

2. Introduction

2.1 Background

Tucson Water has successfully developed and operated an extensive Reclaimed Water System since the mid 1980s. Repurposing effluent derived from the Pima County Regional Wastewater Reclamation Department (PCRWRD); the Tucson Water Reclaimed Water System network consists of approximately 200 miles of purple pipe serving more than 900 sites. In total, the Reclaimed Water System delivers between 15,000 and 20,000 Acre-Feet per year (AFY) of recycled water for nonpotable applications, including turf and agricultural irrigation, groundwater recharge, and ecologic restoration.

The Reclaimed Water System has provided a mix of important benefits to the region. By providing a reliable supplemental water supply in the 1980s, at a time when regional economic development was outpacing sustainable groundwater extraction, the Reclaimed System has facilitated regional population and economic growth, reduced demands on the potable water supply system, contributed to reducing groundwater depletion and subsidence, helped restore native riparian habitat, and supported green spaces that enhance the quality of life for the residents of and visitors to the City of Tucson and the broader region.

While the Reclaimed Water System has provided a range of important benefits, it also imposes a cost. For numerous well-established reasons – including an initial need to attract customer demand by pricing recycled water at less than potable water rates -- reclaimed water for nonpotable reuse typically is sold at rates that are less than the full cost of producing and distributing high quality, fit-for-purpose product water (e.g., Raucher et al., 2019).

Selling reclaimed water at a discount implies that its users are being subsidized by other parties, typically the customers of the local potable and/or wastewater systems. These "cross-subsidies" often are well justified by the benefits the various parties receive from the reclaimed water system, including avoiding the expense of expanding the potable system to meet nonpotable demands. And, as nonpotable water reuse systems mature, and customer demands and long-term contracts become well established, the level of cross-subsidies may be periodically reviewed and adjusted to align rates more closely with the cost of service.

2.2 Objectives

The objective of this Technical Memorandum, and associated supporting appendices, is to provide a technically sound, unbiased empirical basis for evaluating the equity and efficiency of current and potential future Reclaimed Water System rates (and associated cross-subsidies). This analysis is intended to inform an upcoming review of the Reclaimed Water System's rates and rate structure, and any associated cross-subsidies. To support this objective, this report contains information that:

1) Describes and estimates the beneficial values provided by the Reclaimed Water System as well as its beneficiaries throughout Tucson Water's service area.

2) Provides a sound financial framework for establishing the true cost of service for the Reclaimed Water System, and then compares the historical annual costs to revenues received from users of the Reclaimed Water System (both contract and standard customers) to identify the amount and factors contributing to the "subsidy".
3) Evaluates how the size of the subsidy might change if the rate framework were changed to reflect a slightly modified set of reuse pricing principles and approaches.
4) Assesses the extent to which the Reclaimed Water System cross-subsidies align with the benefits and beneficiaries of the Reclaimed Water System.

The information developed is applied to examine: (1) the "*efficiency*" of the Reclaimed Water System in terms of whether the benefits provided by the system outweigh its costs; and (2) the "*equity*" or "fairness" of how well who pays for the system aligns with who benefits from the services and other values the Reclaimed Water System provides the community. Insights from these evaluations can then be applied in deliberations on upcoming rate-setting and cost-sharing agreements across the jurisdictions and customer classes served by the system.

3. The Origins and Rationale for Developing the Tucson Water Reclaimed Water System

Establishment of the Reclaimed Water System was facilitated in the Tucson/Pima County region by an Inter-Governmental Agreement (IGA), forged in 1979 between the Pima County Regional Wastewater Reclamation Department (PCRWRD) and the City of Tucson (located within the eastern portion of Pima County). A brief history and description of the partnership is provided in Appendix A. The agreement entailed having the county take on exclusive responsibility for wastewater management in the region, assigned 90% of the wastewater effluent from Pima County's facilities to the City, and designated the City of Tucson's Water Department for taking on sole responsibility for water supply provision (including reclaimed water) for the City as well as portions of the surrounding county.

There were numerous factors and pressures leading to the IGA and key institutional arrangements within it (see Appendix A). Underlying the details and allocation of responsibilities, the main driver for developing the Reclaimed Water System was the widely recognized need to provide a new, reliable, and sustainable local source of water for the rapidly growing population and economy of the arid desert region that has no viable significant source of surface water supply and receives an average of less than 10.6 inches of precipitation annually.

The greater Tucson area experienced rapid growth following World War II, relying almost exclusively on local groundwater sources to supply the expanding population and economy. By the late 1970s, it was clear that the region was at considerable risk of running short of water by unsustainably drawing down local aquifers. Groundwater levels had declined by 100 to 200 feet (and as much as 400 feet in some areas), and the region was suffering from the associated decline in water quality, and from extensive subsidence (which can cause significant damage to infrastructure and natural systems). The ability to sustain the region's population and economy – much less grow them as its leaders desired – was very much in question.

In addition, State of Arizona legislative initiatives were in progress, culminating in the 1980 Groundwater Management Act (GMA, or Act). The Groundwater Management Act mandates reliance on sustainable water resources, and it established the Tucson Aquifer Management Area (AMA). The Act requires that groundwater use be replaced with renewable water supplies such that the "safe yield" of aquifers in portions of the State designated AMAs, including the Tucson AMA, is achieved by 2025.

A new, sustainable water supply was needed, and reclaimed water was recognized as being available and feasible as a core part of the solution. Tucson Water started producing and distributing reclaimed water to large turf customers in 1984. Tucson Water also started importing Colorado River surface water via the Central Arizona Project (CAP) in 1992 to 1994, and it resumed CAP imports after the Clearwater Program began operation in 2001. Currently, CAP water, groundwater, and reclaimed water comprise Tucson's water supplies, with groundwater still being tapped to meet peak water demands and other contingencies.

Accordingly, from the outset, it was widely recognized that there were important benefits for the region to be realized from developing a successful Reclaimed Water System. This report examines the types and magnitudes of these benefits, by applying a Triple Bottom Line (TBL) perspective to address the questions:

- What are the valuable financial, social, and environmental benefits – both monetizable and qualitative -- associated with the successful deployment of the Reclaimed Water System?
- What is the actual cost of service for producing and delivering reclaimed water to system customers, and who bears these costs?
- Who are the primary beneficiaries of the Reclaimed Water System, and who bears the costs (i.e., how well are the cost allocations aligned with benefits and beneficiaries)?

The section that follows briefly describes the core concepts and process for developing the TBL-based benefit-cost analysis for the Tucson Reclaimed Water System. Subsequent sections provide empirical evaluations of benefits and costs.

4. Approach for Assessing the Beneficial Value of the Tucson Water RWS

This portion of the TM establishes the basic principles for the economic benefit-cost analysis performed here, including the importance of establishing a useful baseline and applicable timeframe for the analysis. This portion of the report also provides a qualitative overview of the key types of benefits and costs associated with the Reclaimed Water System.

4.1 Establishing the Baseline and Timeframe

In assessing the benefits and costs of the Reclaimed Water System, several core economic principles and practices apply. First, the analysis is *comparative*, meaning that we are examining the benefits and costs of the current Reclaimed Water System relative to an alternative of not having the Reclaimed Water System. This is referred to as *establishing the baseline*, where the baseline reflects the situation in which Tucson would *not* have developed, maintained, and operated the Reclaimed Water System (i.e., it is the "without" Reclaimed Water System scenario).

Another key aspect of developing a sound benefit-cost analysis (BCA) is establishing a useful *timeframe* for the analysis. The analysis may be *retrospective* (looking backward to what might have been), or it can be *prospective* (looking forward from today into the future). There are challenges in applying either timeframe. For example:

- A *retrospective* of the Tucson Water Reclaimed Water System would entail hypothesizing how the region would have developed (or not) over the course of the past 40 years if no Reclaimed Water System had been developed – a highly challenging and largely hypothetical exercise. What would the region's economy and population look like today absent 40 years of Reclaimed Water System supply? What actions would have been deployed absent the Reclaimed Water System to comply with the Groundwater Management Act and related Aquifer Management Area requirements? What benefits would have been forgone? What costs were incurred or avoided?

- A *prospective* analysis entails starting from the present and predicting the future. The question addressed is: What would happen if the existing Reclaimed Water System was shut down or scaled back considerably, or redeployed to other uses (e.g., applied primarily for stream restoration instead of turf irrigation focused largely on golf courses)?

This study applies a forward-looking prospective analysis, meaning that it focuses on the current program and circumstances as a means of informing deliberations about potential future directions for the Reclaimed Water System program, and associated deliberations regarding cost recovery and rates. However, the analysis also incorporates some retrospective aspects to establish the relevant baseline. In this hybrid approach, the retrospective aspect entails assuming, that absent the Reclaimed Water System (i.e., the baseline), the City and County would be supporting the existing level of population and economic development as has occurred over the past 40 years, but they would have done so by deploying an alternative water supply (i.e., an expanded potable supply) rather than the Reclaimed Water System to meet the total water demands of the service area.

4.2 Defining Applicable Types of Triple Bottom Line Benefits: Conceptual Discussion

This economic analysis applies a Triple Bottom Line (TBL) perspective that articulates a broad range of applicable financial, social, and environmental benefits and costs associated with the reclaimed water system. These TBL benefits and costs are compared to a baseline alternative of not having reclaimed water available. The analysis also entails describing who receives the key benefits, and who pays for the system.

This section of the TM provides a conceptual discussion of the types of benefits and costs that are attributable to the Reclaimed Water System. Empirical evaluation of applicable benefits and costs are developed in Sections 5 and 6, respectively.

4.2.1 Avoided Costs

One of the primary benefits that typically arises from a water reuse project is the avoided costs arising from being able to eliminate or postpose expanding and upgrading the community's potable water system and/or its wastewater system. Avoided costs typically entail both the (1) capital investment and other upfront costs that would be incurred by the potable water supply and wastewater systems, as well as (2) ongoing operation and maintenance (O&M) costs.

For example, a nonpotable water reuse project often reduces the need to add new potable sources to the community's water supply portfolio – new sources that, absent the reuse system, would be needed to meet growing community water demands. The nonpotable reuse system typically reduces peak season and peak hour demands faced by the potable system, with associated cost savings from not having to upsize the potable water distribution and pumping system. The benefit of these cost savings ultimately accrues to the potable utility customers in the form of water bills that are lower than they otherwise would have been. As detailed in Section 5.1 (and Appendix B), the avoided cost of expanding the potable supply is a considerable monetized benefit arising from the Reclaimed Water System.

Likewise, wastewater system costs may be avoided by creating a reclaimed water system to reuse wastewater effluent that would otherwise require additional treatment to meet increasingly stringent discharge permits. Thus, wastewater system upgrade and/or expansion costs may be avoided or postponed by investing in a water reuse program. Under such a scenario the wastewater utility customers accrue these benefits by having lower wastewater bills than they would have faced otherwise. In the case of the Tucson Water Reclaimed Water System, however, there may be limited wastewater-related avoided costs as, under the terms of the IGA, Pima County has incurred considerable expense to comply with increasingly stringent effluent discharge regulations even though the treated effluent is recycled rather than directly discharged.

Avoided costs are often significant because obtaining new potable water supplies typically would have been an expensive proposition. However, *these cost savings often are overlooked because avoided costs do not appear on any agency's fiscal accounting ledger*. Utility fiscal accounts do an excellent job of tracking expenses that are incurred, but there is no place on a utility's standard accounting ledger for expenses that are avoided due to wise investments in reuse or other cost-saving activities. For our analysis of the Tucson Reclaimed Water System, we examine the avoided costs that would have been incurred to expand the potable system to supply water to the customers who purchased Reclaimed Water System water.

4.2.2 Enhanced Regional Water Supply Reliability and Resiliency Benefits

Diversifying the regional water supply portfolio by including reclaimed water is a valuable way to increase the community's water reliability and resilience. Reclaimed water provides advantages in that it is a locally generated supply and one whose source water is largely drought insensitive.

- As a local supply source, the quantity and quality of the available supply is not subject to potential disruption as may be associated with waters imported from outside the region. For example, imported water supplies -- such as a Central Arizona Project imported surface water from the Colorado River system -- may be periodically curtailed by regulatory limits, political pressures, or natural events such as droughts, seismic disruption, or wildfire. For 2021, CAP allocations statewide were expected to be reduced by 18% due to drought-related impacts on the Colorado River system (Davis, 2021). Although the impact on Tucson Water's CAP allocation is expected to be minimal (i.e., in Tier 1, Tucson's allocation of CAP water was not reduced in 2021), prolonged severe drought conditions continue to adversely impact the Colorado River system.

- As a supply derived from wastewater effluent generated by local indoor water use, there is little fluctuation in the quantity of available source waters. Indoor water use is generally stable regardless of drought conditions. This is because drought-related water supply shortages typically result in curtailments that focus on limiting outdoor uses and typically have modest impacts on indoor water use.

Having a locally generated and controlled supply of effluent, with reliable yields from season to season and year to year, means that the reclaimed supply is more reliable (a predictable, stable yield) and more resilient (avoiding risks imposed by external events). There is real economic value in including a reliable and resilient water supply option in the community's water supply portfolio, as demonstrated by several empirical investigations.

Residential customers value the increased certainty that they will not face water use restrictions that are as severe or frequent as they might otherwise. Business entities likewise value the enhanced certainty (reduced uncertainty) about the availability of a reliable water supply for operating their enterprises, which may incentivize companies to maintain or expand their operations in the region, and may attract new businesses to the region. Raucher et al. (2013, 2015) provides a review of the relevant empirical and conceptual studies on the value of water supply reliability for residential and business customers, and they also offer empirical estimates based on statistically significant analysis.

4.2.3 Contributions to Water Banking via Groundwater Storage and Subsidence Management

The RWS provides water that is applied to (and credited for) groundwater recharge, which has value to the community by contributing to the replenishment of local groundwater resources. Replenishing local aquifer systems contributes to higher regional groundwater levels, reduced subsidence, and increased City of Tucson banked water reserves. Additionally, groundwater replenishment enables Tucson Water to accrue aquifer recharge credits. These recharge credits provide Tucson Water with additional flexibility for drawing additional groundwater in times of need.

Groundwater recharge is accomplished through the direct use of reclaimed water to supplement groundwater banking through net positive recharge at the Sweetwater Wetlands facility. Positive net recharge at the facility occurs in years when Reclaimed Water System recharge volumes in periods of relatively low reclaimed water demand exceed withdrawals to meet peak season Reclaimed Water System demands. On average, Tucson Water receives credits for a net 8,000 to 9,000 AFY of groundwater recharge using Reclaimed Water System water. Groundwater recharge also is conducted at other locations, including the Santa Cruz River Heritage Project, arising from the use of reclaimed water to provide instream flows to targeted portions of the Santa Cruz River.

Groundwater recharge and related water banking provide considerable benefits to the region. The City estimates it now has banked approximately 50-years of water supply through its groundwater banking program, using a portion of its CAP water allocations and reclaimed water. As of 2017, Tucson Water estimates it has stored enough reclaimed water to meet one year of demand (2018 Status of the Aquifer Report, Tucson Water).

4.2.4 Enhanced Ecosystems and Related Recreational and Aesthetic Opportunities

The Reclaimed Water System supports several recreational and aesthetic values and natural functions that enhance ecosystems and provide valuable opportunities for life-enhancing activities for community members. More specifically, the Reclaimed Water System supports several natural systems, including the Sweetwater Wetlands, riparian habitat through portions of the Santa Cruz River via the Santa Cruz River Heritage Project (through downtown Tucson), and the Southeast Houghton Area Recharge Project (SHARP). The Sweetwater Wetlands, for example, provide valuable benefits for community members and others who visit the site for its educational facilities, excellent birdwatching opportunities (including numerous Audubon Society-led birdwatching tours), walking, biking, and other outdoor activities.

4.2.5 Regional Economic Impacts (Multiplier Effects)

The availability of reclaimed water has enabled the Tucson region to develop as a premier destination for golf, thereby drawing in considerable revenues from visitors traveling to the area to engage in the sport and related activities. Tourism-related expenditures brought into the region for lodging, meals, green fees, retail shopping, and other activities stimulate a "multiplier effect" on the regional economy, providing what economists refer to as direct, indirect, and induced economic benefits. These benefits take the form of increased regional economic output, employment, income, and tax revenues. While these economic impacts are not included within benefit-cost analyses (because they reflect a transfer of economic gains from one location to another, rather than a net gain for the national economy), they are nonetheless relevant and important for local and regional entities. As shown in Section 5.4 and Appendix C, the regional economic benefits for the Tucson region arising from the influx of golf-related tourism is significant.

4.3 Defining Applicable Reclaimed Water System Costs

As with most water projects, the RWS has required a mix of upfront expenses (capital outlays) to build the system, as well as recurring, ongoing expenses to operate and properly maintain the system (O&M costs). All these costs need to be recognized and combined within a standard accounting framework to assess the "cost of service" for the Reclaimed Water System RWS. This may be accomplished through a "present value" approach, in which costs incurred in each year are tracked (or estimated for future years), and then discounted back to a base year. An alternative (but essentially equivalent) approach entails annualizing the one-time capital expenses and adding them to the annual O&M costs to develop a "total annualized cost" over the multi-year project period (e.g., 20 or 30 years).

A conceptual discussion of the costs is provided in sections 4.3.1 through 4.3.3, below. Section 6 of this TM provides an empirical evaluation of the estimated cost of service for the Tucson Reclaimed Water System. It also describes the "cross-subsidy" provided by potable water ratepayers, and associated rate setting issues. Appendix D provides a discussion of rate-setting principles and approaches for pricing recycled water.

4.3.1 Capital and other Upfront Costs

Developing the Reclaimed Water System required several upfront investments including permitting, planning, and related project development expenses, as well as the actual expense of building the facilities (e.g., acquiring land and rights of way, constructing facilities, acquiring and installing treatment process equipment, and developing the pipelines and pump stations needed for conveyance of the product water to customers). Most of these capital expenses are large one-time expenditures, or for long-lived assets that will not need to be replaced for decades (e.g., treatment equipment and pipelines typically last for two or more decades before requiring significant replacement, and distribution pipelines may last a century).

Large capital projects often are financed (at least in part) through debt service spread over 20 years or more, and often at favorable rates of interest (e.g., through government-subsidized loan programs such as the federal State Revolving Fund). Grants may be available to help offset a portion of the capital expense.

4.3.2 Operations and Maintenance (O&M) Costs

The Reclaimed Water System incurs ongoing expenses for operating and maintaining the system. The O&M costs include direct expenses for energy, staffing, and other materials and services associated with reclaimed water production and distribution, as well as operational and other support services.

4.3.3 Opportunity Costs

The funds devoted to developing and operating the Reclaimed Water System could have been deployed for other beneficial purposes, if not directed at building and maintaining the Reclaimed Water System.

The concept of opportunity costs reflects the foregone value that would have been obtained had the money been directed to these other activities. For example, the affordability of water is an increasingly pressing issue for lower-income households served by many public water systems. An opportunity cost of the historical and current arrangements for financing the Reclaimed Water System is that some funds used to develop the Reclaimed Water System could have been otherwise dedicated to addressing water access and affordability issues impacting Tucson's most economically disadvantaged.

In terms of the opportunity costs associated with low-income water affordability, the salient issue is not whether the Reclaimed Water System provides tangible (and intangible) benefits to all Tucson Water customers (as outlined in this Technical Memorandum). Rather, an underlying question is whether the extent of subsidy employed to date, and embedded in current rate setting practice, could and should be altered to provide funding for other purposes like more pronounced and substantive redress of low-income water affordability challenges.

Central to this question are several considerations (some of which fall outside the scope of this review) including:

- Whether the extent of subsidy provided to the Reclaimed Water System may be reduced without adversely impacting benefits accrued (as described herein). In other words, are subsidies at current levels required, or may reclaimed system development and operation, supported by local regulation, proceed with reduced levels of subsidy?
    - Tucson Water's historic levels of subsidy (with rates recovering approximately 70 percent of allocated costs over the last 5 years) are marginally higher than the average among a national survey of reclaimed water systems (Carpenter et al., 2008).
    - Tucson Water's reclaimed water system is relatively mature with a supporting regulatory structure, community acceptance, and substantial infrastructure in place – all dampening the need for incentives to prompt accessing the reclaimed system.
- What are the legal and institutional constraints on how funds allocated for Reclaimed Water System development could be redirected for other purposes like funding low-income water affordability measures?
- What are the tangible (and intangible) benefits that may accrue from redirecting the Reclaimed Water System subsidy to instead support alternative purposes, like low-income water affordability program funding, as compared to the benefits that may be foregone by truncating the reclaimed system subsidy?

In general, there seems little question that Tucson Water's historical policies to advance Reclaimed Water System development have led to profound tangible and intangible benefits (unavailable from investment in alternative water supply sources). In this respect, historic opportunity costs were overwhelmed by the investment returns from supply diversification. Yet, with the development and maturation of the Reclaimed Water System, with its attendant delivery of disproportionate benefits to reclaimed water users, key questions arise as to whether historic subsidies should be moderated and related funds redirected to other Tucson Water service delivery imperatives.

4.4 Benefits approach summary

The Reclaimed Water System provides a wide array of benefits to the people, businesses, and communities in the greater Tucson region. The Reclaimed Water System also imposes costs borne by its reuse customers and, through subsidized rates, customers of the City's potable system. The next portions of this report focus on (1) describing the types and estimated size of the benefits, (2) assessing how those benefits are distributed across locations and parties who directly or indirectly are the beneficiaries of the RWS, (3) estimating the actual cost of service for the reclaimed system, and (4) how the allocation of costs and subsidies aligns with the scale and distribution of benefits.

5. Empirical and Qualitative Assessment of Applicable Benefits

This section of the TM provides empirical information regarding the magnitude of the types of benefits and avoided costs that could be readily and reliably estimated for the Tucson Water Reclaimed Water System.

5.1 Potable System Avoided Costs as Benefits Attributed to the Reclaimed Water System

The primary avoided cost arising from the Reclaimed Water System is the estimated expense that would have been incurred by expanding the potable supply (in lieu of developing the Reclaimed Water System) to offset the approximately 35 mgd of peak period reclaim water demand (reclaimed system peak demand was 30.5 mgd in 2012, estimated at 35 mgd for 2021, and projected peak day demand for 2030 is 41 mgd, per Malcolm Pirnie, 2013). That is, we apply an "*avoided cost"* approach to determine the value to the community of having 35 mgd of reclaimed water as an offset to needing to expand the potable system to meet an additional 32 mgd of potable water demands.

Facilitating this assessment is the availability of a recent analysis of the financial benefits of the water conservation/demand management programs implemented by Tucson Water. The report, *Water Conservation Keeps Rates Low in Tucson, Arizona: Demand Reductions Over 30 Years Have Dramatically Reduced Capital Costs in the City of Tucson,* was prepared by Peter Mayer for the Alliance for Water Efficiency (Mayer, June 2017). Mayer estimated that the amount of potable peak demand period water saved through the demand management programs between 1989 and 2015 was 35 mgd. This reduction in peak demand is similar in size to the potable water demand offset provided by the Reclaimed Water System. This similarity in scale enables us to interpret the values derived in the Mayer 2017 report for our purposes of estimating financial benefits derived from the Reclaimed Water System – in the form of avoided costs for the potable system. The methodology and data applied by Mayer is summarized in Appendix B.

Interpreting the Mayer 2017 study enables us to assess the water supply alternative that presumably would have been selected to meet total regional water demands if reclaimed water was not developed. The results of the Mayer study show that, as of 2015, Tucson customers paid combined water and wastewater rates that are at least $133 lower than they would have been if Tucson residents had not lowered demand on the potable system by 35 mgd. As Mayer notes: "Essentially, by conserving water each water and wastewater customer has avoided the costs of acquiring, delivering, and treating additional water supplies that would have been necessary to provide a reliable water supply to a growing population" (Mayer, 2017).

Of this estimated savings, Mayer attributes 62.6% of this savings to the water supply component of avoided costs, for an average potable water supply cost savings of $83.26 per household, in 2015 dollars. Mayer also notes that Tucson Water's potable rates were 17.7% lower in 2017 than they would have been absent the 35 mgd savings. Updating to current year values, avoided costs from reducing the need to expand the potable system amounts to <u>$90.75 in annual average water bill savings per</u>

household for Tucson Water customers, in 2021 dollars (updated using the CPI). The remaining 37.4% of conservation-related savings are attributed to wastewater program avoided costs (which do not apply to our analysis of the Reclaimed Water System, although they do represent a savings enjoyed by City and outside-of-city customers of the Pima wastewater system).

Similarly, by developing the Reclaimed Water System, the associated reduction in customer use of *potable* water has extended the City's water supply decades into the future. This in turn helped Tucson avoid purchasing additional water supplies, defer investments in new large-scale infrastructure and system expansion projects, and has been able to scale down the size of new water supply facilities. As such, savings for potable system customers is estimated to be $91 per year for an average single-family household.[4]

5.2 Reliability and Resiliency Benefits, and Groundwater Storage Values

As noted previously, in section 4.2.2 and 4.2.3, the Reclaimed Water System provides the community with enhanced reliability and resiliency of the region's water supply portfolio, by including a locally generated and controlled, and climate-independent, water source. Additional groundwater recharge and storage/banking benefits accrue as well. Through 2020, Tucson Water has stored over 35,000 acre-feet of reclaimed water underground for future use (per Dee Korich, Tucson Water).

Empirical estimation of the full value of these benefits for the Tucson Reclaimed Water System is limited by the available data. Nonetheless, credible empirical studies conducted in other locations suggest the reliability enhancement values for Tucson Water's business and residential customers may be significant – E.g., on the order of $45 per year per household to avoid 20% water use restrictions in one year out of the next 20 years (Raucher et al., 2013).[5] In terms of regional economic activity, the value of reducing a potential regional water supply shortfall from 25% to 15% (i.e., reducing the shortfall from 25% to 15% of annual demand) has been shown to exceed $500,000 per AFY in terms of regional economic output in California's Bay Area (e.g., M Cubed, 2008).

In addition, Tucson Water's active groundwater recharge program has been enhanced by its use of the Reclaimed Water System, thereby providing the region with the value of a more reliable and sustainable supply (and associated regional economic benefits). Net groundwater recharge attributable to the Reclaimed Water System averages between 8,000 and 9,000 AFY (Scully, 2021). If replaced with CAP water at a cost of $372/AF for the CAP water and expense of groundwater recharge (per Malcolm Pirnie/Arcadis, 2013), then the value of recycled water to the community equals an additional $3.0-$3.4 million per year.

[4] In the context of opportunity costs discussed in Section 4.3, low-income customers also benefit from the savings on water rates associated with the reclaimed water system. However, the current policy question is would/could greater benefits to low-income customers be rendered by reducing the level of subsidy to reclaimed water customers and instead using those subsidy funds to directly provide low-income water customer assistance.

[5] For example, if modest-level water use restrictions were likely to be imposed in 5 of the upcoming 20 years, then the typical household would have a willingness to pay an extra $225 per year (5 * $45) to reduce that risk.

5.3 Recreational, Aesthetic, Ecologic, and Related Quality-of-Life Benefits

In addition to avoided costs and water supply reliability benefits – which are highly valuable in their own right – several other aspects of recycled water use benefit the region, although these are more difficult to quantify. Among these are ecosystem, recreation, and related social "quality-of-life" benefits. The importance of these often nonmonetized benefits is reflected in the fact that the US Water Alliance recently awarded the City of Tucson its 2021 prize for *Outstanding Public Sector Organization.* The Alliance specifically cited Tucson's recycled water and "green stormwater" programs in recognizing the city for its work advancing sustainable, integrated, and inclusive solutions to water challenges. (US Water Alliance, 2021). Ecosystem restoration and recreation are accomplished with recycled water through three notable projects, as described below.

Originally, the filter backwash flow from production of recycled water at Tucson Water's Sweetwater Recycled Water Facility was used to create and maintain the Sweetwater Wetlands. With improved water quality from the Pima County Water Reclamation Facilities, the filters are no longer required, so the Sweetwater Wetlands are now maintained with water from the recycled water system.

The Sweetwater wetlands provide numerous additional recreational uses, including an education program, self-guided tours, field trips, and individual birding and wildlife viewing opportunities. The site is 60 acres and contains paved and unpaved paths open to the public. There are self-guided tours offered through Tucson Water and Arizona Project WET, in which users can use a QR code reader app to view the Wetlands in a scientific way. The Tucson Audubon Society offers weekly birding field trips, and the site is a popular birding site, as it attracts a wide variety of species, several that are hard to find in the broader desert area (personal communication, Luke Safford).

The site is open to the public, and data are not available on the total number of users at the site. However, we can estimate the monetary value of the guided trips conducted by the Tucson Audubon Society. Tucson Audubon Society keeps data on the number of visitors who participate in their weekly field trips. On average[6], about 1,500 participants join their guided trips each year. To estimate monetized values associated with this recreation, we apply the consumer surplus value for wildlife viewing from the publicly available Recreation Use Values Database. The average consumer surplus value for wildlife viewing is $74.50[7] per individual trip (Oregon State University College of Forestry, 2016). Multiplying this value by the number of guided field trips taken with the Tucson Audubon Society at Sweetwater Wetland, we estimate the value of the guided field trips at around $111,000 per year, ranging from $105,000 to $120,000.

There are also anecdotal data sources available that do not quantify or monetize the recreational use at the recycled water-supported sites and indicate these sites provide enhanced recreational opportunities through improved aesthetics and variety of species. The website "eBird" is an online portal for birders to record species sightings and rank birding sites. Sweetwater Wetlands is listed as among the top 4 "hotspots" of birding sites within Arizona.

[6] Data provided by Luke Safford on 6/25/2021. We calculated the average number of participants from 2017 – 2019, the years in which the tours were fully operational.
[7] Converted to 2021 USD using the Consumer Price Index calculator.

Another notable site providing recycled water-generated ecological and recreational benefits is the Santa Cruz River Heritage Project. Launched in June 2019, the Heritage Project reintroduced perennially flowing water into the otherwise dry Santa Cruz River after an 80-year absence. The restored river is not only vital to the environment, but also to Tucson's history, culture, and identity. The project provides enhanced recreational opportunities through improved aesthetics and an increased variety of vegetation and wildlife since recycled water has been added, starting in 2019. The Santa Cruz River Heritage Project site is along the Tucson "Loop" trail, and while the increased flow from Reclaimed Water System does not directly provide additional recreational use, the habitat enhancements improve recreators' enjoyment of the area. As noted in James (2021), "[after 2 years of water Reclaimed Water System discharge] a portion of the Santa Cruz that hadn't flowed continuously since the early 1900s is once again teeming with life: cattails, dragonflies, red-spotted toads, red-winged blackbirds."

In addition, the South Houghton Area Recharge Project (SHARP) is a 40-acre recharge and recycle water project comprised of three recharge basins receiving recycled water from the Houghton Reclaimed Reservoir. This water soaks into an area of the aquifer that has declined in the past years. SHARP also provides opportunities for community recreation and interaction. It is the first recharge project in Tucson open to the public, and it provides green space for walking, running, and biking (US Water Alliance, 2021).

While difficult to express in monetary terms, the benefits provided by the Sweetwater Wetlands, Santa Cruz River Heritage, and Southeast Houghton Area Recharge projects clearly represent considerable recreational, aesthetic, and educational value for the community. Compounding the value provided by recycled water, these projects also help alleviate the "heat island" impact of urban hardscape, which is predicted to intensify risks to public health and well-being under changing climate conditions.

5.4 Regional Economic Impacts Associated with the RWS

The assessment of who benefits from the Reclaimed Water System is examined in greater depth by exploring how the benefits created are magnified and distributed through the region's economies (e.g., between the City and entities outside of City limits served by Tucson Water). Appendix C describes in greater detail both the methodology and empirical results for how the provision and pricing of reclaimed water translate into "regional economic impact" benefits (e.g., employment, income, output), and how those benefits are distributed between the in-City and outside of city limits Tucson Water service area.

5.4.1 Methodology

The technical approach entails applying the well-regarded and widely applied "IMPLAN" regional economic input-output (I/O) model to address the question, "How does the local economy within the City of Tucson – and the local economy in the service area beyond city limits – realize regional economic multiplier beneficial outcomes arising from the direct, indirect and induced economic impacts of enterprises supported by the Reclaimed Water System?"

The empirical approach examines the level of tourism drawn to the Tucson area as a destination golf location. The number of visitor trips drawn by local reclaimed water-reliant golf courses and associated visitor expenditures are allocated between within- and beyond city limits. IMPLAN model runs then provide credible estimates of how that tourism-driven spending translates into valuable local economic outcomes including increased output, employment, labor income, and local tax revenues.

5.4.2 Regional Economic Impact Benefit Estimates

As detailed in Appendix C, there currently are 19 golf courses supplied by the reclaimed system. Six of these are within City limits, and the remaining 13 are located within the service area beyond city limits. An estimated 14,684 golfing destination trips to the reclaim-using golf courses are estimated, with nearly 12,000 of these attributed to service area golf destinations outside of city limits. An average expenditure of more than $2,800 per golf-driven trip translates into more than $41 million annually being added to the local economies in the form of *direct* economic impacts.

As golf courses, hotels, restaurants, and other enterprises provide their goods and services to visiting golf-oriented tourists, these local businesses spend portions of their increased revenues on the intermediate goods and services they require to meet the added demand. The portion of that *indirect* spending on local labor and other local services and commodities in turn provides additional economic stimulus within the regional economies, in the form of a further round of spending[8]. This additional round of *induced* spending – such as additional expenditures made by households for whom incomes have increased from the direct and indirect demands – then further stimulates the local economies. Regional economic impact/multiplier benefits to both the City and the broader region are estimated and summarized below.

Local spending by visiting out-of-region golfers is estimated to generate for the service area economies as a whole:

- 555 added jobs per year
- $16.5 million in added regional employment income per year
- $49 million in additional annual revenues for service area businesses
- $48.4 million in added regional economic output annually
- $7.1 million in added tax revenues per year.

For the City of Tucson, the portion of these total estimated annual economic gains that are expected to be realized within city limits include:

- 144 added jobs per year (26% of total job gains)
- $5.2 million in annual labor income (32% of total)
- $16.1 million in added yearly economic output (33% of total)
- $1.9 million added tax revenue per year (27% of total)

Additional details are provided in Appendix C.

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[8] Note that the portions of direct, indirect, and induced spending that is directed to goods and services provided from *outside* of the local region are *not* included in the estimation of local economic impacts.

5.5 Summary of Reclaimed Water System Benefits

A summary of the benefits provided by the reclaimed water system is provided in Table 5-1. The benefits that can be reasonably monetized amount to more than $49 million annually, or $40 million per year if annual revenues are excluded. Additional important benefits that cannot be readily quantified or monetized also are described.

Note that these monetized "total benefit" estimates do *not* include the regional economic impact benefits (including $41 million in local expenditures by destination golf visitors, nor the additional $5.8 million added to Tucson-area regional economic output). The economics profession discourages including inter-regional transfers of economic activity within benefit-cost analyses, as these results reflect a redistribution of economic activity across locations within the United States and not a net gain in overall national economic values. Nonetheless, these regional economic impact gains are important and relevant for the City of Tucson and its broader service area, and they are developed and presented in this assessment to help inform local policy deliberations.

Table 5-1 Key Benefits provided by the Tucson Reclaimed Water System

Benefits		
Benefits: Monetized	**Estimated Value**	**Comments**
Avoided Costs for Potable System	$37 Million per year ($11M in annualized capital outlays, plus $26M in annual O&M expenses)	Approximately $91 per year savings for a single-family residential household in City
Banked storage in groundwater (average of about 9000 AFY)	$3.0 to $3.4 M/year (on average)	Based on cost of acquiring and groundwater storage of CAP water
Audubon-led birding outings at Sweetwater facility	>$0.1 M/year	Does not include other birding, wildlife observation, or other recreational or educational activities at Sweetwater
Revenues for Reclaimed Water Sales	$9 Million per year	Based on 2019-2020 rates
Regional economic impacts from nonlocal golf course visitors (associated with Reclaimed Water System-enabled golf course turf irrigation)	$8.5 million in added regional economic output (as well as 550 added jobs and $7.1 M in added tax revenues)[9]	Based solely on economic impact of nonlocal visitors to region with express purpose of trip being golf
Benefits: Not Quantified	**Description**	**Comments**
Enhanced diversification and sustainability of water portfolio	More reliable and resilient supply portfolio for the served region	Also aids in restoring groundwater levels
Enhanced ecosystems and related recreational, aesthetic, and quality of life benefits.	Sweetwater Wetlands, Santa Cruz River Heritage Project, and Southeast Houghton Area Recharge Project as examples	Providing recreational, aesthetic, educational, cultural, wildlife and ecosystem restoration values to the community.
Total Benefits	**>$48 million per year[7]**	Does not include nonmonetized and regional economic impact benefits

[9] Regional economic stimulus values are not appropriate to include in the monetized benefits total, as they may be diverting economic activity from other regions (e.g., Phoenix). However, these values are important for the City of Tucson and Pima County.

6. Empirical Assessment of Reclaimed Water System Costs

This section provides an empirical estimate of "cost of service" for providing reclaimed water to the system's customers. The size and allocation of the estimated cross-subsidy from potable water customers is also provided. In addition, Appendix D provides an overview of principles and guidelines for recycled water rate setting.

6.1 Current Rate Setting Framework

Historically, Tucson Water has updated water rates on an annual or biennial basis following standard industry cost-of-service rate setting methods. Under the current framework, annual utility revenue requirements are determined for one or more budget "test" years based on a "cash needs" approach. Cash-needs revenue requirements include O&M expenses, taxes, and capital costs (debt service and annual rate funded capital improvements).

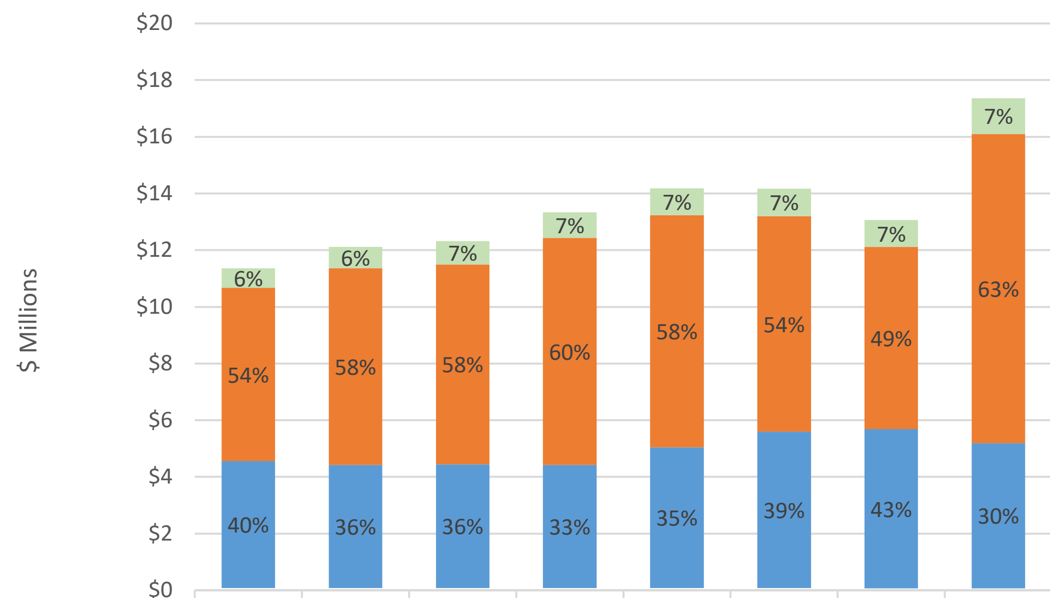
Annual revenue requirements are then allocated among different utility services including potable and reclaimed water services, customer billing, and meter-related services. Potable water costs are further allocated to individual customer classes based on average and peak water usage characteristics. For the reclaimed water system, the basic rate-setting framework does not differentiate among reclaimed water customers when estimating costs of service; however, rates for some customers (e.g., wheeled water and interruptible service) are determined according to provisions established in negotiated contracts.

6.2 Historical Reclaimed Water System Costs

Figure 6-1 provides a summary of reclaimed water system cost components as determined by each rate update over the past decade (with dollar values in millions). Rate updates were performed annually through fiscal year (FY) 2017 and then were performed every two years through FY 2021. The last *adopted* cost-of-service analysis was completed in 2019 and it established reclaimed water rates for standard (i.e., non-contract) customers for FY 2019 and FY 2020. In early 2020, an updated cost-of-service analysis was performed for the FY 2021 test year; however, the resulting rates were not implemented due to the COVID-19 pandemic and City Council's decision to temporarily suspend rate increases. While the rates were not adopted, the FY 2021 reclaimed cost of service results are included in this report for comparison because they are part of the public record[10] and they represent the most recent reclaimed water system cost estimates.

[10] See Mayor and Council Memorandum: *Tucson Water's Five-Year Financial Plan, Rate Revision Process, and Proposal of FY2021-FY2024 Water Rate Schedule (City Wide and Outside City),* March 3, 2020.

Figure 6-1 Annual Reclaimed Cost of Service Components (2012-2021)



	2012	2013	2014	2015	2016	2017	2019	2021
Total	$11.3	$12.0	$12.2	$13.3	$14.1	$14.1	$13.0	$17.3
Other	$0.7	$0.8	$0.8	$0.9	$1.0	$1.0	$1.0	$1.3
Capital	$6.1	$6.9	$7.1	$8.0	$8.2	$7.6	$6.4	$10.9
O&M	$4.5	$4.3	$4.4	$4.3	$5.0	$5.5	$5.6	$5.1
Reclaimed % Total COS	7.7%	7.8%	7.8%	7.8%	7.9%	7.8%	6.2%	7.2%

Total reclaimed water system costs increased at a compound average annual rate of 4.9 percent between 2012 and 2021, which was slightly lower than the average annual increase in total Tucson Water revenue requirements of 5.7 percent. Therefore, the reclaimed system's share of total costs decreased slightly from 7.7 percent to 7.2 percent, as shown in Figure 6-1. The individual revenue requirement components and allocation methods are discussed in the subsections that follow.

6.2.1 Operation and Maintenance Costs

Direct costs for reclaimed water production and distribution include energy, staffing, and other materials and services costs which are budgeted and tracked within a distinct "object code" within Tucson Water's financial system. These direct costs made up over 70 percent of the $5.6 million in reclaimed water O&M costs in FY 2019. Other O&M costs include direct operational and engineering support costs which are allocated to reclaimed water based on staff estimates (in the case of water quality lab and water production plant operations) or in proportion to fixed asset value (in the case of engineering and planning costs). Consistent with standard industry practice, a portion of Tucson Water's general administration and overhead costs are also allocated to reclaimed water customers on an indirect basis (i.e., in proportion to directly allocated costs).

Reclaimed water O&M costs increased at a compound average annual growth rate of 3.3 percent between FY 2012 and FY 2019. Costs increased significantly between 2015 and 2017, in part due to the reclassification of some capital improvement costs such as O&M and increases in power and other direct reclaimed water system costs. In FY 2021, allocated reclaimed water O&M costs decreased by about nine (9) percent compared to the adopted FY 2019 cost of service results, reflecting a re-allocation of 20 percent of reclaimed production and distribution costs to potable water service to account for the portion of reclaimed water that is filtered into the potable water system through SHARP and Heritage facilities.

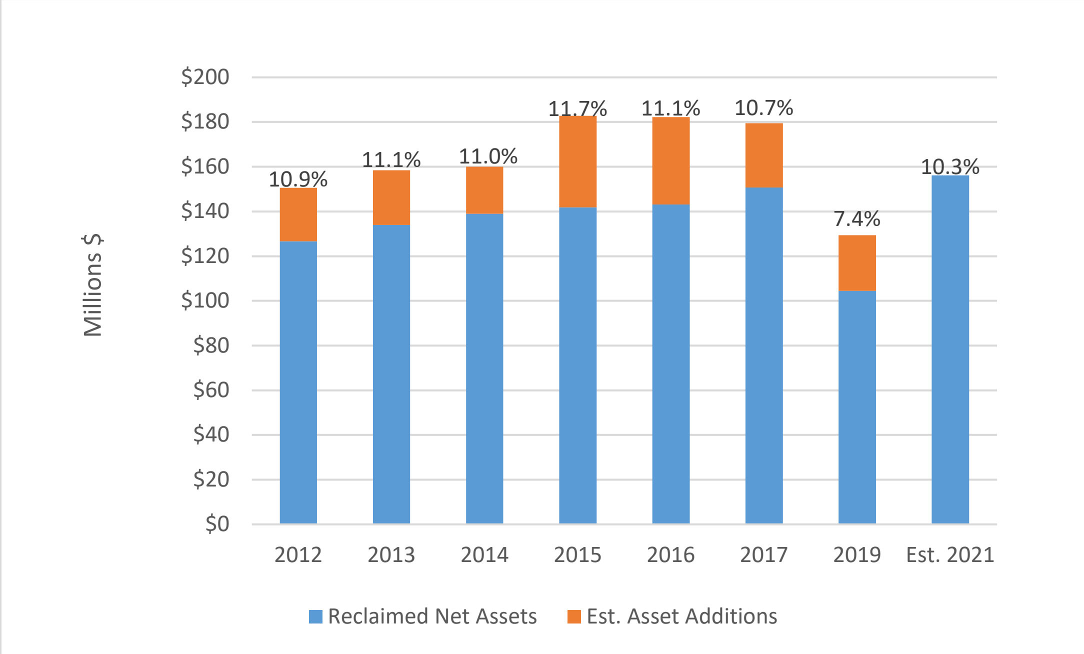
6.2.2 Capital Costs

Tucson Water's annual capital requirements include debt service and current revenue funded capital improvements. Consistent with industry practice, capital costs are allocated to different service categories (including the reclaimed water system) in proportion to system fixed asset values. Specifically, debt service costs are allocated to the reclaimed water system in proportion to net plant investment, and current revenue-funded capital costs are allocated in proportion to annual depreciation expense.

As shown in Figure 6-1, allocated reclaimed water system capital costs have fluctuated significantly over the past 10 years. While capital costs have generally increased for Tucson Water as a whole, the portion allocated to reclaimed has fluctuated due to changes in the share of asset values attributable to reclaimed, as shown in Figure 6-2. Before the most recent cost-of-service analysis conducted in 2020 (for the FY 2021 test year), system asset values used for allocations included existing net plant value plus two years of *estimated* capital improvement expenditures. The reclaimed system's share of total asset value grew between 2012 and 2015 from 10.9 percent to 11.7 percent, driven primarily by an increase in estimated asset additions. Between 2016 and 2019, estimated reclaimed asset additions decreased, leading to a decrease in capital costs and share of total asset value.

Reclassification of a portion of net assets for the 2019 cost-of-service study further contributed to a significant decline in reclaimed water system share of capital costs under the adopted rates; however, the most recent (2021) study reflected reclaimed net assets consistent with the pre-2019 values. Furthermore, the basis for determining asset value for capital cost allocation purposes was changed in 2020 to eliminate the estimated asset additions given the variability of those costs and because the estimates were not an accurate predictor of near-term increases in asset values.

Figure 6-2 Reclaimed Capital Asset Value and Share of Tucson Water Total Asset Value



6.2.3 Other Costs

Other costs included in annual reclaimed system revenue requirements include taxes (both utility and payment in lieu) and customer service and meter costs. Taxes are allocated on an indirect basis within the cost-of-service framework; therefore, the reclaimed system portion fluctuates in proportion to directly allocated costs. Meters and customer service costs are allocated to reclaimed water customers based on the number and size of meters. In total, other costs represent four to seven percent of annual allocated reclaimed water system costs.

6.3 Reclaimed Water Sales

Historical reclaimed water system revenues are a function of sales volumes and rates. Figure 6-3 shows historical estimated sales volumes[11] for standard and special contract customers between 2012 and 2021. Estimated sales volumes decreased significantly (almost 30 percent) between 2012 and 2017. However, during that same time, some golf course customers were transitioned to the standard reclaimed rates; thus, the portion of total reclaimed sales volume subject to the standard rates increased between 2012 and 2017.

Since 2017, sales volumes have increased, though most of that increase has been from special service customers (wheeling and interruptible services) whose contracts provide for significantly lower rates. For 2021, both the estimated and actual volumes are shown, as actual volumes were significantly higher

[11] The annual sales volumes shown in Figure 6-3 are estimated values developed for each rate update. The estimated volumes were used to project annual revenue from existing reclaimed water rates for comparison against the allocated reclaimed costs to determine the annual support provided from potable water customer rates.

than estimates. Because each rate process is based on a future (budgeted) test year, estimated volumes and resulting revenues are used to estimate required potable system support.

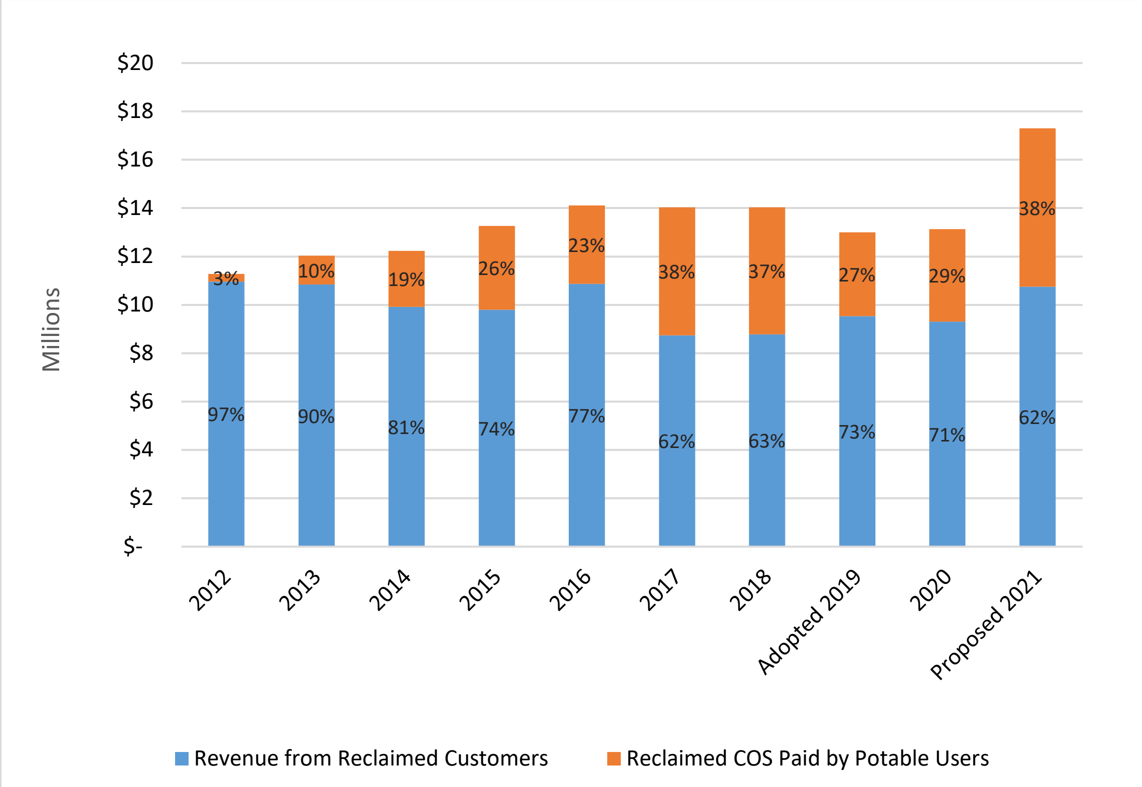
Figure 6-3 Reclaimed Water Sales Volumes (2012-2021)

6.4 Reclaimed Water System Revenues and Incentives (Subsidy)

Figure 6-4 shows the extent to which historical annual reclaimed water system costs were estimated to be funded by reclaimed water system revenues versus incentives paid by potable system customers. As was discussed in preceding sections, reclaimed water system costs increased significantly between 2012 and 2017 (about 25 percent), while estimated reclaimed sales volumes decreased (almost 30 percent), resulting in a significant increase in the reclaimed incentive paid by potable water users (from 3 percent in 2012 to about 38 percent in 2017).

During the same period, concerns were raised by members of the Citizen Water Advisory Committee (CWAC) about the difference between the standard reclaimed rates and lower contract rates charged some golf courses. Based on recommendations from the CWAC, the standard rate increases were limited to a 2.2 percent increase in 2015 to allow the golf course rates (which per the contracts, escalated annually consistent with Tucson Water's overall revenue requirements) to reach standard rate levels by 2017.

Figure 6-4 Reclaimed Revenues and Incentives Paid by Potable Users



The golf course contract and standard rates are shown in Table 6-1. Overall, the rates charged golf course customers subject to the contracts increased 30 percent between 2012 and 2017, while the standard reclaimed rate increased only about 2.2 percent.

Table 6-1 Reclaimed Standard and Contract Rates ($/ccf)

Fiscal Year	Golf Course Contract Rate	Reclaimed Standard Rate
2012	$1.43	$1.83
2013	$1.53	$1.83
2014	$1.64	$1.83
2015	$1.75	$1.87
2016	$1.81	$1.87
2017	$1.87	$1.87
2018	$1.87	$1.87
2019	$2.00	$2.00
2020	$2.13	$2.13
Proposed 2021	$2.25	$2.25

With the rate update in 2019, the estimated portion of reclaimed water system costs paid by reclaimed customer rates increased to over 70 percent, reflecting increases in both reclaimed rates and sales volumes, and a reduction in allocated capital costs. However, the 2021 update projected a significant increase in reclaimed costs supported by the potable rates due to an increase in allocated costs.

6.5 Alternative Rate Setting Frameworks

Two alternative rate setting frameworks are considered for further evaluating reclaimed costs of service and potential subsidies. Both approaches follow accepted rate-setting practices and have been used previously by Tucson Water for rate-related purposes. The first approach ("utility basis" revenue requirements) has implications for the total cost allocated to the reclaimed system, while the second approach (cost allocation to subclasses within the reclaimed system) considers potential intra-class subsidies at existing reclaimed cost of service levels.

6.5.1 Utility Basis Approach

As discussed previously, Tucson Water's regular rate-setting approach establishes annual revenue requirements using a cash needs approach. Another approach used in the water industry generally, and by Tucson Water in some special rate-setting contexts (e.g., for establishing potable water wheeling rates), is the utility basis approach. The major difference between the utility basis approach and the cash needs approach is the way in which capital costs are calculated. Unlike the cash needs approach, the utility basis includes depreciation and a return on rate base as the capital component for determining capital-related revenue requirements as opposed to actual cash expenses for debt service and current revenue funded "pay-as-you-go" capital.

Table 6-2 restates the reclaimed water system revenue requirements as utility basis for FY 2019 (the test year for the last adopted rates) and for two variations for FY 2021 (the test year for the most recent rate analysis). Reclaimed water system O&M costs are the same as under the current rate setting framework. Capital costs include estimated depreciation and a return on rate base calculated from the net assets discussed previously and shown in Figure 6-2. A variation for FY 2021 is that capital asset value is discounted by 20 percent (consistent with O&M) to reflect the benefit to the potable system related to SHARP and Heritage.

Table 6-2 Alternative Rate Approach: Utility Basis Revenue Requirements[1]

		FY2021		
Revenue Requirement Component	**Assumptions**	80% Assets	100% Assets	**FY2019**
O&M		$5.1	$5.1	$5.6
Net Assets		$124.9	$156.2	$104.5
Capital				
Depreciation[2]	1.6%	$2.0	$2.5	$1.7
Return on Rate Base[3]	2.6%	$3.3	$4.1	$2.8
Subtotal Capital		$5.3	$6.6	$4.4
Other		$0.7	$0.7	$0.5
Total Requirements		**$11.1**	**$12.4**	**$10.5**
Revenue (Projected)		$10.2	$10.2	$9.0
Difference		-$0.9	-$2.2	-$1.5
% Support from Potable Rates		7.7%	17.6%	-14.1%
% Support from Potable Rates (Current Framework)		38.8%	38.7%	27.9%

[1]Excludes Meter & Services costs
[2]From Tucson Water
[3]Average cost of debt from vail wheeling analysis

The assumed rate of return on assets is equal to the average cost of debt outstanding (2.6 percent), consistent with calculations from Tucson Water's most recent potable wheeling rate analysis. The assumed rate of return is a policy decision. The average cost of debt is used for illustration purposes since it has been used in other contexts.

As shown in Table 6-2, the capital costs differ significantly between FY 2019 and FY 2021 due to the differences in net assets discussed previously. However, in both test years, the overall revenue requirements for the reclaimed system under the utility basis are significantly less than the cash basis. For FY 2021, utility basis requirements total $12.4 million, compared to $16.7 million under the current cash basis framework[12]. If capital costs are discounted, then reclaimed costs are reduced further to $11.1 million.

With the reduction in revenue requirements under the utility basis approaches, the percent of costs recovered from potable users would have been estimated to be between -14 percent and 17 percent for FY 2019 and FY 2021, compared to 27-38 percent under the current framework.

6.5.2 Costs by Function and Subclass Approach

As discussed previously, the reclaimed water system serves both standard and contract rate customers. Standard rates are set as part of Tucson Water's regular rate-setting process which includes consideration of both the updated cost-of-service analysis and policy considerations (i.e., potable rate incentives). Rates for contract customers are updated according to the specific provisions of individual contracts. While some of the contract rates are based on elements of the cost-of-service framework, the revenue requirements are generally more limited; for example, rates for wheeling and interruptible service customers exclude capital costs entirely.

While a comprehensive cost-of-service study for reclaimed customers is outside the scope of this study, information developed for prior studies has been used to estimate potential intra-class subsidies for reclaimed customers and the extent to which rates paid by standard rate customers (which include golf courses) are aligned with estimated costs of service.

6.6 Functional Allocation of Reclaimed Water System Costs

Tucson Water provides different levels of service to customers within the reclaimed water system class. For example, wheeling customers require only distribution of reclaimed water, while standard customers require both production of the water, as well as distribution. Current contracts require that O&M costs are allocated between the production and distribution functions for determining wheeling and interruptible rates. Table 6-3 summarizes estimated costs by function for the FY 2019 and FY 2021 test years[13] based on staff estimates.

[12] Customer service and meter costs are excluded from costs and revenues shown in Table 6-2 because reclaimed customers pay service charges that recover their full estimated cost of service and the charges do not vary between the cash and utility bases.

[13] While the contracts for wheeling customers require use of actual O&M costs, budgeted test year costs are used in this report (and shown in Table 6-3) to be consistent with Tucson Water's current rate setting framework.

Table 6-3 Functional Allocation of Cash Basis Reclaimed Revenue Requirements ($M)

	% Of Total	FY2021	FY2019
Revenue Requirements Restated (Functions)[1]			
O&M [2]			
Production	67%	$3.43	$3.76
Distribution	33%	$1.69	$1.85
Subtotal	100%	$5.12	$5.62
Capital[3]			
Production	18%	$1.96	$1.16
Distribution	82%	$8.95	$5.29
Subtotal	100%	$10.91	$6.45
Taxes			
Production	34%	$0.22	$0.19
Distribution	66%	$0.44	$0.27
Subtotal		$0.66	$0.46
Total Costs	**100%**	**$16.69**	**$12.53**
Production	34%	$5.62	$5.11
Distribution	66%	$11.08	$7.41

[1]Excludes meter & services costs

[2]From Tucson Water 2014 and 2018 special rates analysis

[3]From 2013 A+ model allocations

Allocation of cash basis capital requirements (from Figure 6-1) to production and distribution functions is based on a prior (2013) allocation of fixed assets values to major system functions. Taxes are allocated to functions in proportion to combined capital and O&M costs. Overall, production and distribution costs are estimated to be 34 percent and 66 percent, respectively.

The costs by functional category are allocated to reclaimed subclasses in proportion to the estimated sales volume of each group, as shown in Table 6-4. Allocation percentages are provided separately for distribution and production costs since wheeling customers are excluded from production costs.

Table 6-4 Projected Sales Volumes by Subclass

	FY2021	FY2019
Volume (Ccf)		
Standard	3,854,988	3,812,996
Wheeling	442,890	469,812
Interruptible	1,598,309	1,561,916
U of A	116,164	102,144
Total	**6,012,351**	**5,946,868**
Percent of Total (Distribution)		
Standard	64.1%	64.1%
Wheeling	7.4%	7.9%
Interruptible	26.6%	26.3%
U of A	1.9%	1.7%
Total	**100.0%**	**100.0%**
Percent of Total net of Wheeling (Production)		
Standard	69.2%	69.6%
Wheeling	0.0%	0.0%
Interruptible	28.7%	28.5%
U of A	2.1%	1.9%
Total	**100.0%**	**100.0%**

The percentages by class and function from Table 6-4 are used to allocate the requirements from Table 6-3 to reclaimed subclasses. The results are shown in Table 6-5, along with the estimated revenue and subsidy for each subclass.

As shown in Figure 6-4, the overall reclaimed incentives (subsidies) estimated to be paid by potable water users in the 2019 and 2021 rate updates ranged from 27 percent to 38 percent. Based on the cost allocations shown in Table 6-5, the standard rate customer costs are being subsidized at a significantly lower rate (8 percent to 21 percent) compared to contract customer costs. The higher subsidies for contract customers result primarily from the inclusion of capital costs in the allocated costs shown in Table 6-5, given the contract rates are calculated based on O&M costs only.

To the extent that there are cost-based reasons for exclusion of some or all capital costs from the contract rates (e.g., prior capital contributions or limitations on facilities used), relatively more of the subsidy would be attributed to the standard rate customers. As previously noted, a comprehensive review of contract customer levels of service and prior infrastructure funding arrangements is beyond the scope of this study. The allocations provided in Table 6-5 reflect consideration of service functions only.

Table 6-5 Costs by Subclass Approach

	Annual Costs		% From Potable	
	FY2021	**FY2019**	**FY2021**	**FY2019**
Estimated Costs by Subclass				
Standard (Prod + Distribution)	$10.99	$8.31		
Wheeling (Distribution only)	$0.82	$0.59		
Interruptible (Prod +Distribution)	$4.56	$3.41		
U of A (Prod +Distribution)	$0.33	$0.22		
Total	**$16.69**	**$12.53**		
Revenue by Subclass				
Standard	$8.67	$7.63		
Wheeling	$0.30	$0.32		
Interruptible	$1.25	$1.08		
U of A	$0.01	$0.01		
Total	**$10.22**	**$9.03**		
Subsidy by Subclass (w/Allocated Costs)				
Standard (Prod + Distribution)	-$2.3	-$0.7	-21.1%	-8.3%
Wheeling (Distribution only)	-$0.5	-$0.3	-63.6%	-44.7%
Interruptible (Prod +Distribution)	-$3.3	-$2.3	-72.6%	-68.4%
U of A (Prod +Distribution)	-$0.3	-$0.2	-97.9%	-97.2%
Total	**-$6.47**	**-$3.49**	-38.7%	-27.9%
Total Subsidy as a % of Standard Costs Only (Assuming subsidy is included in standard class costs)	**-$6.47**		37.1%	29.6%

6.7 Cross-subsidy Findings

As discussed in the previous sections, the portion of reclaimed water system costs included in potable system water rates has varied significantly over the last 10 years, ranging from 3 percent to 38 percent of estimated reclaimed costs. In dollar terms, the support from the potable water system is estimated to have ranged from $0.3 million to $5.3 million, based on adopted rates over the 10-year historical period, and $2 million to $5 million in more recent years. The wide range of potable support reflects both changes in allocated reclaimed costs and estimated sales volumes.

The annual reclaimed water system costs included in the potable water rates can be converted to an estimated typical household cost by dividing the subsidy by the annual potable water sold to determine a cost per unit of volume and then multiplying that rate by typical annual usage of 96 hundred cubic feet. The estimated annual household bill that provides a cross-subsidy to the reclaimed system ranges from less than $1.00 to over $13.00 over the 10-year period, with the last couple of years estimated to be $9-$10 per year.

7. Conclusions

The Tucson Reclaimed Water System provides the City and portions of Pima County beyond city limits with a variety of valuable benefits, including:

- Significant cost savings (largely by avoiding the need to expand the potable system to meet large peak season irrigation demands).
- Enhanced water supply portfolio diversification and associated system wide improvements in reliability, resiliency, and local control.
- Increased groundwater storage and aquifer recovery.
- Recreational, educational, cultural and ecosystem values through streamflow restoration, wetland services, and enhanced green spaces.
- Regional economic impact benefits through direct, indirect, and induced stimulus, as reflected in increased City and regional incomes, output, employment, and tax revenues.

These benefits amount to an estimated value of more than $48 million per year, in addition to the regional economic stimulus provided and nonmonetized benefits. These benefits are enjoyed by both potable and reclaimed water system customers within and outside of city limits. And, the benefits exceed the total annualized cost associated with the reclaimed system of $13 million per year based on the most recently adopted cost-of-service study.

While the benefits of the reclaimed system outweigh the costs by a considerable margin, there remains a concern about the equity (fairness) and efficiency aspects of who pays for the reclaimed system. Because the revenues generated by the system do not fully recover all reclaimed system costs (as estimated by the adopted rate-setting framework), a cross-subsidy (incentive) exists and is partially paid by potable system customers and across some classes of reclaimed water system customers. Regarding the cost recovery and associated cross-subsidies/incentives, points to consider include:

- The incentive (or subsidy) paid by potable water users over the past 10 years has increased due to increases in reclaimed system costs, reductions in reclaimed sales volumes, and policy choices to hold standard rates stable for some years to allow prior golf course contract rates to catch up.
- On a per household basis, the estimated cost borne by an average potable system household in Tucson amounts to between $1-$13 per year in most recent years; whereas those same within city potable system households receive an annual estimated benefit of $91 per year due to cost savings the reclaimed system provides by avoiding the need to expand the potable system.
- An alternative cost-of-service framework (e.g., utility basis approach and recognition of potable system benefits in supplying SHARP and Heritage projects) may result in significantly lower allocated reclaimed water costs (thus reducing the estimated subsidy).
- Over a third of reclaimed water annual sales volumes are from special service customers whose rates are set based on contracts whose rate-setting provisions exclude capital costs. A more

detailed evaluation of whether these exclusions align with cost-of-service principles or policy objectives is beyond the scope of this study, which considers reclaimed costs and benefits collectively.

Appendix A
Brief History of the Tucson Reclaimed Water System[14]

A.1 Timeline

1920s	Groundwater extraction's adverse impacts become evident with drying up of the Santa Cruz River, the region's only perennial surface water body. Regional aquifer is the only available water supply source.
1950-1980	Population grows 6-fold, from 77,000 to 450,000, accompanied by rapid economic growth and associated growth in water demands from 10,000 AFY to 80,000 AFY. Groundwater table experiences severe declines. By the latter part of the 1970s, with a strong regional desire to continue growth, the need to develop a sustainable water source is widely recognized at the local and state level. 1979: Inter-Governmental Agreement (IGA) established: Pima County assumes responsibility for wastewater treatment for City of Tucson and transfers rights to 90% of effluent to Tucson; The City transfers its wastewater treatment plants to Pima County to facilitate access to federal grant monies, and Tucson takes on potable and reclaimed water service responsibilities for city and portions of the surrounding county.
1980-2000	Arizona Groundwater Management Act (GMA) (1980) establishes the Tucson "Active Management Area" and requires Tucson to document groundwater pumping levels and identify plans to reach "safe yield" for the regional aquifer. 1984: City of Tucson begins design and construction of a tertiary treatment facility and an 8 mile pipeline to supply nonpotable water to La Paloma Golf Course and Resort, sharing cost with Pima County; Pima County provides effluent to Tucson at fixed cost. 2000: Pima County and City of Tucson agree to create a Conservation Effluent Pool of up to 10,000 acre-feet per year for approved riparian projects, within the Santa Cruz River and elsewhere.
2020-Present	Mature recycled water program is an instrumental part of reliable and largely sustainable regional water supply portfolio that collectively serves ~800,000 City and county residents. Cost allocation and related equity issues continue to be part of on-going discussions between City of Tucson and the portions of Pima County it serves. 2021: Tucson Water awarded the US Water Prize for Outstanding Public Sector Organization by the US Water Alliance in recognition of TW's work (in partnership with Pima County) advancing sustainable, integrated, and inclusive solutions to water challenges.

[14] Much of this appendix is drawn from a report developed for the USEPA Water Reuse Action Plan, Action 2.16, prepared under contract to Eastern Research Group, by E. Rosenblum, S. Spurlock, F. Marcus, and R. Raucher (final draft, 2021)

By the 1970s, depletion of the Tucson region's local groundwater aquifer – the region's only local water supply option -- resulted in significant declines in groundwater levels. The City of Tucson, Arizona, and Pima County, the jurisdiction that surrounds and includes the city, were faced with the dilemma of a growing population and a declining groundwater table.

Both the city and the county had historically run wastewater treatment plants, but in 1979 they agreed to divide their responsibilities. The County took over the treatment of all wastewater and the City assumed responsibility for further treatment of effluent as well as the production and distribution of recycled water. They codified this arrangement with a formal intergovernmental agreement, which has been occasionally amended and stood the test of time. The agreement was amended in 2000 to reflect infrastructure changes, and to allocate water for approved riparian projects. The two agencies together recover the cost of service through recycled water, potable water, and wastewater charges, and they tend to stagger rate increases. The City manages the combined billing for water, sewage, and environmental services.

A.2 Regional Background

The Tucson metropolitan area, in eastern Pima County, is in the hot, arid Sonoran Desert of southern Arizona. Pima County covers 9,200 square miles (about the size of the State of New Hampshire) with a 2020 population of approximately 1.1 million people. The vast majority of the population (approximately 1 million persons) is based within the Tucson Metropolitan Statistical Area (MSA). (ASU, 2021).

Annual precipitation in the county averages less than 10.6 inches, and there are no remaining natural surface water supply sources in the region. Some rivers, like the Rillito and Santa Cruz, used to flow perennially. Now they flow intermittently when fed by stormwater. Until the beginnings of the Reclaimed Water System (RWS) in the 1980's, the only viable water supply was the regional groundwater basin – the Tucson/Avra Valley Aquifer. Given the rapid growth in water demands, the regional aquifer was tapped at unsustainable levels and groundwater levels declined by as much as 400 feet in some areas, leading to a growing concern.

The Tucson region experienced very rapid population and economic growth following World War II, as people flocked to the warm sunny climate to retire, recreate, and/or pursue the economic opportunities afforded by the area's rapid development. The region's population was 77,000 in 1950, growing nearly six-fold to more than 450,000 people by 1980, and then more than doubling again to reach approximately 1 million people by 2020.

Tucson's rapid population and economic growth generated significant increases in water demands. Total water production in the 1940's was less than 10,000 Acre Feet per Year (AFY), grew to approximately 80,000 AFY by 1980, and peaked at more than 130,000 AFY by 2000.

The City of Tucson currently is home to approximately 550,000 people. Tucson Water is a department within the City of Tucson. Mayor and Council make policy decisions and provide staff direction, but the City Manager handles day to day departmental management. The utility's service area extends into neighboring communities and portions of unincorporated Pima County. Tucson Water provides potable water and nonpotable recycled water to customers within City limits as well as portions of unincorporated Pima County beyond city limits. Tucson Water's service area population nearly doubled from approximately 420,000 in 1980, to 780,000 today. Approximately 30% of Tucson Water customers reside outside of City limits.

Pima County's wastewater agency, the Pima County Regional Water Reclamation Department (PCRWRD), is governed by the County Supervisors. Four of the five County Supervisors serve both in- and outside-city areas, promoting a regional ability to view broader shared regional interests (rather than city versus county perspectives).

Appendix B
Methodology and Data Underlying Mayer's 2017 Avoided Cost Analysis

The following text is drawn from Mayer (2017), briefly describing the approach and data used to develop his avoided cost estimates:
Mayer's avoided cost analysis starts with selecting a baseline year, in this case 1989, before demand management measures implemented in Tucson and nationally began reducing per capita water use. Another reason 1989 was selected is that reliable data for both the water and wastewater systems were available going back to that year. Total potable water production in 1989 averaged 96.4 mgd (188 gallons per capita per day (gpcd)).

In step 2 of the Mayer avoided cost analysis, a hypothetical, non-conserving water production is calculated using the 1989 baseline production of 188 gpcd. This non-conserving gpcd assumes that no conservation was implemented, and the historic level of per capita consumption persisted up to 2015 as population increased. This is the key "what if" assumption in the analysis: What if water use patterns from 1989 had persisted and were unchanged today? Total production for this hypothetical, non-conserving scenario is calculated by multiplying 188 gpcd by the population in 2015 and results in a hypothetical, daily water production for Tucson of 134.4 mgd.

The subsequent analysis steps answer the following questions:

1. What system capacity would be needed to produce and deliver an average of 134.4 mgd potable water and to treat 80 mgd of wastewater?
2. How much additional infrastructure would be required?
3. How much additional operational expense would be required?

In step 3, the additional water supply, treatment capacity, transmission capacity, and wastewater treatment and transmission capacity necessary to adequately serve the hypothetical non-conserving level of demand in Tucson was determined. The costs of expanding Tucson's infrastructure to deliver the water needed to meet the hypothetical additional demands were estimated using the best available information from Tucson Water (TW) and Pima County Wastewater Reclamation (PCWRRP) staff and other experts on the cost of securing new supply and constructing new transmission and facilities.

Per footnotes provided throughout his report, Mayer (2017) describes his working closely with relevant staff at TW and PCWRRP to obtain relevant data and other information he applied in developing the avoided cost estimates described below.

B.1 Water Infrastructure

Based on Mayer's working with TW and Pima County staff, Tucson's current peaking factor was derived as 1.4, but under the non-conserving scenario, a slightly higher peaking factor of 1.6 was used to better represent increased outdoor use. The peaking factor of 1.6 was applied to the hypothetical average day demand of 134.4 mgd, to calculate a hypothetical peak day demand of 216 mgd. The Tucson Water system, which primarily pumps recharged Central Arizona Project water from an extensive groundwater aquifer west of Tucson, has the capacity to pump and treat about 240 mgd; sufficient to meet the hypothetical peak day demand. However, because a hypothetical demand of 216 mgd is very close to maximum capacity, the Water System would need new expansion projects such as the Avra Valley Transmission Main Capital Improvement Project. This project would cost $140 million, providing an additional 40 mgd of capacity at an estimated $3.5 million per mgd.

Additionally, under this hypothetical demand scenario, Tucson Water would have also moved forward to develop new recycled water supplies, specifically the North CAVSARP-3. This 7 mgd project had an estimated cost of $2.2 million per mgd, for a total cost of $15.4 million. Both projects were deferred and may be avoided entirely because of the impact of conservation on total supply.

The total estimated additional cost of water infrastructure required to meet the hypothetical non-conserving demand was set at $155.4 million plus interest. It was assumed this infrastructure would be financed over 20 years at a 2% borrowing rate.

B.2 Water Operations and Maintenance

The current (c 2015) variable costs in the water operations and maintenance budget were found by Mayer to be $51.3 million. Under the non-conserving scenario, it was estimated that Tucson Water's operations budget would be increased by about 30% to $73.8 million, an increase of $22.4 million.

B.3 Impact on Household Water Bills

In 2015, the average single-family home in Tucson used 74,000 gallons of water per year, discharged 63,000 gallons of wastewater per year, and paid a total combined water and wastewater bill of $847 per year. However, under the hypothetical non-conserving scenario the average single-family home in Tucson would have to pay $959 per year for the same service to cover all of the additional infrastructure, operations, and maintenance charges. This additional $133 per year represents a 13.3% increase over current water and wastewater rates. The study attributes 62.6% of this savings to the water supply component of avoided costs, for a potable water supply savings of $83.26 per household (in 2015 dollars), and the remaining 37.4% to wastewater savings. Tucson Water rates were estimated to be 17.7% lower in 2017 than they would have needed to be (and PCRWRD's rates 9.4% lower than would have been necessary) if per capita potable water demand had not been reduced.

Attributing only the water supply portion of the avoided cost, Mayer's (2017) analysis indicates an estimated savings of $91 per average single family residential account ($83.26, updated from 2015 to 2021 dollars)

Appendix C
City and Regional Economic Impacts of Tucson Water's Reclaimed Water System's Golf Courses

This Appendix provides details on our analyses of the regional economic impacts associated with golf visitation at RWS customer golf courses. We describe the objectives, methods, data, and findings of the economic impact analysis.

C.1 Background and Objectives

The 2008 study, *The Importance of the Tucson Water Regional Reclaimed Water System to the Economic Vitality of the City of Tucson-Pima County Region*, asserted that "The largest economic index that is associated directly with the success of the regional reclaimed water program is the destination resort golf industry. Through the use of reclaimed water, the destination resort golf industry can expand and continually invest in ventures throughout the greater Tucson community" (Thomure and Kmiec, 2008. P. 1). This appendix describes the methods and resulting empirical estimates of the beneficial regional economic impacts of tourism at the reclaimed water system's golf course customers and explores the regional distribution of the impacts on the City of Tucson and Pima County.

Golf is important to the City of Tucson and Pima County, and to the state of Arizona. A 2016 study by the University of Arizona estimated the economic impact of Arizona's out-of-state golf tourism had an estimated $1.2 billion in sales, $641 million in value added, and nearly 10,500 jobs earning $382 million in labor income (Duval, D., et al. 2016[15]).

Tucson is known as a destination golf region and, as such, attracts visitors whose primary purpose of the trip is to golf. These visiting golfers then spend money in the region and that influx of nonresident spending provides a positive economic impact on the region.

The economic impact of reclaimed water-supported destination golf is driven by the spending made by golf-related visitors and the resulting impacts on other consumers and businesses in the region. The economic impact includes both direct spending by visitors on golf-related activities, plus the indirect and induced economic multiplier impacts that this direct spending provides in stimulating the local economy.

C.2 Golf Tourism as the Key Driver for the Analysis

There are 18 golf courses that use Tucson-provided reclaimed water, 6 of which are in the city of Tucson and 12 of which are outside of the city limits (Figure C-1). Table C.1 lists the TWS golf course customers, and Table C.2 summarizes the geographic distribution of these courses by type of course.

[15] The study estimated impacts in 2014. Dollars were escalated to 2021USD using the CPI.

Figure C-1 RWS Golf Course Customer

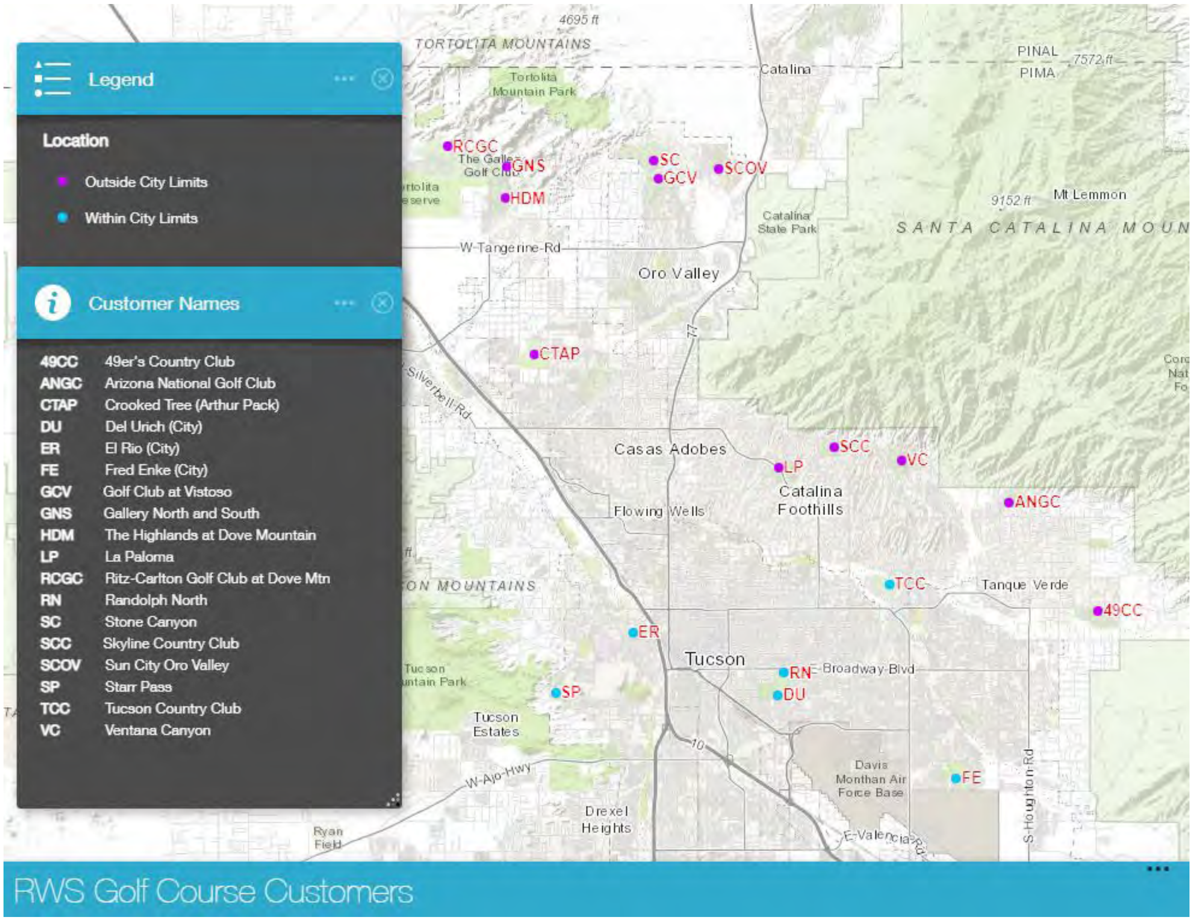


Table C.1 RWS Golf Course Customers

	Type of course	Area	Within city limits
49er's Country Club	Public	Tanque Verde	No
Arizona National Golf Club	Public	Tanque Verde	No
Crooked Tree (Arthur Pack)	Public	Casas Adobes	No
The Highlands at Dove Mountain (previously Heritage Highlands)	Public	Marana	No
Ritz-Carlton Golf Club at Dove Mtn	Private	Marana	No
Gallery North and South	Private	Marana	No
La Paloma	Private	Catalina Foothills	No
Skyline Country Club	Private	Catalina Foothills	No
Ventana Canyon	Public	Catalina Foothills	No
Stone Canyon	Private	Oro Valley	No
Golf Club at Vistoso	Public	Oro Valley	No
Sun City Oro Valley (formerly Sun City Rancho Vistoso Golf Course)	Public	Oro Valley	No
Del Urich (City)	Municipal	Tucson	Yes
El Rio (City)	Municipal	Tucson	Yes
Fred Enke (City)	Municipal	Tucson	Yes
Randolph North (City)	Municipal	Tucson	Yes
Starr Pass	Public	Tucson	Yes
Tucson Country Club	Private	Tucson	Yes

Table C.2 RWS golf course customers by geography and course type

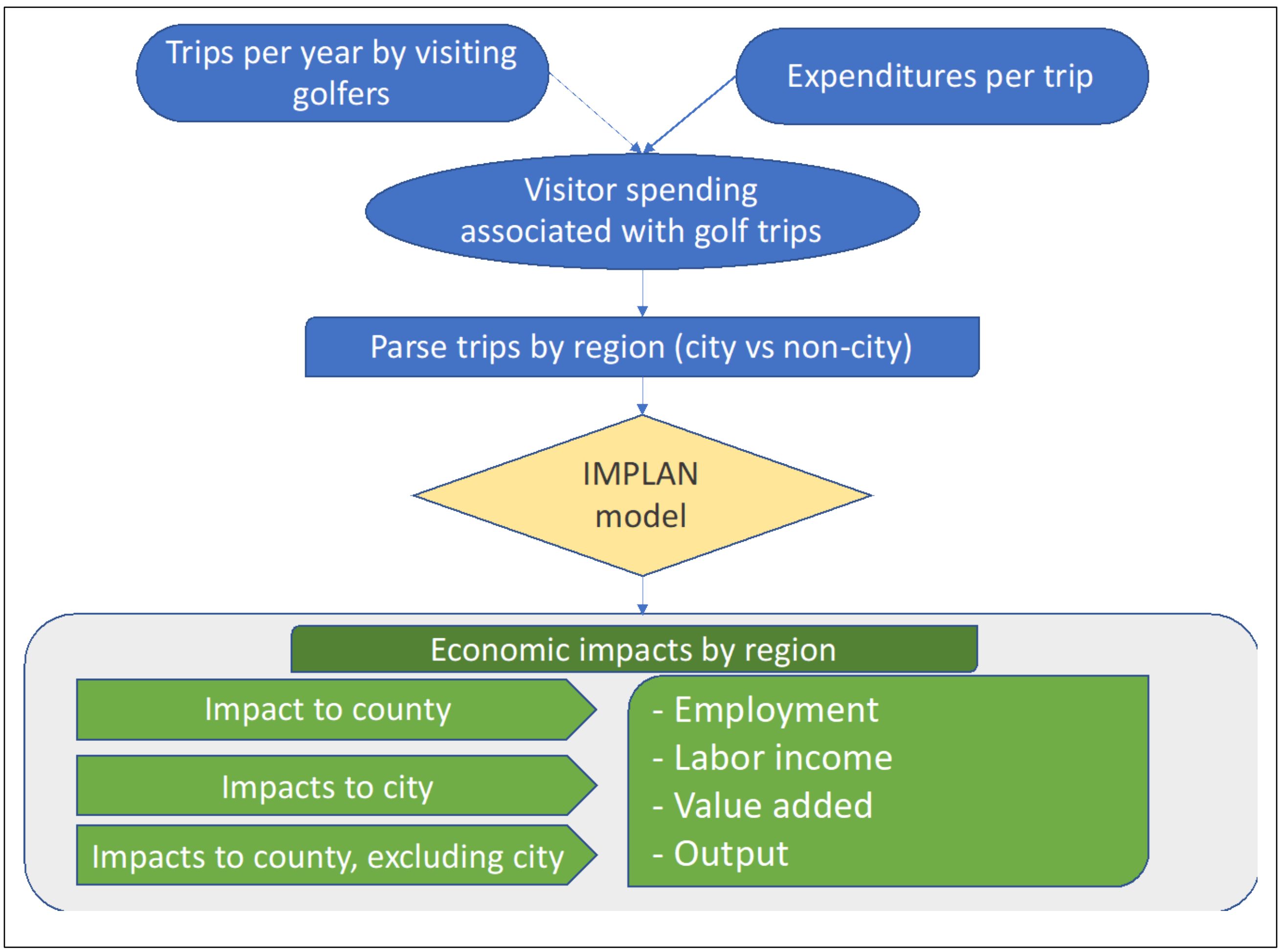
Location	Number of municipal golf courses	Number of Public golf courses	Number of Private golf courses	Total number of golf courses
Within city limits				
Tucson	4	1	1	**6**
Outside city limits				
Casas Adobes	0	1	0	**1**
Catalina Foothills	0	1	2	**3**
Marana	0	1	2	**3**
Oro Valley	0	2	1	**3**
Tanque Verde	0	2	0	**2**
Total outside city limits	**0**	**7**	**5**	**12**
Total	**4**	**8**	**6**	**18**

C.3 Methods

Golfing contributes to the local economy by bringing **outside** money into the economy in the form of **visitor spending**. The total economic impact of golf visits includes direct expenditures and subsequent flow-on impacts, which includes both indirect and induced expenditures. The process and terminology are as follows:

- Direct expenditures include money that tourists spend while visiting the area for golf. These include money spent on golf and other trip expenses such as transportation, food, lodging, and retail purchases.
- Local businesses that benefit from direct spending then, in turn, spend additional money on goods and services that they need to operate their businesses. These are termed indirect expenditures.
- Direct and indirect spending generates employment in the local region, creating additional income for households, which generates further spending known as induced expenditures.
- Figure C-2 presents a flowchart of the analysis.

Figure C-2 Flowchart for estimating economic impacts of visitation associated with RWS golf course customers.



Visiting golfers spend money on several goods and services, including hotel rooms, food, and retail, which affect several local industries, including restaurants, hotels, retail shops, and other tourist-related enterprises. These industries directly affect the economy by purchasing intermediate goods, such as restaurant supplies and wholesale goods, and by providing jobs. The industries that provide intermediate goods and services to the recreation and tourism industry purchase their own intermediate goods and services from other local industries, and the pattern repeats itself. Thus, the original money from visitor spending creates a multiplier effect on the local economy. At every stage, some portion of expenditures goes toward goods or services generated outside the local area. This is known as "leakage" and is incorporated in (i.e., netted out of) the calculations of multiplier effects (Bess and Ambargis, 2011).

This study uses the IMPLAN model (IMpact Analysis for PLANning) to assess the regional economic impacts associated with golf tourism. IMPLAN is an economic input-output (I-O) model, originally developed by the federal government, that contains information on the relationships within an economy, both between businesses and between businesses and final consumers. IMPLAN uses this information to predict changes in overall economic activity resulting from a flow of money into the local economy (e.g., visitor spending). IMPLAN is widely used by academics and the private sector, and it is generally accepted as the standard for economic I-O analysis.

To estimate regional economic impacts, IMPLAN constructs local level multipliers. Multipliers describe the response of the economy to a change in demand or production. Multipliers measure the economic impact of direct effects, as well as how the direct effects ripple through the economy to create indirect and induced impacts. The magnitude of indirect and induced effects depends on the propensity of businesses and households in the region to purchase goods and services from local suppliers. Purchases from local suppliers have ripple effects on the economy, whereas purchases from non-local (outside of the county in this case) suppliers do not result in ripple effects because the money spent for inputs leaves the local economy. IMPLAN accounts for this in the development of local multipliers by assigning regional purchase coefficients to goods and services purchased by individual sectors and households. IMPLAN also reports implications for state and local tax revenues. The model is based on 2019 data, and all input values were inflated to 2019 US dollars (USD) based on the Consumer Price Index (CPI). All model output reported here is updated and provided in 2021 US dollars (based on the CPI).

Our analysis of the economic impacts of golf tourism associated with the RWS golf courses can be summarized in the following steps:

1) We began by estimating the number of **trips per year by visiting golfers** to the golf courses that use reclaimed water for irrigation.
2) Next, we applied estimates of **expenditures per trip** to the number of trips to get an estimate of the amount of money being spent each year by visiting golfers.
3) We parsed the served golf courses by two regions: (1) within the City of Tucson and (2) outside the city to obtain estimates of money being spent by trips to golf courses in each of those areas.

4) Lastly, we used IMPLAN to estimate the economic impacts of the trips from visiting golfers, by region.

Thus, the first step to estimate the economic impacts associated with golf tourism is to obtain data on the number of golfing trips and how much money is spent on each trip. This data is used as primary inputs in the Input/Output analysis model in IMPLAN. This study relied on secondary data published in a 2014 study conducted by the University of Arizona on the *Contribution of the Golf Industry to the Arizona Economy in 2014* for estimates of both **visits per course** and **expenditures per visit** (Duval et al, 2014). Multiplying these together and by the number of courses in each region (i.e., within the city and outside of the city), we estimate the amount of **visitor spending** coming into each region.

C.4 Number of Golf Trips

We focus our analysis on travelers who visit Tucson for the primary purpose of playing golf. Our analysis estimates the economic impact of *outside money* coming into a region; thus, we estimate the economic impact of trips to the region where the **primary purpose of the trip is golf**. [16]

Duval et al, 2014 report the total number of unique visits to Arizona attributable to golf as 306,415 (p. 24). They also report the number of facilities included in their analysis as 313 (p. 63). Doing simple division, we estimate the **number of unique visits per course is 979**. This calculation implicitly assumes all the courses attract the same number of unique visits, which likely is not accurate. To investigate the validity of this assumption, we look at the two portions of the reclaimed water service area separately (i.e., within City limits, and beyond city limits).

Out-of-city golf courses. As shown previously, in Table C.2, there are 12 reclaimed water-using golf courses outside the City boundary; 5 private, 7 public, and 0 municipal. For our analysis, we assume public and private courses attract the same average number of visits as reported in Duval et al (2014). It is important to note that we are interested in the number of unique golf trips to the area, not the number of rounds played at individual golf courses.

Within-city golf courses. Of the 6 reclaimed water-using golf courses within the city, 4 of them are municipal. It is likely municipal courses attract fewer than average visitor golf trips. To account for this, we reduce the assumed number of visitor trips to reclaimed water system-supplied golf courses within the city as follows: we assume that the courses within the city attract 50% of average visits, which equates to an estimated 489 visits per course.

[16] While we rely on Duval et al, 2014 for our estimated number of trips, it should be noted that the number of trips used in that study originally came from a survey conducted by Sport & Leisure Research Group in 2016 that obtained information on golf traveler expenditures and visitation habits to the Tucson and Phoenix/Scottsdale markets. We relied on the Duval et al estimates because they reported the expenditures in the format needed for inputs into the IMPLAN model, specifically **visiting golfers, whose primary purpose of the trip was golf**.

C.5 Trip Expenditures

Duval et al, 2014 provide expenditures per visitor trip by expenditure category (Table C.3). Different sectors of the economy, such as lodging and food service, contribute to the regional economy in varying amounts. IMPLAN includes 546 unaggregated industries. We mapped the expenditure categories in which visiting golfers reported spending money to the appropriate IMPLAN industry (Table C.3).

Table C.3 Expenditures per visitor trip

Expenditure category	Amount per trip	IMPLAN industry
Car rental [a]	$205.24	3450 - Automotive equipment rental and leasing services
Golf	$528.46	3504 - Other amusement and recreation
Lodging/accommodations	$718.38	3507 - Hotels and motel services, including casino hotels
Local transportation	$152.17	3418 - Transit and ground passenger transportation services
Food/dining	$480.10	3509 - Full-service restaurant services
Entertainment [b]	$300.80	3504 - Other amusement and recreation 3502 - Amusement parks and arcades
Shopping/retail	419.94	3409 - Retail services - Clothing and clothing accessories stores
Total expenditures	**$2,805.08**	

a) We scaled rental car to account for a portion of visitors will rent their car outside of the region. We used a ratio of regional transportation costs provided in Dean Runyan Associates, 2018.
b) Entertainment expenditures are split evenly into the two corresponding IMPLAN industries.

C.6 Regional Distributions of the Economic Impacts

To explore how the benefits created are magnified and distributed through the regional economies, specifically between the City and entities outside of City limits served by the RWS, we used IMPLAN's Multi-Regional Input-Output Analysis (MRIO). "Multi-Regional Input-Output (MRIO) analysis makes it possible to track how an impact on any of the 546 IMPLAN Industries in a Study Area region affects the production of all 546 Industries and household spending in any other region in the US (state to state, county to county, zip code to zip code, county to multi-county, county to state, etc.)" (IMPLAN 2021a). We defined our regions as follows:

- All zip codes within the City of Tucson; and
- All zip codes within Pima county, not within the Tucson city limits.

A key assumption of this analysis is the assumption made about where (i.e., in which jurisdiction) the visitor money is being spent. For this analysis, we assume all expenses occur within the jurisdiction within which the trip is allocated. That is, we assume that all trip expenditures associated with visits to golf courses outside of the city limits occur outside the city limits; Likewise, trips for golfing at courses within city limits are assumed here to have all associated tourist expenditures made within city limits. See Section C.6 Caveats and Uncertainties for additional details.

We used IMPLAN's MRIO analysis tool to estimate the impact of tourism within each area, as well as across the jurisdictions, and on the combined broader jurisdictions. To estimate the impacts of visitor spending, in IMPLAN, we modeled a change in ***commodity output*** for the economic sectors in which visit spending occurs. Table C.4 presents a summary of golf visits and expenditures by region.

Table C.4 Summary of golf visits and expenditures by region

	Number of golf courses	Number of trips/golf course	Total number of trips	Expenditures per trip	Annual expenditures from golf trips
Out-of-city golf courses	12	979	11,748	$2,805.08	$32.95 M
Within city golf courses	6	489	2,937		$8.24 M
Total	18		14,684		$41.19 M

To explore the full range of benefits, we ran IMPLAN for all combinations of geographic areas and expenditures. This was done so that we could evaluate how expenditures within each area impact the same area (i.e., within City expenditures impacting within City economic outcomes), as well as to reveal how those expenditures impact the other geographic area (e.g., how expenditures made outside of City limits impact the City's economic outcomes) and, finally, how expenditures within the total service area impact the individual and combined jurisdictions.

To provide the desired mix of analyses and results, the following sets of simulations needed to be executed:

- Impacts to the entire region
  - Impacts from golf visitation to all reclaimed water courses (within city and out-of-city courses)
  - Impacts from golf visitation to out-of-city courses
  - Impacts from golf visitation to within-city courses
- Impacts to the City of Tucson
  - Impacts from golf visitation to all reclaimed water courses (within city and out-of-city courses)
  - Impacts from golf visitation to out-of-city courses
  - Impacts from golf visitation to within-city courses
- Impacts to the area within Pima County outside the City of Tucson
  - Impacts from golf visitation to all reclaimed water courses (within city and out-of-city courses)
  - Impacts from golf visitation to out-of-city courses
  - Impacts from golf visitation to within-city courses

In the following section, we present our key findings. Specifically, we provide findings on the (1) overall economic impacts of visitation to reclaimed water-served golf courses to Pima County outside of City limits, (2) the impacts of visitation to all reclaimed-served courses to the City of Tucson, and (3) the impacts of visitation to all non-city courses to the City of Tucson. Supplement A provides the results of all the other combinations.

C.7 Key Findings

Golf visits to the reclaim system customer golf courses contribute **$19.25M in value added** annually to the economy of Pima County and **support 450.7 jobs**. The golf course visits also bring in an estimated additional $7.06M in taxes per year, of which $1.9M is at the local level (e.g., county, sub county special districts).

The full economic impact of all reclaim water customer golf courses on Pima County (including the City of Tucson) is reported in Table C.5a and the tax impacts are reported in Table C.5b.

Table C.5a Economic impacts of reclaimed water golf course visits to Pima County

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	450.7	$12.00	$19.25	$33.14
Indirect	69.4	$3.13	$5.07	$10.84
Induced	30.0	$1.35	$2.54	$4.43
Total	550.1	$16.49	$26.86	$48.41

Table C.5b Tax impacts of outside-of-city reclaim-served golf course visits to Pima County

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$402,600	$702,000	$505,400	$1,570,200	$2,407,800	$5,588,100
Indirect	$48,500	$84,900	$61,100	$208,000	$558,200	$960,600
Induced	$31,900	$55,700	$40,100	$129,700	$258,500	$515,900
Total	$483,000	$842,600	$606,700	$1,907,900	$3,224,500	$7,064,600

We next explore the jurisdictional distribution of the economic impacts by looking at the impacts on the City of Tucson. The Supplement in section C.10 includes the results of the IMPLAN runs for all combinations of jurisdictions and expenditures as described above.

C.8 Economic Impact Benefits for the City of Tucson

This section details the impact of visits to the reclaimed-served golf courses on the City of Tucson. We look at scenarios to explore the benefit of the reclaim water golf courses to the city's economy and tax revenues. We first look at the impact of golf trips to all the reclaim-served golf courses and then separate out the impact of golf trips to the reclaim-served golf courses outside of City limits.

C.8.1. Impacts of all Reclaim Golf Courses on the City of Tucson

As reported in Tables C.6a and C.6b, reclaimed water golf course visitation at all served golf courses contributes $1.35M and $2.42M in value added and output, respectively. The spending provides $1.9M in tax revenue, $127,300 of which is to the City of Tucson.

Table C.6a Economic impacts of all reclaim golf course visits to the City of Tucson

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	76.9	$2.11	$3.48	$5.89
Indirect	50.4	$2.33	$3.73	$7.82
Induced	16.8	$0.75	$1.35	$2.42
Total	144.0	$5.19	$8.56	$16.14

Table C.6b Tax impacts of reclaim golf course visits to the City of Tucson and other Jurisdictions

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$71,000	$123,600	$88,900	$267,300	$368,300	$919,100
Indirect	$38,700	$67,600	$48,700	$160,400	$405,500	$720,800
Induced	$17,600	$30,700	$22,100	$70,000	$135,400	$275,900
Total	$127,300	$221,900	$159,700	$497,600	$909,300	$1,915,800

C.8.2. Impacts of Outside-of-City Limit Reclaim-Served Golf Courses on City of Tucson

We next explore the impacts associated with only the trips to the reclaim-served golf courses outside of the city limits; Specifically, trips to the 12 reclaim-served customer courses outside the city limits. As reported above, these courses attract an estimated **11,748 unique visits attributable to golf**, which brings an additional $32.95M of direct spending to the service area outside of city limits. For purposes of our analysis, we assume this spending occurs outside of city limits. Because of this assumption, there are no direct impacts on the city. As reported in Tables C.7a and C.7b, the indirect and induced economic impacts to the city are $4.18M in value added and $8.45M in output; and contribute $46,200 to city tax revenue.

Table C.7a Economic impacts of non-city RWS golf course visits to the City of Tucson

Impact type	Employment	Labor income	Value added	Output
Indirect	41.8	$1.93	$3.09	$6.50
Induced	13.5	$0.60	$1.08	$1.95
Total	55.3	$2.53	$4.18	$8.45

Table C.7b Tax impacts of non-city RWS golf course visits to the City of Tucson

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Indirect	$32,100	$56,100	$40,400	$133,200	$336,200	$598,000
Induced	$14,100	$24,700	$17,700	$56,100	$109,000	$221,700
Total	$46,200	$80,800	$58,200	$189,300	$445,200	$819,700

C.9 Caveats and Uncertainties

As described in Section C.3, a key assumption to conducting this analysis pertains to where (i.e., in which portion of the service area jurisdiction – within or beyond City limits) the visitor money is being spent. For this analysis, we assume all expenses occur within the geographic portion of the service area of the trip. That is, we assume that all trip expenditures associated with visits to golf courses outside of the city take place in the portion of the service area that is outside of City limits.

We also assume an even distribution of unique visits attributable to each golf course, with the additional assumption that the golf courses within the city (mostly municipal) attract 50% as many trips. The methods needed to obtain better estimates of where golfers spend money and the number of trips from visiting golfers require a primary data collection effort that is outside the scope of this effort.

C.10 Supplemental Information: Economic impacts from other combinations of jurisdictions

In this supplement, we present the results of all the combinations of geographic areas within the service area (i.e., the entire service area across Pima County, within City limits, and outside of City limits) and impacts (visitation at all reclaim system golf courses, within-city reclaim courses and reclaim-irrigated golf courses outside of city limits). Specifically:

- Impacts on the full study area (all of Pima County)
  - Impacts from golf visitation to all RWS courses (within city and out-of-city courses) – included in Key Findings
  - Impacts from golf visitation to out-of-city courses
  - Impacts from golf visitation to within-city courses

- Impacts on the City of Tucson
  - Impacts from golf visitation to all RWS courses (within city and out-of-city courses) – included in Key Findings
  - Impacts from golf visitation to out-of-city courses – included in Key Findings
  - Impacts from golf visitation to within-city courses
- Impacts on the area within Pima County outside the city of Tucson
  - Impacts from golf visitation to all RWS courses (within city and out-of-city courses)
  - Impacts from golf visitation to out-of-city courses
  - Impacts from golf visitation to within-city courses

C.10.1 Impacts from outside-of-city-limits courses on entire Pima County service area

Economic impacts

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	373.8	$9.89	$15.77	$27.25
Indirect	57.7	$2.60	$4.22	$9.02
Induced	24.6	$1.11	$2.08	$3.64
Total	456.2	$13.60	$22.07	$39.91

Tax impacts

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$331,600	$578,400	$416,500	$1,302,900	$2,039,500	$4,668,900
Indirect	$40,300	$70,600	$50,900	$173,000	$463,500	$798,300
Induced	$26,200	$45,700	$32,900	$106,400	$212,500	$423,600
Total	$398,100	$694,700	$500,200	$1,582,300	$2,715,500	$5,890,900

C.10.2 Impacts from within-City courses on full Pima County Service Area

Economic impacts

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	76.9	$2.11	$3.48	$5.89
Indirect	11.7	$0.53	$0.85	$1.81
Induced	5.4	$0.24	$0.45	$0.79
Total	93.9	$2.89	$4.79	$8.50

Tax impacts

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$71,000	$123,600	$88,900	$267,300	$368,300	$919,100
Indirect	$8,100	$14,300	$10,300	$35,000	$94,700	$162,400
Induced	$5,800	$10,000	$7,200	$23,300	$45,900	$92,300
Total	$84,900	$147,900	$106,500	$325,600	$509,000	$1,173,800

C.10.3 Impacts from within City Limits golf courses on City of Tucson

Economic impacts

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	76.9	$2.11	$3.48	$5.89
Indirect	8.5	$0.40	$0.63	$1.32
Induced	3.3	$0.15	$0.26	$0.47
Total	88.7	$2.66	$4.38	$7.69

Tax impacts

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$71,000	$123,600	$88,900	$267,300	$368,300	$919,100
Indirect	$6,600	$11,500	$8,200	$27,200	$69,300	$122,800
Induced	$3,500	$6,100	$4,400	$13,800	$26,400	$54,200
Total	$81,100	$141,100	$101,600	$308,300	$464,100	$1,096,100

C.10.4 Impacts from all courses on the portion of Pima County outside of the City of Tucson

Economic impacts

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	373.8	$9.89	$15.77	$27.25
Indirect	19.0	$0.81	$1.34	$3.01
Induced	13.2	$0.60	$1.19	$2.01
Total	406.1	$11.30	$18.30	$32.27

Tax impacts

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$331,600	$578,400	$416,500	$1,302,900	$2,039,500	$4,668,900
Indirect	$9,800	$17,300	$12,500	$47,600	$152,600	$239,800
Induced	$14,300	$25,000	$18,000	$59,800	$123,100	$240,000
Total	$355,700	$620,700	$446,900	$1,410,300	$2,315,200	$5,148,800

C.10.5 Impacts from within City courses on Pima County outside the City of Tucson

Economic impacts

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Indirect	3.1	$0.13	$0.22	$0.49
Induced	2.1	$0.10	$0.19	$0.32
Total	5.2	$0.23	$0.41	$0.81

Tax impacts

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Indirect	$1,600	$2,800	$2,000	$7,800	$25,400	$39,600
Induced	$2,300	$4,000	$2,800	$9,500	$19,600	$38,100
Total	$3,900	$6,800	$4,900	$17,300	$44,900	$77,700

C.10.6 Impacts from golf courses beyond city limits on Pima County outside the City of Tucson

Economic impacts

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Direct	373.8	$9.89	$15.77	$27.25
Indirect	15.9	$0.67	$1.12	$2.52
Induced	11.1	$0.51	$1.00	$1.69
Total	400.9	$11.07	$17.89	$31.46

Tax impacts

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Direct	$331,600	$578,400	$416,500	$1,302,900	$2,039,500	$4,668,900
Indirect	$8,200	$14,500	$10,400	$39,800	$127,200	$200,200
Induced	$12,000	$21,000	$15,100	$50,300	$103,500	$201,900
Total	$351,900	$613,900	$442,100	$1,393,000	$2,270,300	$5,071,100

Tables C.8a and C.8b provide a summary of the economic and tax impacts across geographic areas.

Table C.8a Summary of Economic impacts by Geographical Area

Impact type	Employment	Labor income ($M)	Value added ($M)	Output ($M)
Impacts from outside-of-city-limits courses on entire Pima County service area				
Direct	373.8	$9.89	$15.77	$27.25
Indirect	57.7	$2.60	$4.22	$9.02
Induced	24.6	$1.11	$2.08	$3.64
Total	456.2	$13.60	$22.07	$39.91
Impacts from within-City courses on full Pima County Service Area				
Direct	76.9	$2.11	$3.48	$5.89
Indirect	11.7	$0.53	$0.85	$1.81
Induced	5.4	$0.24	$0.45	$0.79
Total	93.9	$2.89	$4.79	$8.50
Impacts from within City Limits golf courses on City of Tucson				
Direct	76.9	$2.11	$3.48	$5.89
Indirect	8.5	$0.40	$0.63	$1.32
Induced	3.3	$0.15	$0.26	$0.47
Total	88.7	$2.66	$4.38	$7.69
Impacts from all courses on the portion of Pima County outside of the City of Tucson				
Direct	373.8	$9.89	$15.77	$27.25
Indirect	19	$0.81	$1.34	$3.01
Induced	13.2	$0.60	$1.19	$2.01
Total	406.1	$11.30	$18.30	$32.27
Impacts from within City courses on Pima County outside the City of Tucson				
Indirect	3.1	$0.13	$0.22	$0.49
Induced	2.1	$0.10	$0.19	$0.32
Total	5.2	$0.23	$0.41	$0.81
Impacts from golf courses beyond city limits on Pima County outside the City of Tucson				
Direct	373.8	$9.89	$15.77	$27.25
Indirect	15.9	$0.67	$1.12	$2.52
Induced	11.1	$0.51	$1.00	$1.69
Total	400.9	$11.07	$17.89	$31.46

Table C.8b Summary of Tax Impacts by Geographical Area

Impact type	City of Tucson (Sub County General)	Sub County Special Districts	County	State	Federal	Total
Impacts from outside-of-city-limits courses on entire Pima County service area						
Direct	$331,600	$578,400	$416,500	$1,302,900	$2,039,500	$4,668,900
Indirect	$40,300	$70,600	$50,900	$173,000	$463,500	$798,300
Induced	$26,200	$45,700	$32,900	$106,400	$212,500	$423,600
Total	$398,100	$694,700	$500,200	$1,582,300	$2,715,500	$5,890,900
Impacts from within-City courses on full Pima County Service Area						
Direct	$71,000	$123,600	$88,900	$267,300	$368,300	$919,100
Indirect	$8,100	$14,300	$10,300	$35,000	$94,700	$162,400
Induced	$5,800	$10,000	$7,200	$23,300	$45,900	$92,300
Total	$84,900	$147,900	$106,500	$325,600	$509,000	$1,173,800
Impacts from within City Limits golf courses on City of Tucson						
Direct	$71,000	$123,600	$88,900	$267,300	$368,300	$919,100
Indirect	$6,600	$11,500	$8,200	$27,200	$69,300	$122,800
Induced	$3,500	$6,100	$4,400	$13,800	$26,400	$54,200
Total	$81,100	$141,100	$101,600	$308,300	$464,100	$1,096,100
Impacts from all courses on the portion of Pima County outside of the City of Tucson						
Direct	$331,600	$578,400	$416,500	$1,302,900	$2,039,500	$4,668,900
Indirect	$9,800	$17,300	$12,500	$47,600	$152,600	$239,800
Induced	$14,300	$25,000	$18,000	$59,800	$123,100	$240,000
Total	$355,700	$620,700	$446,900	$1,410,300	$2,315,200	$5,148,800
Impacts from within City courses on Pima County outside the City of Tucson						
Indirect	$1,600	$2,800	$2,000	$7,800	$25,400	$39,600
Induced	$2,300	$4,000	$2,800	$9,500	$19,600	$38,100
Total	$3,900	$6,800	$4,900	$17,300	$44,900	$77,700
Impacts from golf courses beyond city limits on Pima County outside the City of Tucson						
Direct	$331,600	$578,400	$416,500	$1,302,900	$2,039,500	$4,668,900
Indirect	$8,200	$14,500	$10,400	$39,800	$127,200	$200,200
Induced	$12,000	$21,000	$15,100	$50,300	$103,500	$201,900
Total	$351,900	$613,900	$442,100	$1,393,000	$2,270,300	$5,071,100

Appendix D
Principles and Guidelines for Setting Rates for Recycled Water: Insights for Tucson Water's Reclaimed Water System

This Appendix addresses key issues pertaining to the rate-setting challenges associated with the Tucson Water Reclaimed Water System, by:

- Articulating the current framework for establishing the cost of service (COS) for the reclaimed water system
- Comparing the historical annual costs to serve, and revenues received from, users of the reclaimed system (both contract and standard customers) to identify the amount and factors contributing to the "subsidy" need for complete cost recovery.
- Evaluating how the size of the subsidy might change if the rate framework were updated to reflect a slightly modified set of principles and approaches.
- Assessing the extent to which the reclaimed water system cross-subsidies align the benefits with the beneficiaries of the reclaimed system.

In addressing these topics, we provide an overview of established guidelines and principles that have emerged regarding rate-setting for recycled water, with a focus on nonpotable reuse (NPR).

D.1 Summary of Findings

Cost of Service-based pricing is a well-established standard practice throughout the water sector for the goods and services provided by water supply and wastewater utilities. However, there are several well documented challenges to applying COS pricing to nonpotable reuse water such as provided by the RWS. Consequently, NPR water typically is priced at rates below the prices charged for potable supplies, which in turn generally results in system revenues recovering less than the full cost of building and operating NPR systems.

Such is the case for Tucson Water's Reclaimed Water System, for which total annualized costs – i.e., annualized capital outlays such as debt service, plus annual operation and maintenance (O&M) costs – amount to $13 million per year (based on the most recently adopted cost-of-service analysis), while revenues from sales of recycled water have ranged from $8 to $11 million in recent years depending on sales volume. The resulting revenue shortfall ($2-5 million per year) between 2017 and 2021 is made up through a "cross-subsidy" derived from charges levied on TW's potable water system customers.

It is common and often economically justified to impose a cross-subsidy to help recover the full COS for nonpotable reuse. The economic justification stems from the concept of "beneficiary pays," reflecting circumstances in which those who receive some of the benefits from a water reuse program may extend beyond those entities that receive (i.e., purchase) the NPR water. More specifically, the beneficiaries may include potable water system customers, to the extent that the NPR program reduces the expense associated with the potable system.

Whether a cross-subsidy is an efficient and equitable solution to covering the full COS for nonpotable reclaimed water systems depends on the specific circumstances in each community. In the case of Tucson's reclaimed system, there is empirical evidence that a reuse surcharge on potable system customers is likely to be economically justified based on benefits received by potable system ratepayers. For example, based on 2019-2020 rates, a typical City of Tucson single family households pays a surcharge of less than $10 per year to support the Reclaimed Water System, whereas those households save an estimated $91 annually on their potable costs due to the RWS reducing demands on the potable system (see Appendix B for details).

D.2 Challenges Posed by Pricing Nonpotable Reuse Water

A significant challenge utilities face in pricing reuse water is developing a suitable balance between (1) Creating and sustaining a market demand for reuse water—by offering attractive, competitive pricing and other incentivizing terms; and (2) Concurrently generating sufficient revenue to cover their costs of producing and delivering reuse water to their customers (Raucher et al., 2019).

The need for market creation (i.e., stimulating and retaining the demand for NPR water) often is a significant challenge, for an assortment of reasons (per Cristiano and Henderson, 2009; AWWA 2017, 2019; Raucher et al., 2019), including:

- The relatively attractive price for potential NPR customers of available substitute and in-place water sources, such as potable supplies and self-supply (e.g., well pumping).
- The up-front retrofit costs many nonpotable reuse customers face in converting to NPR water (including signage and related expenses).
- Initial reluctance to use what may be perceived as a "lower quality" and "used" water.
- Concerns by potential customers over system reliability and water quality.
- Concern by business owners over how their customers may perceive the quality or risk they face from exposure at NPR user facilities (e.g., golf courses).
- The seasonal demand patterns associated with irrigation demands for NPR water.

For many potential NPR customers, potable and other alternative sources of water supply typically already exist, are already the current water source being used, and often are obtained at a relatively modest cost by the customer. In contrast, reuse water generally is relatively costly for the utility to produce and deliver, and often requires end-users to incur retrofit or other additional expenses. There may also be concerns related to reuse water quality (Raucher et al., 2019).

Consequently, reuse water often is sold at less than its full cost (at least in the initial years when a reuse program is starting up). This in turn requires some form of subsidy to cover the gap when rate-driven revenues are less than the program's full costs. These subsidies may be available from third parties (e.g., grants from state or federal agencies), and/or from cross-subsidies from local potable and/or wastewater utility customers.

Such subsidies often are "economically justified" by the avoided costs and other positive externalities (i.e., financial, social, and/or environmental benefits) that arise from prudently tapping reuse water as part of the regional water supply portfolio. For example, reclaimed water yields are typically insensitive to drought or other climate impacts, and reuse water can reduce demands on over-tapped potable supply systems, thereby increasing the overall reliability and reducing the costs of a community's total water supply portfolio.

In the context of Tucson's reclaimed system, state and county requirements instituted 40+ years ago -- including provisions for using sustainable water supplies for turf irrigation under the 1980 State of Arizona *Groundwater Management Act* – created the necessity for golf course developers to tap a renewable source such as recycled water to build new courses and associated resorts. Even with such mandates, securing sufficient and sustained demand for the reclaimed system has required incentivizing terms for securing long-term commitments from potential customers.

D.3 Pricing Nonpotable Reclaimed Water to Create Demand vs. Attaining Full Cost Recovery

Recycled water typically is relatively expensive to produce and deliver, as it requires advanced forms of treatment. And, construction and operation of a separate purple pipe distribution system is required for NPR water, adding considerable up-front and recurring expense. Reuse systems also are typically newer than traditional water source systems, where traditional water sources tapped decades ago were relatively cheaper to acquire, and for which the expense of existing treatment infrastructure and distribution lines has already been depreciated (Cuthbert and Hajnosz, 1999).

Also, potable water pricing often is based on *average costs* across historical supplies (i.e., averaged across all the sources tapped by the potable utility), rather than *marginal costs* of the next water source (Watson, Mitchell, and Fane 2013). As a result of these various factors, the average COS for traditional water sources is often less costly than for NPR (Raucher et al. 2006).

Further, different customer classes for recycled water projects can have distinctly different seasonal water demands and water usage characteristics. This can potentially result in excess recycled water capacity in non-peak months, adding financial strain on a nonpotable recycled water program.

Given these challenges, it is common practice across the United States (and other nations) to sell NPR water at rates that recover revenues less than the full cost of service of producing and distributing high quality, fit-for-purpose product water. Survey results of water reuse utilities confirm that utilities often need to offer incentives to encourage the use of reclaimed water, especially for nonpotable purposes, because of the higher unit cost of most reclaimed water supplies relative to potable supplies, and the need to anticipate upward pressure on water and wastewater rates due to substitution (e.g., American Water Works Association's (AWWA), 2019). Hence, the price charged for reclaimed water is often capped at the potable water price, and frequently the costs recovered are less than the full cost. An AWWA-sponsored survey of reclaimed water rates in 2000 and 2007 showed rates for reclaimed water vary greatly from 20% to 100% of the potable water rate, with a median rate of 80% (Carpenter et al., 2008).

The inability to fully recover all capital (e.g., debt service) and operation and maintenance expenses through the revenues collected from NPR customers raises a host of issues and concerns. Among these concerns is the need for a "cross-subsidy" from another source (e.g., potable system customers to help cover NPR costs), which in turn raises the economic issues of *equity* (i.e., fairness in terms of who pays versus who benefits) and *efficiency* (putting recycled water to its best and highest uses).

D.4 The Cost of Service for Tucson's Reclaimed Water System

D.4.1 The Role of Cost-Based Pricing in the Water Sector

Cost of service-based pricing is a foundational premise for water sector rate-setting. Water and wastewater utilities typically use a cost-of-service rate setting methodology, based on utility-specific studies reflecting system characteristics, to recover the full cost of providing the utility's service. This is the predominant pricing methodology adopted in the U.S.

A definitive discussion of the COS methodology for water service can be found in the AWWA's M1 service manual, *Manual of Water Supply Practices*. The M1 manual details the multi-step cost allocation process that underlies the COS methodology (AWWA, 2017).

COS-based rate-setting is widely recommended and adopted because:

- COS-based pricing supports the notion that households, businesses, and other customers of water supply and wastewater agencies pay what it costs to deliver the valuable goods and services they receive, while not being gouged by the local utility monopolies providing those services. COS pricing helps set rates so that different customer classes pay their share in a fair and equitable manner.
- Concurrently, COS-based pricing ensures that the utilities—as providers of services essential to the community's public health, welfare, and economic activity—accrue revenues adequate to sustain their enterprises, including full coverage of reasonably incurred capital costs, operation and management expenses, and reserves to provide for periodic replacement and necessary upgrade expenses.

Thus, for standard potable water supply and wastewater utility services, COS-based pricing provides a prudent balance in which the utilities can remain fiscally sustainable in their ability to provide essential services to the communities they serve, while their customers are protected from monopolistic price gouging when purchasing essential water services. COS-based pricing is thus the standard of practice, and it is codified in how investor-owned utilities (IOUs), as well as publicly owned utilities in some states, are economically regulated by state public utility commissions (PUCs). And, COS-based pricing requirements also are extended to many publicly owned water systems through state and local requirements and policies, such as California's Proposition 218 (California Legislative Analyst's Office 1996).

Unfortunately, for water reuse (especially NPR), COS-based pricing typically is not feasible, as creating a market for NPR requires incentivized pricing below the competing potable rate, resulting in a fiscal loss (reuse revenues less than costs) for most NPR programs. As described elsewhere, cross-subsidies from potable water customers often are justified, however, based on benefits accruing to the potable system (e.g., avoided costs).

D.4.2 The Cost of Service for Tucson Water's Reclaimed Water System

Under Tucson Water's cost-of-service framework, annual revenue requirements are allocated among different utility services including potable and reclaimed water services, customer billing, and meter-related services. Potable water costs are further allocated to individual customer classes based on average and peak water usage characteristics.

For the reclaimed water system, the basic rate-setting framework does not differentiate among reclaimed water customers when estimating costs of service; however, rates for some customers (e.g., wheeled water and interruptible service) are determined according to provisions established in negotiated contracts.

Tucson's reclaimed water system has an estimated annual cost of $13 million based on the most recently adopted cost-of-service study and consists of capital and operation and maintenance expenses. Annual revenues from the sale of recycled water in recent years have amounted to about $8 million to $11 million (e.g., Kmiec, 2021). The resulting revenue shortfall of $2 to $5 million per year (i.e., the annual revenue deficit relative to the full COS) is covered through cross-subsidies from potable customers (at a level of $9 to $10 per year for a typical city of Tucson residential potable system customer).

D.5 A "Beneficiary Pays" Approach to Nonpotable Reuse Rate-Setting

A distinction can be made between traditional COS-based cost recovery (which is rarely fully feasible for NPR) and an alternative of applying a COS approach that is blended with a "beneficiary pays" approach that provides sound justification for cross-subsidies (e.g., from potable and/or wastewater system customers) to help cover reuse costs. Such a blended approach is described below.

D.5.1 Reclaimed Water System Benefits and Beneficiaries: Cross-Subsidies May be Justified (but Not Always Allowed)

The reuse pricing challenge is complicated because many of the ultimate beneficiaries of a reuse program extend well beyond those who directly use and pay for reuse water through reuse rates (Raucher et al. 2006). The fact that benefits are widely disbursed creates a potential disconnect between those customers who obtain and pay directly for recycled water and those who ultimately benefit from the reuse program.

Communities typically invest in water reuse because it provides important and widespread benefits, such as offsetting the need to develop or expand other water supply options that would be very expensive, unsustainable, unreliable, and/or environmentally harmful. When other potable water supply options are unavailable or less desirable, a water reuse program may avoid periodic water shortages and their associated adverse consequences across the community. In such cases, the entire water-using community benefits from a reuse program because it provides a less expensive and more reliable overall water supply for all, even if only a small portion of that community directly receives reuse water.

Under such circumstances, aligning who pays with those who benefit entails "subsidizing" reuse pricing with revenues collected from the broader water supply rate base. These cross-subsidies often are economically justified based on the principle of having beneficiaries pay for their share of value-added or avoided costs. However, applying such cross-subsidies may be difficult to justify, and may even be illegal in some communities and institutional settings. This is especially relevant for public systems in California, which are subject to the strict application of cost-of-service pricing, and prohibitions on (or key limitations for) cross-subsidies under Proposition 218.

D.5.2 Third-Party Subsidies Help, but Are Limited

In some cases, subsidies for reuse projects may be available from third parties, such as the federal Bureau of Reclamation (e.g., Title XVI), or various state agencies (e.g., California's Proposition 50, Proposition 84, and Proposition 1 grants). These grants, cost-shares, and local resource development subsidies are intended to help systems bear the costs of water reuse projects by helping to compensate utilities for some of the "external benefits" that reuse generates (i.e., benefits beyond those who directly receive and pay for the product water). These outside subsidies help moderate COS pricing, but the available funding is limited and unlikely to expand significantly in the current economic climate.

In short, the concept "beneficiary pays" may be fundamentally consistent with traditional COS-based rate-setting based on the circumstances under which more than the reuse system customers who are beneficiaries and, thus, receive the "service". However, beneficiary pays approaches may not be applicable in all circumstances when setting recycled water rates, because even when beneficiaries are identified there may be no convenient mechanism available to charge them. In the face of this challenge, some agencies have adopted non-economic strategies like mandatory reuse policies to reduce the discount required for creating a market for recycled water.

On the other hand, an important ruling by the California Public Utilities Commission (CPUC, the economic regulator for investor-owned water utilities in the state) recognizes that traditional COS-based pricing is unsustainable to support many water reuse projects. CPUC has thus implemented a policy that recognizes that cross-subsidies from potable system (and/or wastewater system) customers is justified and allowed in its rate case determinations (CPUC 2014).

Methods are available to allocate costs under a COS methodology that is blended with a beneficiary pays concept. One such method is the Separable Costs-Remaining Benefits (SCRB) method. The SCRB method is suited to allocating costs across users and purposes for the project in a manner that aligns with beneficiary pays. Costs are distributed among project purposes by identifying separable costs for each user or participant (the "private" costs that can be directly associated with that user) and then determining joint costs by subtracting separable costs from total project costs. The method then allocates joint costs or joint savings in proportion to each user's share of the remaining public benefits (De Souza et al., 2011).

D.5.3 Reuse Pricing Practices Across the U.S.

A recent AWWA-sponsored study developed a survey, conducted interviews, and reported on patterns in the cost allocation and pricing for reuse water service in the United States. The objective was to illustrate practices and to draw out lessons and opportunities, based on the practices of a sample of water utilities drawn from across the country. They found that utility efforts at water reuse cost allocation and pricing are highly varied and disconnected (AWWA 2019).

The authors discovered a wide diversity of approaches to pricing and cost recovery for reuse water programs. Their primary conclusion was that a "one size fits all" approach does not apply, and that:

> A fully informed approach to reuse pricing must focus on utility-specific policies and objectives, not on specific [cost] allocation processes, and be fully responsive to the unique conditions facing each reuse utility. It is not that cost of service principles do not apply, or that revenue adequacy, financial stability, or any other fundamental principle of utility management is irrelevant, it is rather that successful reuse programs are especially sensitive to local conditions, and that these conditions require the use of very different cost allocation and pricing strategies from locale to locale… (AWWA, 2019).

D.5.4 The City of Tucson - Pima County Context

Selling reclaimed water at a discount (i.e., at a rate less than the full COS) implies that its users (e.g., golf courses) are being subsidized by other parties, typically the customers of the local potable and/or wastewater systems (as is the case in Tucson). The use of "cross-subsidies" often are well justified by the benefits the various parties receive from the reclaimed water system, including avoiding the expense of expanding the potable system to meet nonpotable demands. The main body of this TM explores the extent to which the benefits and the associated beneficiaries compare to the Reclaimed Water System's costs and the allocation of those costs.

The Tucson reclaimed system provides a range of valuable benefits to the residents, businesses, and other entities in the region. The Reclaimed Water System: (1) facilitated regional population and economic growth, (2) reduces demands on the potable water supply system (thereby providing significant cost savings for potable system customers), (3) contributes to stored groundwater reserves while (4) reducing groundwater depletion and subsidence, (5) restores native riparian habitat, and (6) supports green spaces that enhance the quality of life for the residents of and visitors to the City of Tucson and the broader region.

As described elsewhere in this TM, one way to explore the beneficiaries pay approach entails applying a Triple Bottom Line (TBL) approach to fully identify, describe, and – to the extent feasible and credible – quantify and monetize all the benefits and costs associated with a water reuse option. A key distinction is made here between a ***financial*** analysis (focused on *revenues* and costs), and an ***economic*** analysis (focused on *benefits* and costs). By understanding the full range of benefits, a reuse project can be properly evaluated relative to its anticipated costs. And, by understanding the full range of benefits, the beneficiary pays approach can be more readily developed to generate the fiscal revenues required to pay for reuse programs generating positive net benefits.

D.6 Local Circumstances Amend a "One-Size-Fits-All" Reuse Rate-Setting Approach

Regardless of the rationale or availability of cross-subsidies, the presence of a gap between reuse program costs and the revenues generated by NPR sales often creates a fiscal challenge that may be difficult for a utility to sustain over the long term. The valid economic rationale that community-wide benefits may well outweigh reuse water program costs is not always sufficient for addressing concerns aired by those focusing on the financial accounting ledger and observing that costs exceed revenues. In a sector that is predominantly governed by cost-of-service principles, water reuse programs may thus stand out as a fiscal challenge.

For Tucson Water and its challenge for Reclaimed Water System rate setting, the cross-subsidies from potable customers may be justified in terms of cost savings realized by potable customers, and in light of the need to build demand for the reclaimed system by attracting and holding NPR customers as the system was initially developed and became well established. The reclaimed system's success has also generated significant benefits to the city and county's regional economy as well as other important benefits enjoyed by city and county residents alike.

As the reclaimed system continues to evolve in terms of the type of customers served (e.g., standard and special service customers) and the system's relationship to the potable water system (e.g., providing water for potable system aquifers through SHARP and Heritage projects), a fresh examination of the rate setting framework and assumptions may be warranted to further refine overall reclaimed system cost estimates, and the varying costs for serving different customer types within the reclaimed system.

For example, golf course and associated resort owners realize considerable benefits by having reuse water, as those golf courses and resorts might not exist or be as attractive and successful but for access to the reclaimed system for turf and landscape irrigation. A more comprehensive cost-of-service framework that considers the different levels of service provided by the reclaimed system may be desirable to better evaluate intra-class subsidies between standard reclaimed customers (like golf courses) and special rate customers

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Appendix G

ONE WATER 2100 CONSERVATION PROJECTIONS

Tucson Water
One Water 2100 Master Plan

Technical Memorandum

WATER CONSERVATION PROGRAM 10-YEAR SAVINGS PROJECTION

Peter Mayer, P.E., Principal, WaterDM

August 2, 2021

One Water 2100 Master Plan

This document is released for the purpose of information exchange review and planning only under the authority of Peter Mayer, P.E. Colorado, PE license number 0038126.

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WATER CONSERVATION PROGRAM 10-YEAR SAVINGS PROJECTION

1.0 Executive Summary

Water conservation is an essential component of Tucson Water's long-term strategy to provide high-quality, reliable water service for the future. A water conservation program does not produce additional water resources above and beyond what is physically available. Instead it preserves and extends currently available water supplies by increasing water-use efficiency and reducing per capita use. With this goal in mind, the Tucson Water Conservation Program's investments in the community and outreach to water users has demonstrably and steadily decreased per capita use and total water demand for more than 20 years.

Water conservation is important to the community and vital for the long-term sustainability of the City. This technical memo analyzes the potential of the conservation program's water savings over the next ten years. The analysis supports the water demand projections developed by Jacobs for the One Water 2100 Master Plan. Direct input, ideas, and feedback were obtained from stakeholders and the broader Tucson community in the development of this analysis.

The Water Conservation Program 10-Year Savings Projection (the Technical Memo) was prepared to:

- Examine the impacts of the water conservation program through a review of demand trends in Tucson as a whole and for each customer sector.
- Project water savings likely to be achieved over the next 10 years for a range of program implementation scenarios.[1]
- Develop a deeper understanding of current program impacts and industry trends to inform a strategic planning process for the Conservation Program.

1.1 Conservation Program Recommendations

The Tucson Water Conservation Program (Conservation Program) plays an important role in ensuring Tucson uses water resources wisely and practices water efficiency for the benefit of the community and environment. Peter Mayer, P.E., Principal of WaterDM, prepared a set of recommendations for Tucson Water to consider based on his review of local and national water demand trends and Tucson's current water conservation program offerings. These recommendations are intended to increase the overall effectiveness of the Tucson Water Conservation Program to ensure continued, sustained, equitable demand reductions across all sectors of water customers.

[1] Note: these projections do not take potential future pricing changes into account. Mayor and Council are currently considering differential rates and Tier 2 of the drought plan gives decision makers the option of increasing rates to accommodate higher charges from the Central Arizona Project as there is less water to allocate among customers.

WaterDM's six recommendations are:

1. Adjust rebate levels and increase efficiency of fixtures and appliances for which rebates are offered to increase cost-effectiveness.
2. Increase savings opportunities for commercial customers.
3. Expand focus on outdoor water use, with emphasis on resilient, desert-adapted landscapes.
4. Improve Tucson Water's ability to understand customer water use and ability to target conservation programs with customer-specific water budgets.
5. Increase customer-side leak detection to reduce water waste and loss.
6. Support efforts to improve fixture efficiency in plumbing and building codes and consider additional policies to ensure community water savings.

These recommendations will be incorporated into a planning effort for the Conservation Program. The planning effort will align with the public engagement strategy for the One Water 2100 master plan. The public engagement strategy is currently under development with an anticipated launch in the Fall of 2021.

1.2 Estimated 10-Year Water Savings

Over the next ten years, Tucson Water intends to extend and strengthen its water conservation program with the goal of saving at least an additional 11,805 acre-feet of water directly through the implementation of a wide range of indoor and outdoor measures and substantially more through pricing, codes and standards, and education programs.

A range of three water savings estimates were developed based on the indoor and outdoor measures. The low, mid, and high scenarios in Table 1 are based are varying levels of rebate program activity, reflected as an annual number of incentives, and correlated to a range of costs to achieve estimated savings. Using the mid-level savings estimate, Tucson's incentive programs alone are estimated to reduce Tucson water demand by 11,661 acre-feet over the next ten years. The range of savings estimates are shown in Table 1. The detailed list developed for the middle water saving scenario can be found in Table 5 on page 20. The detailed list for the high and low water saving scenarios can be found in Appendix B.

Table 1 10-Year Water Savings Estimates

Scenario	10-Year Water Savings Estimate (AF)	Avg. Savings/Yr. (AF)
High	16,931	1,693
Mid	11,661	1,166
Low	7,055	705

Additional demand reductions beyond these estimates are expected through Tucson Water's education and outreach efforts and through the natural replacement of older fixtures and appliances that occurs without incentive from Tucson Water. The water use projections developed by Jacobs for the One Water 2100 project incorporates the active savings from the Tucson Water Conservation Program. Many conservation programs such and landscape transformation and rainwater harvesting can have multiple benefits that are not fully accounted for in an analysis that is intended to look exclusively at water savings.

1.3 Connections with Tucson Water's Drought Response Plan

Water conservation as discussed in this technical memo refers to the program Tucson Water has implemented since the 1970s to promote the efficient use of water and gradually reduce per capita consumption. Tucson Water recognizes that drought planning and drought response are distinct and separate from annual water conservation. Tucson Water updated the Drought Preparedness and Response Plan in 2020. Planning for the conservation program will be an aspect of the One Water 2100 public engagement effort and will include the updated drought response measures.

Tucson's Drought Preparedness and Response Plan recognizes that with proper planning and review it is unlikely the community will find itself in an emergency caused solely by drought. It also ensures that Tucson Water staff will implement drought response measures early enough to avoid crisis-mode decision making and to help the community anticipate what measures will come next if drought impacts become more severe.

The Drought Preparedness and Response Plan aligns Tucson's drought stages to the Drought Contingency Plan. It also introduces the concept of customer-specific "water use guidelines" which will be used to help Tucson Water provide customized water use information to customers based on billing and GIS data.- Water use guidelines are synonymous with the more technical term "water budgets", which is the quantity of water that is required for various indoor and outdoor uses.[2]

Water use guidelines are incorporated into Tucson's drought response tiers as follows:

- Under Tier 0 of a drought Tucson Water develops *water use guidelines* for residential, commercial, and reclaimed customers using historic consumption data for both indoor and outdoor end uses.
- Under Tier 1 & 2, Tucson Water continues the development and implementation of water use guidelines for all customers. Tucson Water will provide targeted conservation program information for customers whose consumption exceeds the water use guidelines.
- Under Tier 3, if water consumption does not decrease as a result of earlier drought tier responses, Mayor and Council may consider water use restrictions for customers whose consumption continues to exceed their water use guidelines.

The Drought Preparedness and Response Plan recognizes that drought does not occur suddenly and without warning. Rather, careful observation of key drought indicators will allow for implementation of responses to avoid reaching emergency conditions. This is the primary motivation for implementing the strategic, data driven approach of targeting customers whose consumption exceeds expected water use guidelines.

Additionally, these water use guidelines will be developed and disseminated by conservation staff and are the nexus between the Drought Preparedness and Response Plan and conservation program. As Tucson Water develops customer specific water budgets for indoor and outdoor use the concept of targeting conservation efforts at customers with high consumption can be an important component of the water conservation program as well.

[2] Mayer, P., et. al. 2008. Water Budges and Rate Structures: Innovative Management Tools. AWWA Research Foundation. Denver, Colorado.

2.0 Analysis of Demand Trends in Tucson

2.1 Forty Years of Water Conservation Experience

The City of Tucson is located at 2,389 feet above sea level in the Sonoran Desert of Arizona, a geography that presents substantial water supply challenges for a growing community. As a groundwater user within the Tucson Active Management Area (AMA), Tucson Water is required participate in a mandatory conservation program for large municipal providers with a designation of Assured Water Supply. Tucson Water currently participates in the Total Gallons Per Capita Per Day (GPCD) program under the Fourth Management Plan for the Tucson AMA. Tucson Water's GPCD requirement is currently set at 162.[3] The Total GPCD program does not specify which conservation actions or programs to implement in the service area.

> Conservation has been a major factor in de-coupling Tucson's population growth and increases in water consumption. Tucson water now delivers the same amount of water that was supplied in 1985 despite a 20% increase in population.

Demand management has been one of the core components of Tucson Water's water resource planning efforts since the early 1970s. The focus of demand management over the last 40 years has shifted from an initial strategy based on resource-management to one with a conservation-driven focus. For Tucson Water, management of available water resources is critical to the community's long-term sustainability. Conservation programs seek to promote efficiency in the use of available water resources. A conservation-based program does not produce additional water resources above and beyond what is physically available. Instead it preserves and extends currently available water supplies by increasing water-use efficiency and reducing per capita use. Conservation programming is an important element in any comprehensive demand management program.

To be effective, the conservation components of a demand management program should provide an equitable distribution of benefits to all customer classes, employ a targeted mix of methods to achieve desired results, and be continuously evaluated to optimize program performance. Tucson Water implements a range of programs that have been developed and refined over the years to accomplish this. Since 1998, Tucson Water steadily achieved state-mandated conservation goals ahead of schedule. This has been accomplished by offering a suite of education and conservation programs coupled with conservation-oriented water pricing, national plumbing codes, and the EPA WaterSense program. Additionally, the Tucson Water conservation program meets all the requirements of the American Water Works Association's G480 Water Conservation Program Operation and Management Standard. A summary of G480 requirements is presented in Appendix C.

2.2 Water Demand in Tucson

Water demand in Tucson has declined steadily since 2006 across nearly every customer category. Since 2006 both non-seasonal (indoor) and seasonal (outdoor) demands have declined and seasonal demand has declined as percent of total demand, indicating reduced outdoor use. WaterDM analyzed Tucson Water's recent historic demand trends across the customer categories included in the available water billing dataset. This analysis shows each sector's role in achieving the overall reductions. Water use trend data are essential

[3] Arizona DWR. 2016. Fourth Management Plan. Tucson Active Management Area. Arizona Department of Water Resources. May 13, 2016.

to the conservation planning process for the design of an effective on-going conservation program and are used to monitor program impacts over time.

2.2.1 Metered Monthly and Annual Deliveries

Monthly billed potable water consumption data were provided to the One Water 2100 project team in an Excel spreadsheet format. WaterDM worked from this dataset to prepare an analysis of water demand trends. Figure 1 shows total metered monthly deliveries by Tucson Water from January 1985 – December 2020. Tucson's seasonal demand patterns swing from winter season minimums in February to peak summer maximums which typically occur in July. Starting in 2005, monthly variability started to reduce as overall demand steadily declined through 2017 and has been stabilized over the past three years.

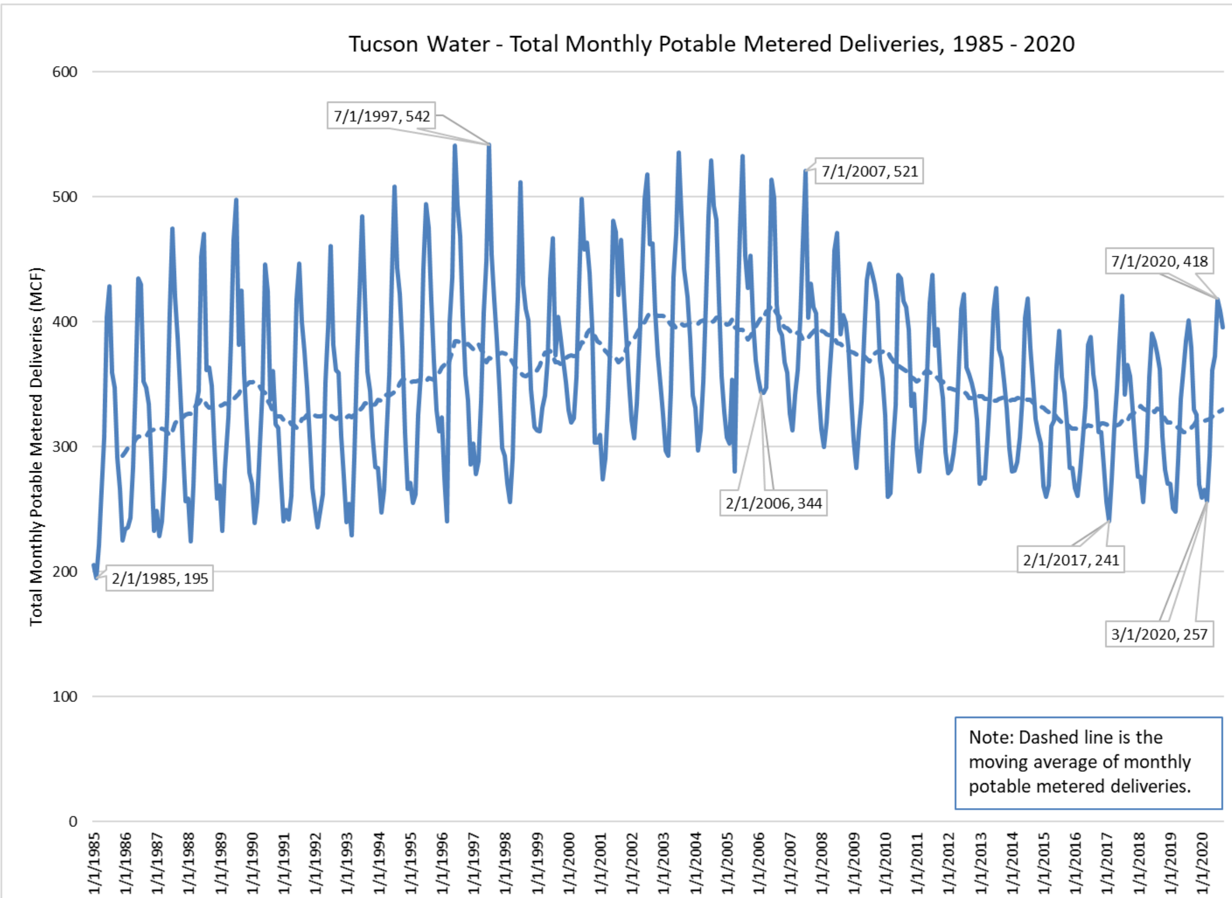


Figure 1 Total Monthly Potable Metered Deliveries, 1985 – 2020

Figure 2 shows 35 years of annual potable metered demand from 1985 – 2020 and it also shows the monthly minimum and maximum (the months with the highest and lowest demand) for each year. Annual water use increased in Tucson until it peaked in 2002 at 48.5 million CCF. From 2002 – 2007 annual use stabilized and starting in 2008 demand declined steadily. Total metered water use in 2019 was 38.5 million CCF, a decline of 10 million CCF and is now as low as it was in the late 1980s. This is a remarkable achievement given the substantial population growth Tucson has experienced over this period.

The trends in minimum and maximum month use reveal important changes in both indoor and outdoor demand in Tucson. Maximum month metered use peaked in the mid-2000s and has been on a declining trend since 2006. Maximum month demands typically occur in June and July and are caused largely by increased outdoor irrigation. The declining trend in maximum month demand is an indication that peak month irrigation in Tucson is declining and reduced outdoor use has contributed to demand reductions.

Minimum month use increased until 2006 but since then has decreased and been on a declining trend ever since (Figure 1). The minimum month use from 2019 had returned to about the same as it was in 1998, after two decades of higher monthly minimums recorded. This suggests a substantial increase in indoor efficiency over this time period that saw significant population growth in Tucson without using any additional water.

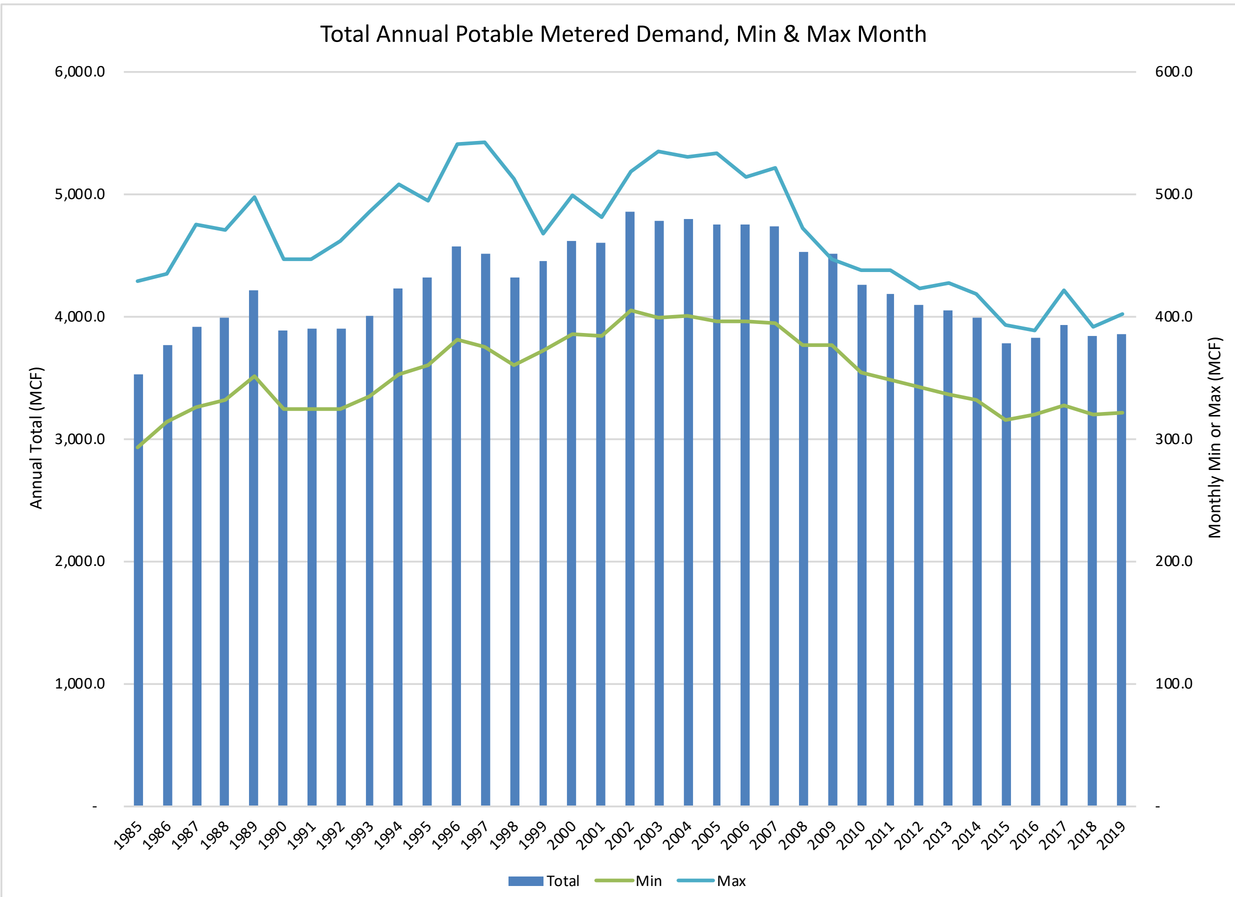


Figure 2 Total Annual Potable Metered Demand with Minimum and Maximum Month

To further examine changes in indoor and outdoor demand over time, WaterDM calculated seasonal and non-seasonal demand in Tucson for each year from 1985-2019. To estimate non-seasonal (indoor) use, WaterDM averaged consumption in Jan, Feb. Mar., and Dec. and then multiplied the average by 12. Seasonal (outdoor and other temperature-driven demand) was estimated by subtracting the calculated non-seasonal use from total annual use. The results are shown in Figure 3 along with the percentage of seasonal use.

Both non-seasonal and seasonal use have declined since 2006, but seasonal use is more variable from year to year. The percentage of seasonal use has generally declined over the long-term but has increased over the past five years. This indicates that reductions (and annual fluctuations) in outdoor use proportionally out-pacing reductions in indoor use until 2015 and then flattened. The trend in seasonal use shown in Figure 3 is one of the motivations for the recommendation to expand outdoor conservation programs.

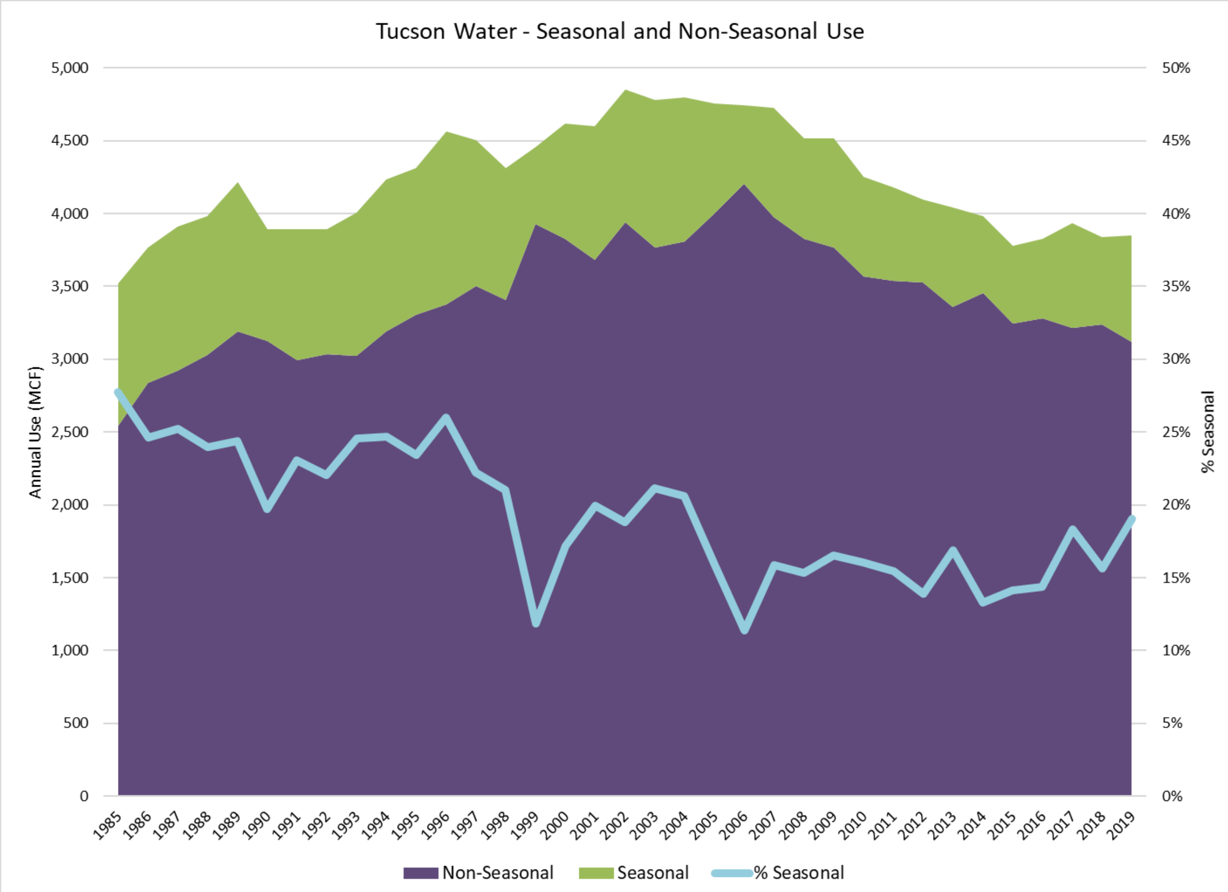


Figure 3 Annual Potable Seasonal and Non-seasonal Use and % Seasonal, 1985 – 2019

2.2.2 Water Use by Customer Category

The three preceding figures show the long-term trends in water demand by Tucson Water customers and provide clear indication of the impacts of water conservation on both indoor and outdoor use. Customers have reduced consumption both indoors and outdoors, particularly since 2006. Tucson Water classifies customers into six categories for billing purposes as follows:

1. Single-family residential
2. Duplex and triplex residential (small multifamily)
3. Multifamily
4. Commercial (includes HOAs and most school districts)
5. Industrial
6. Other

The annual water used by each of these categories in 2019 is shown as a pie chart in Figure 4. The residential sector, including single-family, duplex and triplex, and multifamily accounted for about three-quarters (74%) of the total demand in Tucson with the commercial and industrial sectors accounting for rest (25%).

The demand trends from 2009 – 2019 for each of these categories is more closely examined in the figures below.

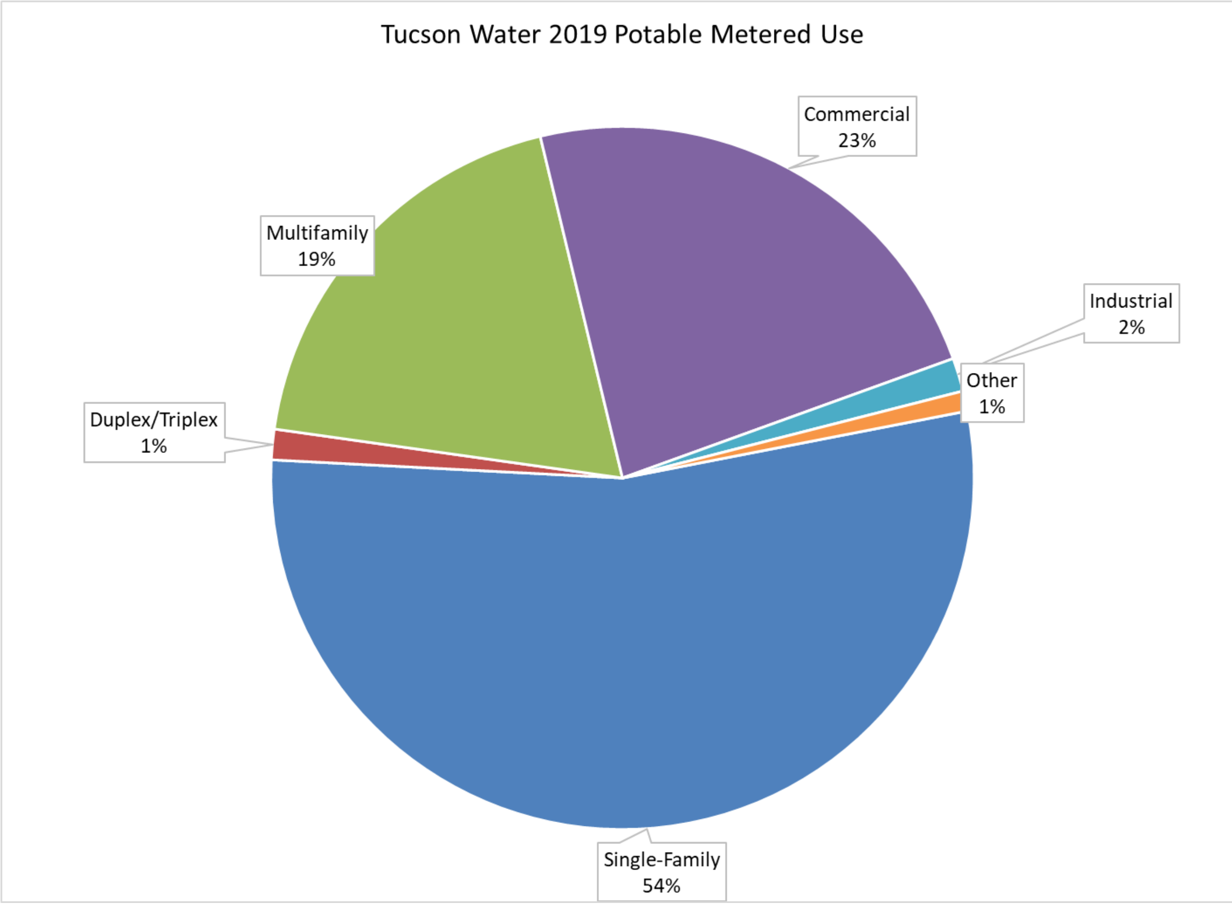


Figure 4 2019 Water Use by Customer Category

Water use by customer category in 2008 and 2018 is presented in Table 2. Annual water use declined in every sector over this ten-year period, even as the number of customer accounts grew by 4.6% overall. Reductions are observed in the minimum month and the maximum month, suggesting reductions in both indoor and outdoor water use have been achieved over this time period. A more detailed analysis of the changes in water use by sector is presented in the next few sections.

Table 2 Tucson customer categories and water use, 2008 and 2018

			Water Demand (MCF)			
Customer Category	**Year**	**# of Accts**	**Annual Total**	**Avg. Month**	**Max. Month**	**Min. Month**
Single-Family	2008	199,008	2,499.2	208.3	261.7	163.4
	2018	209,025	2,068.8	172.4	213.6	138.6
	% Change	*5.0%*	-17.2%	-17.2%	-18.4%	-15.2%
Multifamily	2008	5,711	847.5	70.6	82.6	61.4
	2018	5,645	723.6	60.3	69.1	51.7
	% Change	***-1.2%***	-14.6%	-14.6%	-16.4%	-15.9%
Duplex & Triplex	2008	4,340	67.5	5.6	7.0	4.8
	2018	4,433	54.5	4.5	5.3	3.8
	% Change	*2.1%*	-19.2%	-19.2%	-24.6%	-20.9%
Commercial	2008	14,714	970.8	80.9	105.8	61.4
	2018	15,151	896.6	74.7	93.5	57.0
	% Change	*3.0%*	-7.6%	-7.6%	-11.7%	-7.1%
Industrial	2008	379	84.9	7.1	11.0	3.8
	2018	317	58.3	4.9	7.9	2.5
	% Change	***-16.4%***	-31.4%	-31.4%	-28.3%	-34.3%
Other[4]	2008	477	47.0	3.9	5.6	2.8
	2018	370	34.2	2.9	5.6	1.5
	% Change	***-22.4%***	-27.1%	-27.1%	-0.2%	-45.4%
Total	2008	224,629	4,516.9	376.4	471.3	299.8
	2018	234,941	3,836.0	319.7	390.7	255.8
	% Change	*4.6%*	-15.1%	-15.1%	-17.1%	-14.7%

[4] "Other" includes construction meters, master-metered mobile home communities, and more.

2.2.2.1 Residential Demand Trends

Water use among all of Tucson's residential categories (SF, MF, duplex-triplex), has declined over the past 10 years as shown in Table 2, Figure 5, Figure 6, and Figure 7.

Total annual metered use has reduced steadily in all three residential categories and both the minimum and maximum monthly use has declined. This indicates customers are reducing usage both indoors and outdoors in the residential sector. The decline in maximum monthly demand is steeper suggesting outdoor use reductions are occurring more rapidly than indoor reduction among Tucson's residential customers.

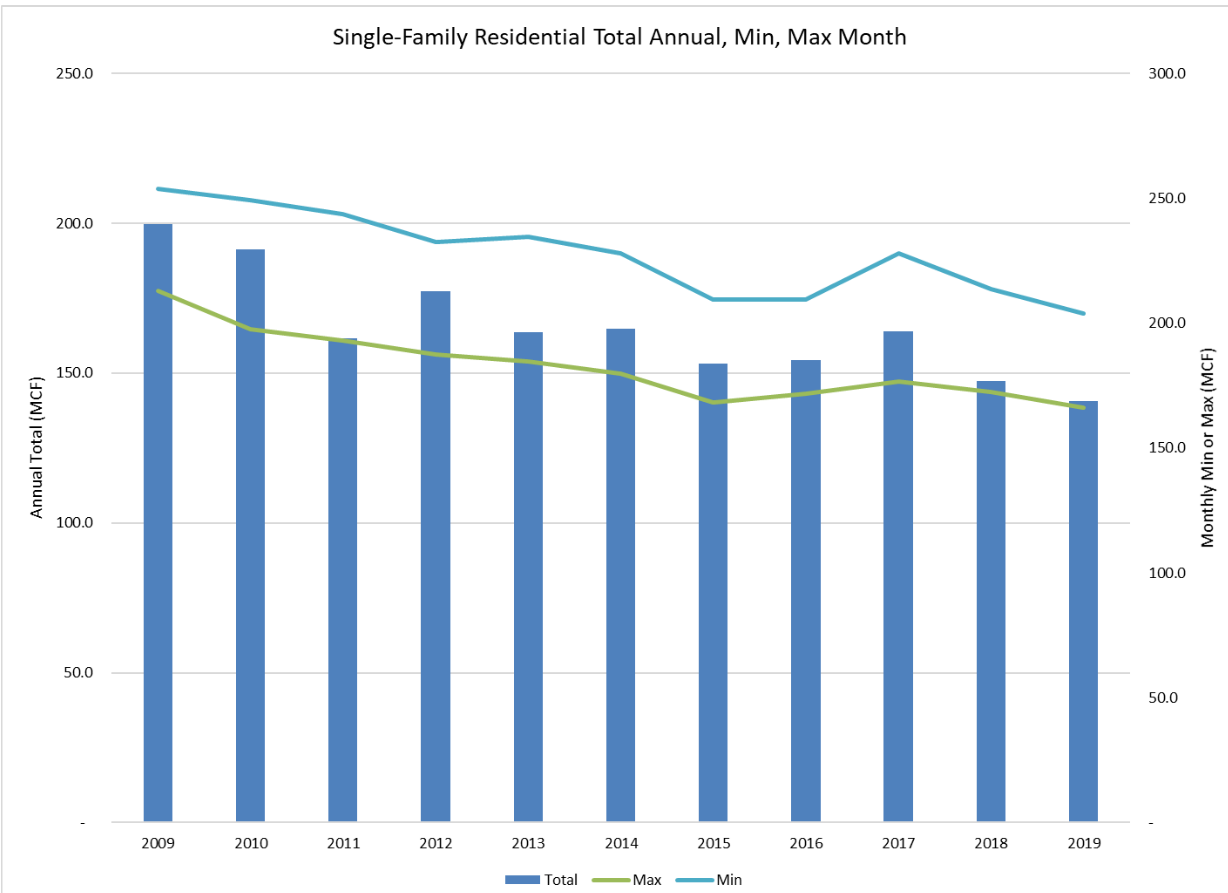


Figure 5 Single-family Residential Annual and Minimum and Maximum Month Water Use, 2009 – 2019

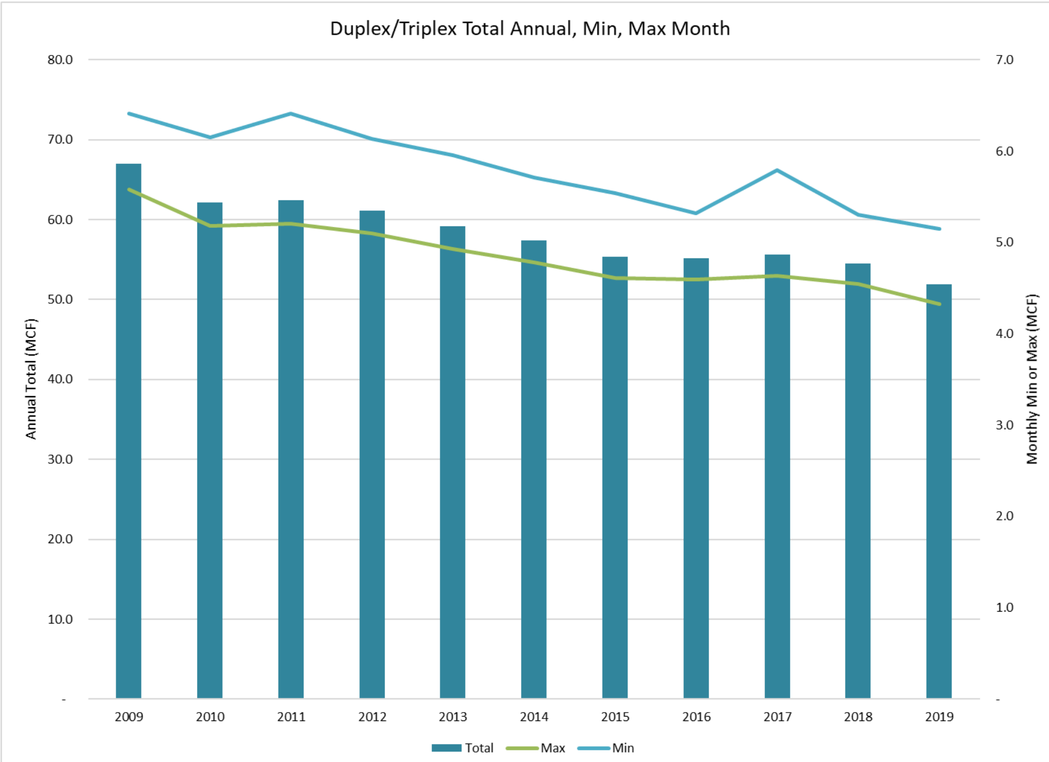


Figure 6 Duplex/Triplex Annual and Minimum and Maximum Month Water Use, 2009 – 2019

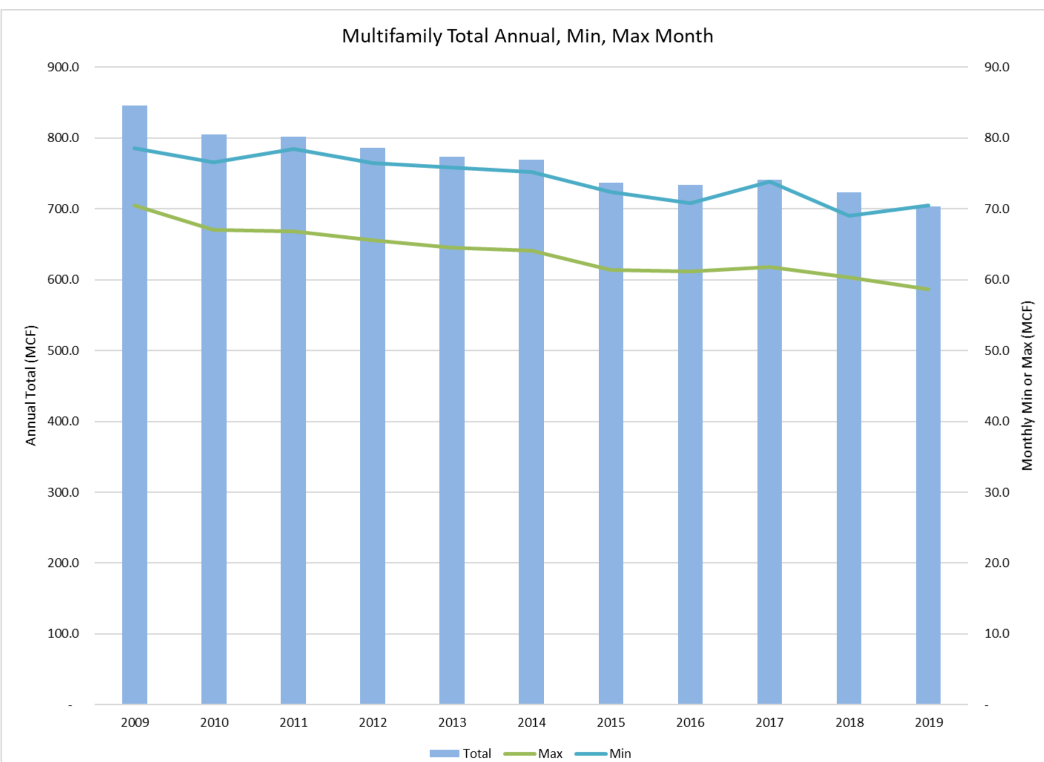


Figure 7 Multifamily Residential Annual and Minimum and Maximum Month Water Use, 2009 – 2019

Multifamily Per Unit Demand - 2018

To better inform the understanding of multifamily water use, a special data set was prepared which enabled the calculation of per unit water demand in 2018 across Tucson. To create the dataset, Tucson Water and WaterDM combined 2018 consumption data from the multifamily and the duplex and triplex categories to create a single multifamily data set that was then linked information about each property including the number of apartment or condominium units associated with each water meter. This combined dataset made it possible to calculate multifamily water use on a per unit per day basis. The results from this analysis are shown in Figure 8 and Figure 9.

The average water use in the multifamily sector is 128.8 gallons per unit per day. The median is 111 gallons per unit per day. About 90% of the multifamily properties in Tucson use less than 220 gallons per unit per day.

In Figure 9 the water use of small and large multifamily buildings is compared. In Tucson, smaller buildings with 10 units or less use a little less water on a per unit basis than larger buildings. This makes sense because larger multifamily properties are more likely to include a swimming pool, an irrigated landscape, and other common amenities that use water. Properties with between 50 and 100 dwelling units had the highest average water use. Properties with more than 100 units have a lower average per unit use.

The analysis of multifamily demand offers Tucson Water the ability to identify multifamily properties with particularly high-water use (>220 gal/unit/day) and to target water conservation efforts including rebates and landscape programs at customers with the most potential to reduce demand.

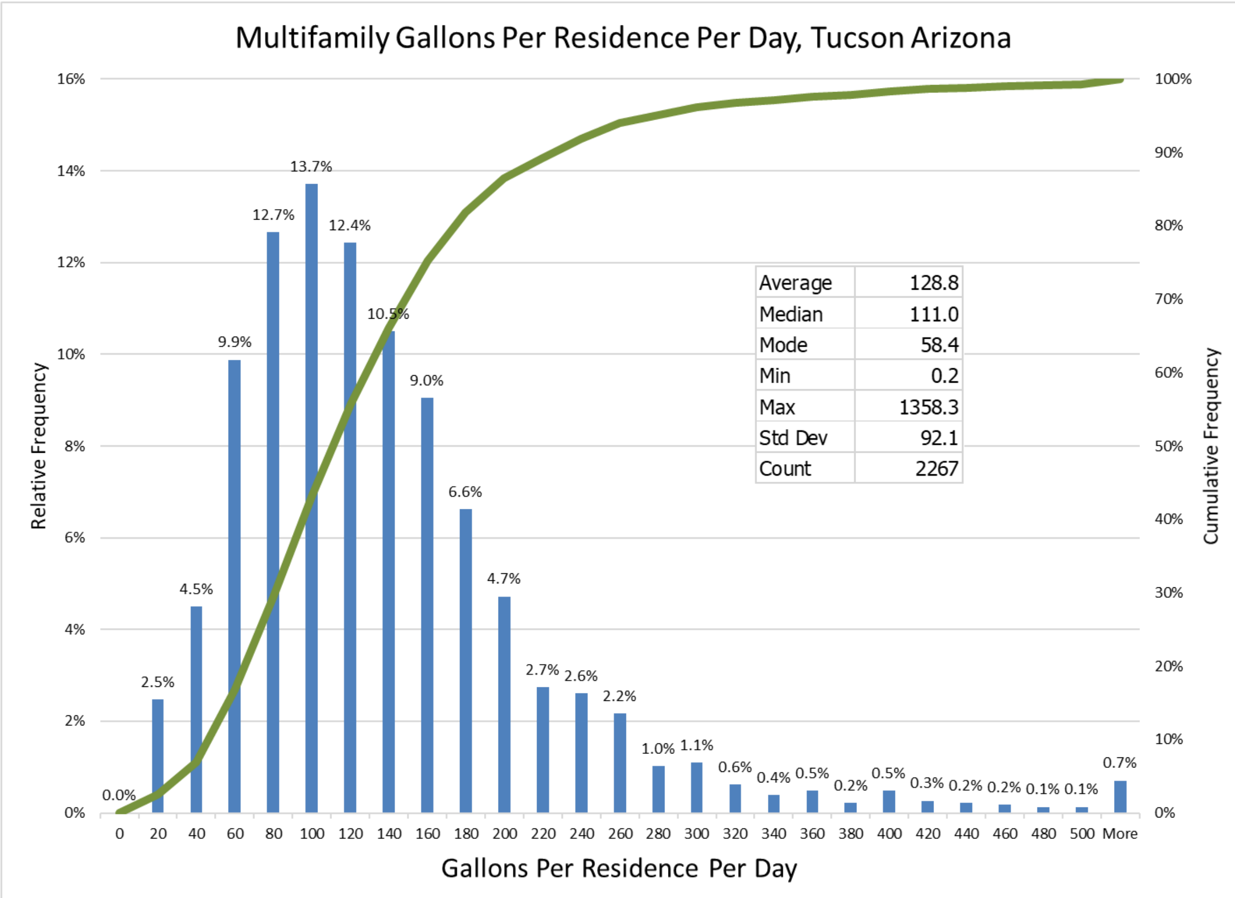
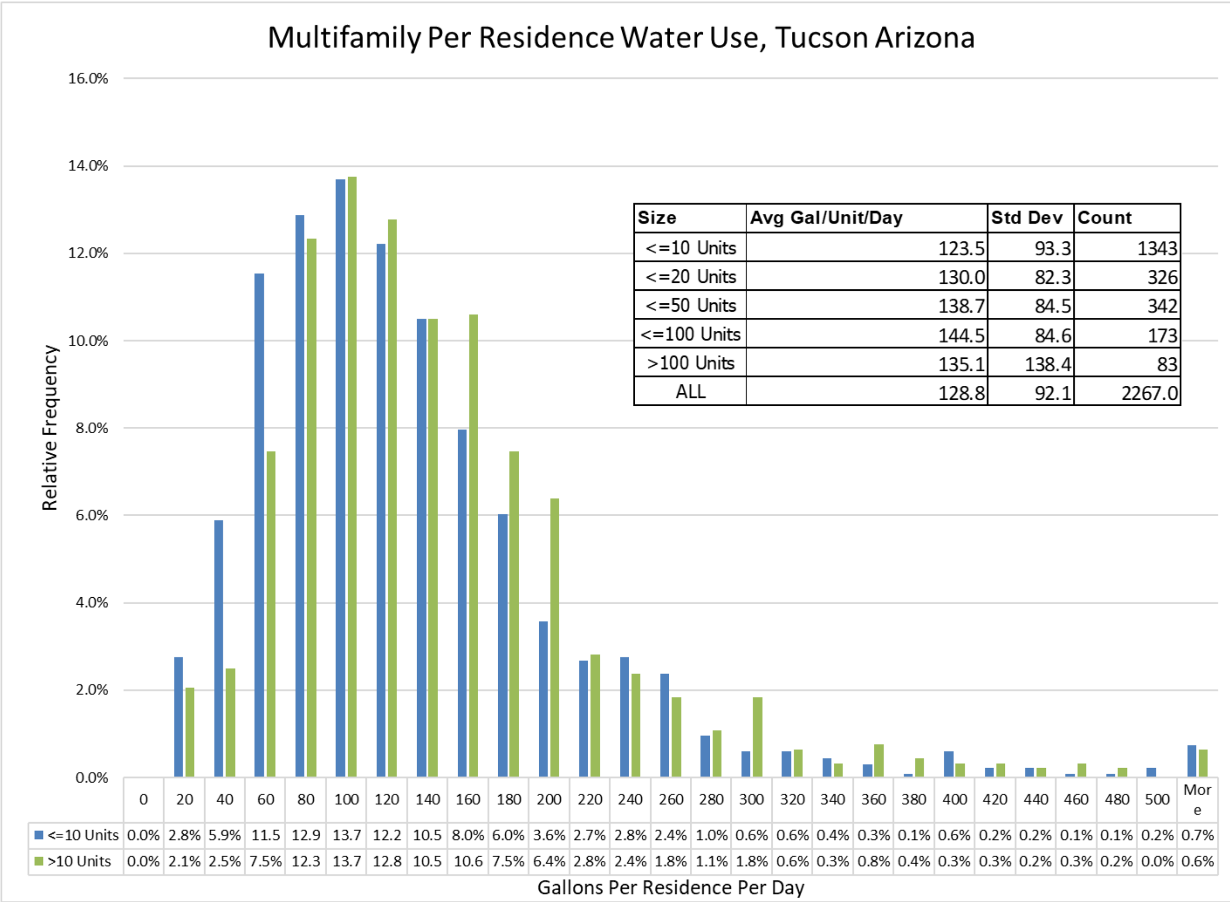


Figure 8 Multifamily Gallons per Residence per Day, 2018



Size	Avg Gal/Unit/Day	Std Dev	Count
<=10 Units	123.5	93.3	1343
<=20 Units	130.0	82.3	326
<=50 Units	138.7	84.5	342
<=100 Units	144.5	84.6	173
>100 Units	135.1	138.4	83
ALL	128.8	92.1	2267.0

	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	More
<=10 Units	0.0%	2.8%	5.9%	11.5	12.9	13.7	12.2	10.5	8.0%	6.0%	3.6%	2.7%	2.8%	2.4%	1.0%	0.6%	0.6%	0.4%	0.3%	0.1%	0.6%	0.2%	0.2%	0.1%	0.1%	0.2%	0.7%
>10 Units	0.0%	2.1%	2.5%	7.5%	12.3	13.7	12.8	10.5	10.6	7.5%	6.4%	2.8%	2.4%	1.8%	1.1%	1.8%	0.6%	0.3%	0.8%	0.4%	0.3%	0.3%	0.2%	0.3%	0.2%	0.0%	0.6%

Figure 9 Multifamily Gallons per Residence per Day, Small and Large Buildings, 2018

2.2.2.2 Commercial, Industrial, and Institutional Trends

Water use in Tucson's CII sector declined since 2008 as shown in Figure 10, but the decline is less sharply defined than in the residential sectors. Minimum monthly use has not changed much since 2008 and maximum monthly use has reduced only slightly. One of the recommendations from this program analysis is to further extend and enhance commercial conservation programs based on their proportional consumption as shown in Figure 4. The fact that that residential sector has declined more steeply suggests additional potential may exist for commercial customers to increase efficiency and this sector is deserving of additional conservation program resources.

In contrast, water demand in Tucson's industrial and institutional sectors declined steeply since 2008 as shown in Figure 11. Total annual industrial sector use declined sharply from 2008 – 2015, bounced back up in 2016 and 2017 and down again in 2018. This trend also reflects the decrease in the number of industrial accounts, dropping by over 16% during this time period. Industrial users account for the smallest percent of usage of all customer classes. Both minimum monthly use and maximum monthly use followed the declining demand trend.

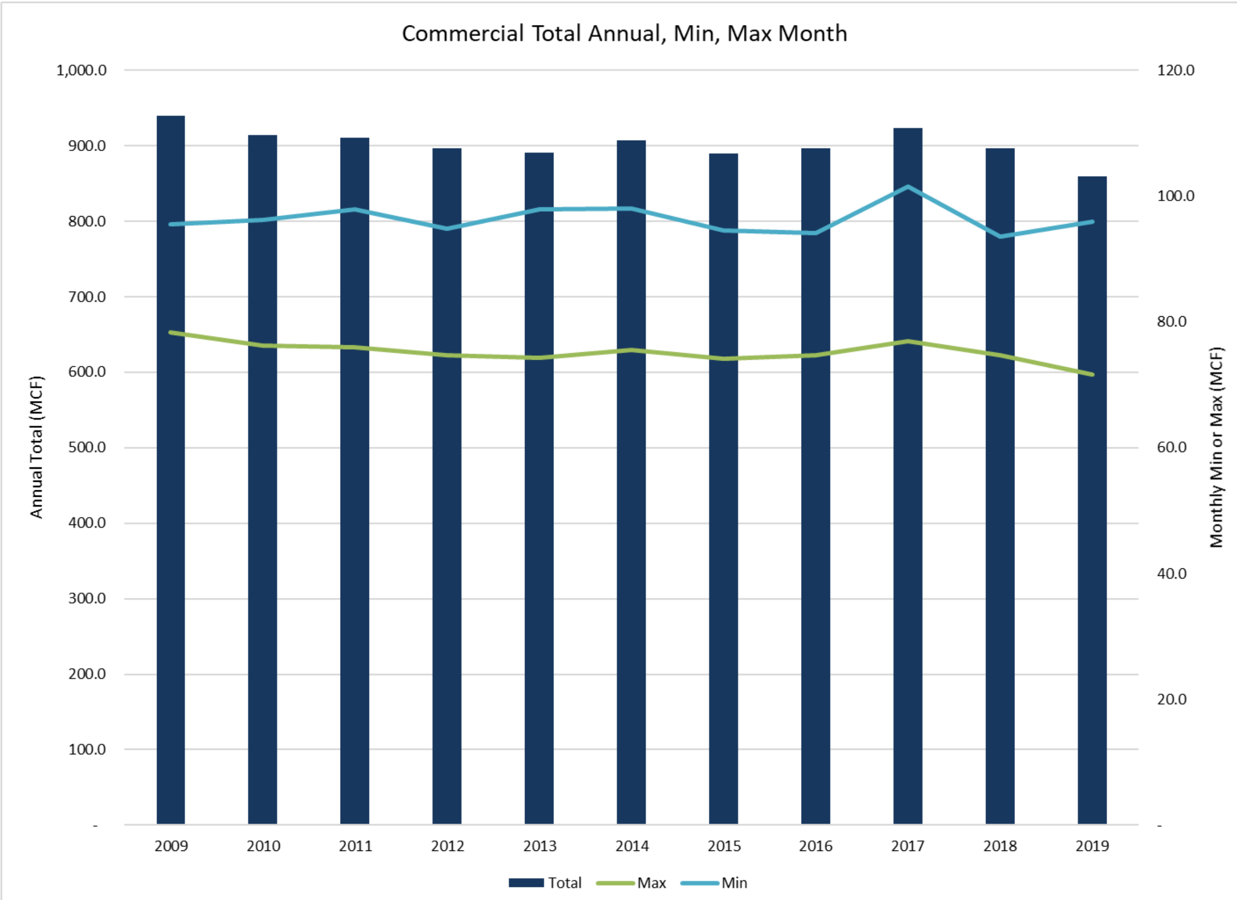


Figure 10 Commercial Annual and Minimum and Maximum Month Water Use, 2009 – 2019

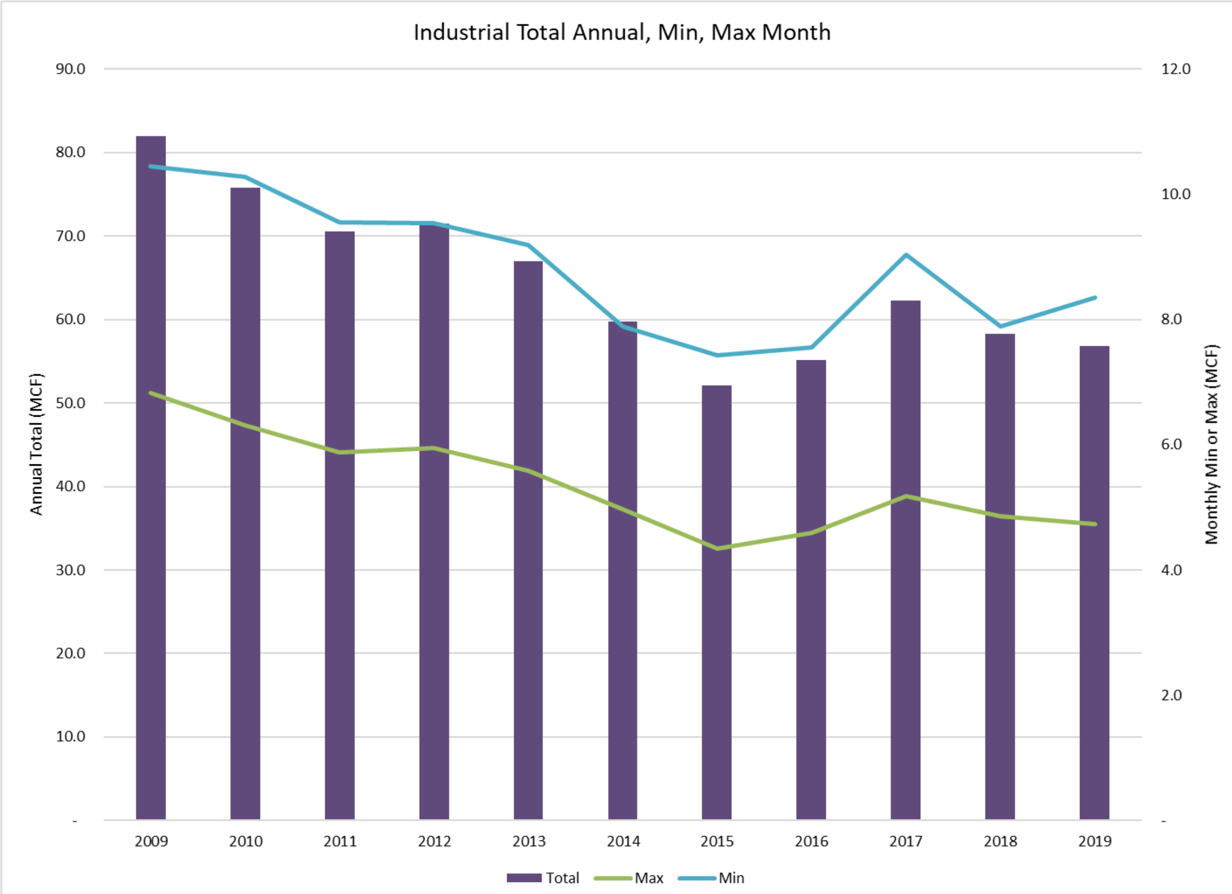


Figure 11 Industrial Annual and Minimum and Maximum Month Water Use, 2009 – 2019

3.0 Water Conservation 2030 – Ten-Year Savings Analysis

WaterDM prepared high, mid, and low range water savings estimates based on the financial incentives and rebates Tucson Water currently implements, as well as some they are evaluating and considering adding to the program. These estimates project water savings over the next 10 years, assuming annual fund revenue remains fairly constant. The mid-range estimate is based on Tucson Water's projected ten-year program implementation levels within current budget constraints. The low estimate assumes a 25% reduction in incentives and the high estimate assumes a 25% increase in incentives compared with the mid-range.

Using the mid-level savings estimate, Tucson's incentive programs alone are estimated to reduce Tucson water demand by 11,805 acre-feet over the next ten years. Summary results for each of the program implementation scenarios are shown in Table 5.

To develop the 10-year savings analysis, engineering estimates of water savings were calculated based on the goal number of incentives Tucson Water may offer each year and the estimated annual water savings achieved by each measure at the customer level. The calculated savings are combination of existing incentives that ongoing and expected to continue into the next decade and additional incentives that represent new areas of opportunity, based on emerging trends, technology and analysis findings. The useful life of each product was also taken into consideration. Water savings accrue each year for the useful life of the specific program measure (e.g. toilet, clothes washer, etc.).

Annual average per unit annual water savings estimates were based on the best available research for each program measure.[5] In most instances the water savings estimates come from research conducted by the Alliance for Water Efficiency for their water tracking tool, or the Water Research Foundation, and in others the best available, locally relevant research was used to develop the savings estimates.

Water savings for each measure is assumed to continue and accrue for the useful life of the product. Table 3 presents the estimated useful life for each of the major incentive categories along with a source reference for the information. In general, the useful life of the measures Tucson Water implements extends beyond the 10-year time frame of this analysis.

Table 3 Useful life estimates for Tucson Water incentive programs and references

Incentive Program	Useful Life (years)	Reference for Useful Life
Single-Family HET	25	Alliance for Water Efficiency Tracking tool
Low-Income HET	25	Alliance for Water Efficiency Tracking tool
Multi-Family HET	25	Alliance for Water Efficiency Tracking tool
Commercial HET	25	Alliance for Water Efficiency Tracking tool
High-Efficiency Urinal	25	Alliance for Water Efficiency Tracking tool
Clothes Washer	15	Alliance for Water Efficiency Tracking tool
Gray Water	15	Not in AWE tracker, but set same as useful life of clothes washers since laundry water capture is the most common type of graywater system
Irrigation Upgrade	10	Alliance for Water Efficiency Tracking tool
TAP Commercial Upgrade	20	Alliance for Water Efficiency Tracking tool
Rainwater Harvesting	20	Batchelor, C., Fonseca, C. and Smits, S., 2011. *Life-cycle costs of rainwater harvesting systems.*

4.0 Conservation Program Recommendations

To develop the water savings estimate, the total anticipated water reductions from all incentivized measures that will be achieved over the next 10 years were aggregated. This provides an estimate of the water savings Tucson Water will over the next decade. This approach to estimating water savings is consistent with the approach that Tucson Water has used for many years and is similar to the method developed by the Alliance for Water Efficiency for their Water Conservation Tracking Tool.[6]

[5] The Alliance for Water Efficiency Water Conservation Tracking Tool, and the Water Research Foundation Residential, Multifamily, and CII end use studies formed the basis for the savings estimates.
[6] Water savings estimates should be reviewed and revised every five years to account for changes in fixtures and demand patterns.

4.1 10-Year Savings Estimates

A range of three water savings estimates were developed for the financial incentive and rebate program measures Tucson Water already implements and intends implement over the coming years. The range of savings estimates is shown in 4 (same as Table 1; reinserted here for reference). These engineering estimates of water savings were calculated based on quantities of incentives Tucson may offer each year, the expected useful life of each measure, and assumed annual water savings values based on research from the Alliance for Water Efficiency, the Water Research Foundation, and Tucson Water.

The mid-level water savings estimate was designed to model Tucson Water's current conservation incentive program implementation levels. The high savings estimate assumes a 25% increase in incentives compared with the mid-range and the low savings estimate assumes a 25% decrease in incentives. The specific savings contribution of each program component is shown in Table 5. The high and low estimates are presented in detail in Appendix B.

Table 4 Tucson Water New 10-Year Water Savings Estimates

Scenario	10-Year Water Savings Estimate (AF)	Avg. Savings/Yr. (AF)
High	16,931	1,693
Mid	11,661	1,166
Low	7,055	705

The low, mid and high scenarios in Table 4 are based are varying levels of rebate program activity, reflected as an annual number of incentives, and correlated to a range of costs to achieve estimated savings. These scenarios reflect conservation program design options described by staff and stakeholders gathered during input sessions in 2019. More specifically, the mid scenario reflects rebate expenditures based on the current allocation of program resources, with incentives accounting for about 30% of the total conservation budget annually. The high scenario reflects investment in additional future incentives, based on current demand trends and savings opportunities. Particularly, this technical memo identified savings potential in the commercial customer class, as well as outdoor savings in all customer classes, which may be addressed in part through incentives. The low scenario reflects a shift in resources from incentives to more investment in education, research and outreach to reinforce community-wide conservation actions. This scenario also reflects customized incentive packages for customers like Homeowners Associations and commercial businesses. Developing customized incentive packages is requires more staff resources and strong customer commitment. These constraints may reduce the number of these packages which is why this measure was included in the low estimate.

Substantial additional demand reductions beyond these estimates are expected due to Tucson Water's education and outreach efforts and through the natural replacement of older fixtures and appliances that occurs without incentive from Tucson Water. The long-term demand forecast developed for the One Water 2100 project should incorporate the totality of the impacts of the Tucson Water Conservation Program which go well beyond the more limited estimates presented in Table 5. Also included in Table 5 are estimates of total savings including ongoing water savings from programs Tucson Water has implemented previously.[7]

[7] When forecasting future demand from the current baseline, only the future water savings estimate should be used. The total including ongoing savings from previous measures is useful for program evaluation, cost-effectiveness analysis, and understanding where water savings are being achieved.

Table 5 Mid-Range Water Savings Estimates for Financial Incentive and Rebate Program Measures

Tucson Water Conservation Program Incentive Measures	Mid-Range Items Per Year	Water Savings Per Item (gal/year)*	Mid-Range	
			10-Year Savings (MG)	10-Year Savings + Ongoing Previous (MG)
Existing Incentive Programs				
Single-Family High-Efficiency Toilet (HET)	1,500	7,483	741	2,478
Multi-Family HET	2,250	7,483	1,094	3,350
Commercial HET - (tank-type toilets)	150	8,030	78	403
Commercial HET - (flushometer-type toilets)	38	16,425	41	99
Low-Income HET	563	8,577	314	961
High-Efficiency Urinal	75	6,206	30	80
Gray Water	19	13,615	17	43
Irrigation Efficiency	0	229,950	0	76
Clothes Washer	1,125	7,043	515	1,081
Commercial Upgrade	56	40,000	146	234
Low-Income HET - Emergency Repairs	150	2,000	13	13
Rainwater harvesting rebate	225	5,535	81	81
Low Income Rainwater harvesting rebate	75	5,535	27	27
Existing Incentive Programs Total	**MG**		**3,097**	**8,926**
	Acre-Feet		**9,504**	**27,393**
Potential New Incentive Programs				
Turf removal rebates – (focus on public and non-residential, streetscapes & medians)	100	26,298	128	128
Customized landscape incentive package	100	13,149	64	64
Customized incentives for multifamily and HOAs	100	59,275	289	289
Multifamily Smart Controllers	250	1,250	15	15
Commercial Smart Controllers	250	1,250	15	15
Commercial Cooling Tower Program	20	120,000	119	119
Customer leak detection device rebate	500	2,969	72	72
Potential New Incentive Programs Total	**MG**		703	703
	Acre-Feet		2,157	2,157
Total Existing and Potential New Programs	**MG**		**3,800**	**9,629**
	Acre-Feet		**11,661**	**29,550**

Sources: Tucson Water, Alliance for Water Efficiency Water Conservation Tracking Tool, DeOreo, W. et. al. 2016. Residential End Uses of Water, Version 2. Water Research Foundation. Denver, CO.; Kiefer, J. et. al. 2018. Water Use in the Multi-Family Housing Sector. Water Research Foundation. Denver, CO.; Dziegielewski, B.et. al. 2000. Commercial and Institutional End Uses of Water. American Water Works Association and AWWA Research Foundation. ISBN 1-58321-035-0.; Chesnutt, T. et. al. 2019. Landscape Transformation: Assessment of Water Utility Program and Market Readiness Evaluation. Alliance for Water Efficiency. Chicago, IL; Tucson Water Conservation Program 2020 .

Water demand expert, Peter Mayer, P.E., Principal of WaterDM, prepared a set of recommendations for Tucson Water to consider based on his review of local and national water demand trends and Tucson's current water conservation program offerings. These recommendations are intended to increase the overall effectiveness of the Tucson Water Conservation Program to ensure continued, sustained, equitable demand reductions across all sectors of water customers.

1. **Adjust rebate levels and increase efficiency of fixtures and appliances for which rebates are offered to increase cost-effectiveness.**

Tucson Water only incentivizes the purchase of high-efficiency products that offer measurable improvement over other available options. To ensure this continues, fixture efficiency and performance must be considered because the volumetric differences between some products have become smaller. For example, the efficiency level of the toilets eligible for rebates can be reduced from 1.28 to 1.1 gallons/flush based on Maximum Performance Testing (MaP) scores, and similar adjustments could be made in the future if clothes washer efficiency increases. Tucson Water conservation staff should continue to manage both the efficiency level of incentivized products and the dollar amount of the incentive offered over the next decade to make best use of available funding and to ensure maximum water savings.

2. **Increased emphasis on commercial customers.**

Water demand in the commercial sector did not decline significantly over the past 10 years as it has in other sectors. Over the next 10 years Tucson Water could renew focus on commercial customers. This could include increased marketing of the customized efficiency packages created to fit the requirement of the customer.

For large water users such as multifamily complexes, HOAs, commercial properties, schools, and other institutional customers, Tucson Water currently offers the combination of account analysis and a water audit to identify areas for improvement, coupled with a package of financial incentives to pay for implementing the recommended efficiency improvements. The customized efficiency packages can include incentives for both indoor and outdoor measures including fixture replacement and landscape changes. It is recommended that Tucson Water increase the emphasis of this effort for commercial properties which will likely require extended outreach to high-demand commercial customers.

3. **Expand focus on desert-adapted landscapes.**

Tucson's urban landscape has undergone multiple transformations over the last half-century. As Tucson's population grew, water-intensive, non-native species and large amounts of turf gained popularity, but necessary water demand management led to widespread adoption of xeric plants over the last several decades. Today, sustainable practices like water harvesting are visible throughout the community. Given future climate projections and the policy focus of increasing shade canopy to reduce the urban heat island impact and mitigate community hotspots, there is a present opportunity for the next era of urban landscape transformation. A focus on landscape water-efficiency and resiliency, including increased tree canopy, and the continued transformation of high-water demand landscapes must be a cornerstone of the Tucson Water Conservation Program. It is recommended that Tucson Water expand efforts to incentivize customers to remove high-water use landscape areas and replace them with appropriate, desert-adapted landscapes, including trees, that requires less water.

This effort would be aided by the further strategic development of landscape water budgets which enable the conservation team to identify customers who are using water inefficiently outdoors. Many Tucson Water customers are already highly efficient in their outdoor use but identifying those who are not provides a way to target landscape transformation incentives to those customers with real opportunity to reduce use.

4. Improve Tucson Water's ability to understand customer water use and ability to target conservation programs with customer-specific water budgets.

Tucson Water's recently updated Drought Preparedness and Response Plan clearly ties Tucson's drought stages to water levels in Lake Mead and Tucson Water's Central Arizona Project (CAP) allocation. It also introduces the concept of customer-specific "water use guidelines" which will be used to help customers and Tucson Water understand who is using water reasonably and efficiently and who is not. Water use guidelines are synonym for the more technical term "water budgets", which is the quantity of water that is required for an efficient level of use.

Tucson Water has begun to develop landscape water budgets as a tool for targeting water efficiency, managing demand across the service area and extending outreach to the commercial sector. Tucson Water plans to expand development of customer-specific water use guidelines, which can include both indoor and landscape water budgets, for use in the water conservation program and in the drought response planning process.

5. Increase customer-side leak detection.

Large customer-side water leaks caused by toilets, irrigation systems, leaky services lines, fixtures left on, or other sources occur infrequently, but when they do happen, substantial volumes of water are wasted. New technology for monitoring water uses at the customer level, either through utility-scale advanced metering infrastructure (AMI) or using customer-level devices capable of detecting leaks is now widely available. The Tucson Water Conservation Program should continue to explore, deploy, and incentivize these technologies whenever appropriate. Reducing customer-side leakage should be an important water savings measure going forward.

6. Support efforts to improve fixture efficiency in plumbing and building codes.

Strong plumbing codes have proven one of the most effective ways to ensure water efficiency today and into the future. The efficiency of fixtures like toilets and faucets that can be installed in Tucson is established in the International Plumbing Code, 2012 Edition, which sets maximum uses for indoor fixtures.

Since 2012, the voluntary EPA WaterSense program has increased the efficiency of toilets, showerheads, faucets, and other water using fixtures and equipment. WaterSense sets voluntary efficiency standards that manufacturers may choose to meet and thus receive the WaterSense label designating the product for water efficiency and performance. Yet uncertainty about long-term funding for WaterSense make it problematic to include in codes.

To increase the efficiency of fixtures in all new buildings and remodels, Tucson could adopt an updated version of the International Plumbing Code or the Green Plumbing and Mechanical Code Supplement from IAPMO (www.iapmo.org), which includes specifications for high-efficiency fixtures. This would help ensure that only high-efficiency fixtures and appliances are installed in both new construction and renovation projects. Tucson Water conservation staff should work with stakeholders and the City's Planning and Development Services Department to advance this effort in the coming years.

5.0 Summary

Water conservation is an essential component of Tucson Water's long-term strategy to provide high-quality, reliable water service for the future. A water conservation program does not produce additional water resources above and beyond what is physically available. Instead, it preserves and extends currently available water supplies by increasing water-use efficiency and reducing per capita use. With this goal in mind, the Tucson Water Conservation Program's investments in the community and outreach to water users has demonstrably and steadily decreased per capita use and total water demand for more than 20 years.

The importance of water conservation to Tucson to the community and the long-term sustainability of the City motivated Tucson Water to take a closer look at the impact and future water savings of the Water Conservation Program in conjunction with the One Water 2100 Master Plan.

5.1 Water Conservation Program Recommendations

WaterDM, prepared a set of recommendations for Tucson Water to consider based on a review of local and national water demand trends and Tucson's current water conservation program offerings. These recommendations are intended to increase the overall effectiveness of the Tucson Water Conservation Program to ensure continued, sustained, equitable demand reductions across all sectors of water customers.

WaterDM's six recommendations are:

1. Adjust rebate levels and increase efficiency of fixtures and appliances for which rebates are offered to increase cost-effectiveness.
2. Increased savings opportunities for commercial customers.
3. Expand focus on outdoor water use, with emphasis on resilient, desert-adapted landscapes.
4. Improve Tucson Water's ability to understand customer water use and ability to target conservation programs with customer-specific water budgets.
5. Increase customer-side leak detection to reduce water waste and loss.
6. Support efforts to improve fixture efficiency in plumbing and building codes and consider additional policies to ensure community water savings.

5.2 Estimated 10-Year Water Savings

Over the next ten years, Tucson Water intends to extend and strengthen its water conservation program with the goal of saving an additional 11,805 acre-feet of water directly through the implementation of a wide range of indoor and outdoor measures and substantially more through pricing, codes and standards, and education programs.

A range of three water savings estimates were developed for the financial incentive and rebate program measures Tucson Water intends implement over the coming years. Using the mid-level savings estimate, Tucson's incentive programs alone are estimated to reduce Tucson water demand by 11,805 acre-feet over the next ten years. The engineering estimates of water savings were calculated based on the quantities of incentives Tucson may offer and annual water savings values based on research conducted by Tucson Water and WaterDM.

Additional demand reductions beyond these estimates are expected through Tucson Water's education and outreach efforts and through the natural replacement of older fixtures and appliances that occurs without incentive from Tucson Water. The long-term demand forecast developed for the One Water 2100 project developed by Jacobs incorporates the totality of the impacts of the Tucson Water Conservation Program and passive savings that will continue to accrue from previous incentives.

6.0 References

American Water Works Association. 2013. G480 Water Conservation Program Operation and Management Standard. AWWA. Denver, CO.

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7.0 Appendix A

7.1 AWWA G480 Water Conservation Standard Checklist

The American Water Works Association G480 Water Conservation Standard is a voluntary G-series standard that sets out minimum requirements for effective water conservation programs. Peter Mayer of WaterDM sat on the committee that developed the G40 standard in 2013 and 2020. WaterDM has prepared a check-list to help water utilities determine if they are fully compliant with the G480's 2020 voluntary requirements. Tucson Water meets or exceeds most of the G480 requirements and is almost fully compliant with this industry performance standard.

Water Conservation Program Operation and Management
ANSI/AWWA G48-20

		Tucson Water Yes/No/NA
4.1	Regulatory Requirements	Yes
4.1.1	Meets or exceeds state and local regulatory requirements	Yes
4.2	Top-Level Organization Functions	Yes
4.2.1	Staff for conservation initiatives (point of contact)	Yes
4.2.2	Water conservation & efficiency planning	Yes
4.2.3	Water efficiency in integrated resources planning	Yes
4.2.4	Water shortage or drought plan	Yes
4.2.5	Public information and education program	Yes
4.2.6	Water waste ordinance	Yes
4.3	Internal Utility Actions and Requirements	Yes
4.3.1	Metering of all sources and service connections	Yes
4.3.1.1	Universal metering (in progress at least)	Yes
4.3.1.2	Source water metering	Yes
4.3.2.1	Nonpromotional rate structure with financial incentive to reduce use	Yes
4.3.2.2	Volumetric components in sewer rate structure	Yes
4.3.3	Billing Practices	Yes
4.3.3.1	Monthly or bi-monthly billing	Yes
4.3.3.2	Bills clearly report consumption	Yes

4.3.3.3	Estimated readings a maximum of twice per year	Yes
4.3.4	Landscape efficiency program	Yes
4.3.4.1	Programs to improve design, installation, and maintenance practices	Yes
4.3.4.2	Irrigation scheduling based on plant needs and time of day	Yes
4.3.4.3	Landscape water budgets	Yes
4.3.4.4	Landscape transformations	Yes
4.3.5	Water loss control program	Yes
4.3.5.1	Utility water audit	Yes
4.3.5.2	Water audit validation	No
4.3.5.3	Public availability of water loss audit	No
4.4	External Policy Requirements	Yes
4.4.1	Water efficiency in building codes and standards	Yes
4.4.2	Integration of water efficiency and land use planning	Yes
4.5	Wholesale agency requirements	NA

8.0 Appendix B

8.1 Conservation Program Low and High Range Estimates

Table 6 High-Range Water Savings Estimates for Financial Incentive and Rebate Program Measures

Tucson Water Conservation Program Incentive Measures	High-Range Items Per Year	Water Savings Per Item (gal/year)*	High-Range	
			New 10-Year Savings (MG)	New + Ongoing 10-Year Savings (MG)
Existing Incentive Programs				
Single-Family High-Efficiency Toilet (HET)	2,000	7,483	988	2,725
Multi-Family HET	3,000	7,483	1,459	3,715
Commercial HET - (tank-type toilets)	200	8,030	377	429
Commercial HET - (flushometer-type toilets)	50	16,425	85	112
Low-Income HET	750	8,578	857	1,066
High-Efficiency Urinal	100	6,206	70	90
Gray Water	25	13,615	37	48
Irrigation Efficiency	0	229,950	0	76
Clothes Washer	1,500	7,043	909	1,253
Commercial Upgrade	75	40,000	185	283
Low-Income HET - Emergency Repairs	200	2,000	9	18
Rainwater harvesting rebate	300	5,535	54	108
Low Income Rainwater harvesting rebate	100	5,535	18	36
Existing Incentive Programs Total	MG		5,048	9,958
	Acre-Feet		15,493	30,561
Potential New Incentive Programs				
Turf removal rebates – (focus on public and non-residential, streetscapes & medians)	100	26,298	85	85
Customized landscape incentive package	100	13,149	43	43
Customized incentives for multifamily and HOAs	100	59,275	193	193

Multifamily Smart Controllers	250	1,250	10	10
Commercial Smart Controllers	250	1,250	10	10
Commercial Cooling Tower Program	20	120,000	79	79
Customer leak detection device rebate	500	2,969	48	48
Potential New Incentive Programs Total	MG		469	469
	Acre-Feet		1,438	1,438
Total Existing and Potential New Programs	MG		5,517	10,427
	Acre-Feet		16,931	31,999

Sources: Tucson Water, Alliance for Water Efficiency Water Conservation Tracking Tool, DeOreo, W. et. al. 2016. Residential End Uses of Water, Version 2. Water Research Foundation. Denver, CO.; Kiefer, J. et. al. 2018. Water Use in the Multi-Family Housing Sector. Water Research Foundation. Denver, CO.; Dziegielewski, B.et. al. 2000. Commercial and Institutional End Uses of Water. American Water Works Association and AWWA Research Foundation. ISBN 1-58321-035-0.; Chesnutt, T. et. al. 2019. Landscape Transformation: Assessment of Water Utility Program and Market Readiness Evaluation. Alliance for Water Efficiency. Chicago, IL.

Table 7 Low-Range Water Savings Estimates for Financial Incentive and Rebate Program Measures

Tucson Water Conservation Program Incentive Measures	Low-Range Items Per Year	Water Savings Per Item (gal/year)*	Low-Range New 10-Year Savings (MG)	Low-Range New + Ongoing 10-Year Savings (gal)
Existing Incentive Programs				
Single-Family High-Efficiency Toilet (HET)	1,000	7,483	494	2,231
Multi-Family HET	1,500	7,483	730	2,985
Commercial HET - (tank-type toilets)	100	8,030	52	377
Commercial HET - (flushometer-type toilets)	25	16,425	27	85
Low-Income HET	375	8,578	209	857
High-Efficiency Urinal	50	6,206	20	70
Gray Water	13	13,615	11	37
Irrigation Efficiency	-	229,950	0	0
Clothes Washer	750	7,043	343	909
Commercial Upgrade	38	40,000	98	185
Low-Income HET - Emergency Repairs	100	2,000	9	9
Rainwater harvesting rebate	150	5,535	54	54
Low Income Rainwater harvesting rebate	50	5,535	18	18
Existing Incentive Programs Total			2,065	7,818
			6,336	23,992
Potential New Incentive Programs				
Turf removal rebates – (focus on public and non-residential, streetscapes & medians)	50	26,298	43	43
Customized landscape incentive package	50	13,149	21	21
Customized incentives for multifamily and HOAs	50	59,275	96	96
Multifamily Smart Controllers	125	1,250	5	5
Commercial Smart Controllers	125	1,250	5	5

Commercial Cooling Tower Program	10	120,000	40	40
Customer leak detection device rebate	250	2,969	24	24
Potential New Incentive Programs Total	MG		234	234
	Acre-Feet		719	719
Total Existing and Potential New Programs	MG		2,299	8,052
	Acre-Feet		7,055	24,711

Sources: Tucson Water, Alliance for Water Efficiency Water Conservation Tracking Tool, DeOreo, W. et. al. 2016. Residential End Uses of Water, Version 2. Water Research Foundation. Denver, CO.; Kiefer, J. et. al. 2018. Water Use in the Multi-Family Housing Sector. Water Research Foundation. Denver, CO.; Dziegielewski, B.et. al. 2000. Commercial and Institutional End Uses of Water. American Water Works Association and AWWA Research Foundation. ISBN 1-58321-035-0.; Chesnutt, T. et. al. 2019. Landscape Transformation: Assessment of Water Utility Program and Market Readiness Evaluation. Alliance for Water Efficiency. Chicago, IL.

Appendix H

ONE WATER 2100 SMART METERING

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
SMART METERING

JANUARY 21, 2022

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
SMART METERING

JANUARY 21, 2022

Contents

Technical Memorandum

SMART METERING

1.0 Introduction

As part of Tucson Water's "One Water 2100 Master Plan", the utility is undertaking an updated analysis of the potential benefits associated with implementing Advanced Metering Infrastructure (AMI), an approach to "smart metering". The objectives of this analysis are to build upon Tucson Water's prior AMI evaluations to identify recent changes or trends in the AMI industry, identify a broader range of applicable AMI benefits, develop an updated business case analysis, and explore effects of AMI on customer water use behaviors.

The purpose of this technical memorandum (TM) is to document Tucson Water's updated assessment of AMI and recommend next steps for consideration. The document is organized as follows:

- Section 2 presents a summary of Tucson Water's recent history of meter replacements, the current meter reading approach (Automated Meter Reading, or AMR), and efforts completed to-date in exploring the potential of AMI.
- Sections 3 and 4 describe many of the benefits associated with AMI as compared to the current AMR program.
- Section 5 summarizes a literature review of the potential impacts of AMI systems on customer water consumption behaviors.
- Section 6 presents an update to the AMI business case analysis previously developed for Tucson Water, considering quantitative and qualitative differences between AMI and AMR.
- Section 7 summarizes the findings of this evaluation and outlines recommended next steps.

Based on the enumeration of benefits and the updated business case analysis presented in this TM, transitioning to AMI outweighs the alternative of continuing to operate a full AMR meter reading system. Although additional capital costs are required to make the move to AMI, the benefits associated with AMI are significant and when viewed over a 15-year life cycle, they exceed the costs. Therefore, transitioning to AMI is recommended.

2.0 Tucson Water AMI History

Tucson Water (also referred to throughout this document as the Utility) is a department of the City of Tucson. The Utility has nearly 250,000 water customer connections. The Utility initiated a meter replacement program in 2004 to replace meters 20 years and older. As old meters were changed out, many were replaced with AMR (i.e., drive-by meter reading) capabilities if the area of the system being replaced met specific criteria. In 2011, Tucson Water established a policy requiring all new meter installations to have AMR capabilities. The Utility made the Itron AMR system standard and has been installing the 100W encoder receiver transmitter (ERT) on all replacement and new meters.

The transition to AMI was envisioned to occur if and when taking that step would add sufficient value to warrant the additional investment required. Additional studies have been or are being conducted to inform next steps in considering the AMI transition, including an AMI pilot study and meter technology evaluation. A detailed AMI Strategic Plan was developed in 2013, which established a business case for transition to system-wide AMI (Malcom Pirnie, 2013).

In recent years the Utility, and more broadly the City of Tucson, has made significant strides in implementing new technologies and business processes that leverage the ever-increasing amount of data that are available to support decision-making in systems operations. As part of its IT Business Operation Plan (ITBOP), Tucson Water has identified steps to become a "digital utility", using data to drive business operations. One technical item related to this is the City's rollout of a low-power wide area network (LoRaWAN) to manage communication between various devices and network gateways. This network provides an opportunity for backhaul of AMI information, through connection of a portion of Itron's proposed AMI collectors to the LoRaWAN gateway.

Tucson Water has always planned for the move from AMR to AMI to occur when the benefits associated with AMI outweighed the additional costs of making that shift. The sections that follow update prior AMI evaluations to inform the Utility's meter reading pathway forward.

3.0 Benefits of AMI – Consumption Data

In previous studies, Tucson Water has considered a range of benefits imparted by AMI. These benefits continue to be the primary drivers in the industry that lead utilities to implement AMI. Below is a summary of a recent exploration into AMI benefits specifically related to the nature of consumption data obtained, conducted as part of a Water Research Foundation project (Brueck et. al., 2018).

3.1 Water Consumption Feedback

Water consumption feedback is a significant benefit to both the customer and utility. From a customer's perspective, this refers to the capability where customers may view their water consumption data in real time. Several options exist for water consumption feedback depending on the intended purpose of reviewing the data. Options include:

- Online metering data. Customers with access to an online data portal can review real time water consumption data. The time intervals may be on the scale of hours down to 15 minutes.
- In-home display (IHD). Customers may use IHDs to track their usage at a more granular level such as a single fixture, a specific group of fixtures, and/or a specific time of day. This allows them to better understand how behavioral changes can lower their water use.
- Shorter billing cycles. Automatic data collection allows the utility the freedom to choose the most optimal billing cycle for the utility and customers.

These benefits are similar to those the Utility is exploring through implementation of its Flume pilot study, where the Flume devices have been utilized by a small number of customers and staff, allowing for customers to monitor their usage in real-time.

From the utility's perspective, the consumption data provided by AMI systems impart benefits such as:

- Customer class or geographic-based standards/comparisons. Utilities can provide customers with detailed information about consumption usage and patterns by household size, square footage, and outdoor watering habits, creating standards against which consumers can measure their own usage. This can be done at the customer class level, or more often at the neighborhood scale, where customers can understand their level of use compared to averages or ranges of use by groups of nearby customers.

- Conservation measure effectiveness tracking. AMI data can trace the immediate before-and-after effect on new installation of conservation measures such as low flow toilets, low water use washers, drip irrigation, rainwater harvesting systems, etc. This kind of information provides valuable feedback to the utility in adjusting conservation programs and planning for future program investments.
- Better water balance calculations. A typical benefit that utilities realize with the increased understanding of water consumption is enhanced abilities to compare water consumption against water production, including on a pressure zone or demand zone basis. This information can also be used to refine peaking factor calculations, both system-wide as well as within specific portions of a system.
- Meter right-sizing. Highly granular data can inform meter sizing criteria used when replacing aging meters, particularly for larger customer accounts.

3.2 Water Loss and Leak Detection

Near real-time consumption data allows utilities and customers to catch leaks in a timely manner. Leaks manifest in consumption data as a consistent and unchanging quantity of consumption at all hours of the day. Benefits of leak detection include:

- Rapid response. Leaks can be costly for customers who are unaware of a leak during a billing cycle (potentially up to two months). Automatic leak detection can inform a customer almost immediately if they have a leak, which can be addressed and resolved promptly to save the customer significant costs.
- Reduced production costs. AMI-equipped sensors installed in the transmission and distribution systems can aid the utility in identifying distribution system leakage. Prompt identification and resolution of water loss in transmission and distribution systems ensures the utility is not producing excessive amounts of water they are not selling which may save money by reducing the water production required if significant leaks are fixed.

3.3 Improved Meter Performance and Maintenance Efficiency

Water meters, particularly mechanical meters, suffer accuracy declines over their useful life. AMI may help a utility refine their meter replacement program and system maintenance protocols.

- Meter accuracy. Long term granular data allows the utility to conduct detailed analyses of meter accuracy over time, which can help inform a more appropriate meter replacement schedule to optimize revenue generation.
- Increased revenue. Old meters that are "under billing" reduce utility revenue per unit volume of water produced. AMI data can indicate when meters are beginning to under register the volume of water a customer purchases and the costs can be recovered promptly with meter replacement or consumption adjustments, the latter of which would require a utility policy change.

3.4 Improved Customer Service

In addition to the customer service benefits mentioned above such as customer-side leak detection (and subsequent savings) and online access to consumption data, the granularity and near real time nature of AMI data provide a significant resource to customer service representatives when responding to customer inquiries regarding utility bills and water use.

Additionally, AMI vendors now offer remote turn on and shut off options, allowing the utility to promptly adjust a customer's status of service if requested or necessary (e.g., due to non-payment). Most devices of this nature provide three "positions" of the valve: fully open, partially open, fully closed. The partially open position provides for a minimal amount of flow, often referred to as "life-sustaining", and is being used by utilities in lieu of fully shutting of service for non-payment so that water for basic needs such as drinking can be made available, though full use of the service connection is prevented.

3.5 Modified Rate Designs

The granularity of consumption data generated by AMI allows utilities to experiment with rate designs other than the traditional volumetric one. One possibility is to create water budgets for different kinds of customers based on characteristics such as lot size, family size, number of bathrooms, and landscaping. Another example, albeit little used by water utilities compared to electric utilities, is time-of-day pricing.

4.0 Benefits of AMI – Operational and Environmental

While the consumption related benefits highlighted in Section 3 were the focus of this review, additional benefits are summarized below.

4.1 Operational Optimization

Full implementation of AMI can streamline utility operation through reducing the amount of staff time associated with obtaining meter reads. This frees up staff resources to attend to other priorities. Many utilities find that more effort can be spent on deferred maintenance or improved customer service activities by reducing the manual labor previously spent on routine meter reads and re-read activities

4.2 Improved Staff Safety

By greatly reducing the amount of time staff are in the field to obtain meter readings through use of AMI, staff safety is improved. This results in lowered potential for worker injury claims and time lost due to safety or hazard related incidents.

4.3 Greenhouse Gas Emission Reduction

The benefit noted above of reduced staff time needed for meter reading results in an environmental benefit through significant reductions in truck rolls and use of fleet motor vehicles; thus, greenhouse gas (GHG) emissions from gasoline use would be avoided. To estimate these avoided GHG emissions, based upon data from Tucson Water, an evaluation was made given the fleet vehicles used, the mileage driven and fuel use for calendar years 2018 and 2019. A review of Utility fleet vehicles used for water meter reading indicates use of an average of fifty gasoline fueled vehicles per year. The predominant vehicle type used in 2018 and 2019 for meter reading was a pick-up truck; with most being Ford F150 trucks, and a few Ford Ranger, Ford F250, and Chevy Blazer trucks.

GHG emissions from fuel used in Utility-owned on-road vehicles were calculated using The Climate Registry's protocol and are consistent with the methods used by HDR to calculate Tucson Water's 2018 Carbon Footprint. The results are shown in Table 1. GHG emissions from replaced Utility fleet vehicle refrigerants in the AC systems were not included.

Water meter reading trucks account for a small fraction of Tucson Water's overall GHG emissions inventory. In 2018, the last year for which HDR has comprehensive emissions data, the calculated water meter reading truck emissions represented 0.36% of the Utility's direct carbon emissions, and 0.07% of the Utility's total GHG emissions (which take into account indirect carbon emissions from the upstream electricity use associated with water delivery from the Central Arizona Project).

Table 1. Tucson Water Meter-Reading Vehicle GHG Emissions

Year	Mileage (mi)	Unleaded Gasoline Fuel (gal)	GHG (Metric Tons [MT] CO_2e/yr)
2018	475,630	38,860	342
2019	504,558	40,756	358

5.0 Benefits of AMI – Impacts on Customer Use Behaviors

The relationship of AMI to changes in customer consumption behavior is complex. Based on the literature review conducted as part of this effort, no peer-reviewed study has been identified that specifically isolates implementation of AMI as a sole or primary variable in changing water use behavior. Therefore, it is difficult to draw strong conclusions about the degree to which activation of Tucson Water's AMI system may alter customer behavior. Unquestionably, the additional data that comes from AMI is beneficial in being able to manage and modify conservation measures and monitor their effectiveness, but direct effects on customer use behavior are more challenging to discern. Summaries of the related literature are provided below.

Primary drivers of water use patterns include customer billing tolerance (i.e., the amount a customer is willing to pay to use their desired quantity of water) and a customer's personal water conservation ethic. Both drivers rely on water consumption data to determine how to adjust consumption behavior and can be engaged when a connection is metered. Much of the behavior adjustment only requires a meter, and AMI may provide only marginally greater information with which to continue to refine behavior. Therefore, it is difficult to conclude whether implementation of an AMI system in and of itself will enhance customer conservation patterns across the board. AMI may provide added benefit to customers looking to further refine their current water use for billing or conservation purposes (Sonderland, 2014; Brueck, et al, 2020).

If customers are educated on water use patterns, water conservation options, and how to interpret their water use data, live AMI data is useful in guiding customer action to reduce water consumption as they feel appropriate:

- In-home displays can be installed on individual fixtures, which can allow customers to observe their water use patterns and change behavior to lower consumption by individual fixtures. This could also act as motivation to replace fixtures with more efficient models if customers are so inclined. This however can also work in the opposite manner, if a customer learns they are using less water than expected or recommended and they then increase usage (Sonderland, 2014).
- Customers may discover leaks through analyzing their consumption data. This is particularly true if the customer has access to their detailed data through an online customer portal, which can also be used by the utility to proactively send leak alerts and other notifications. Leaks can significantly impact a customer's water bill, and timely identification and resolution of customer-side leaks saves customers money and reduces the total quantity of water the utility must produce. This could be

considered a behavior change if customers are generally quicker to repair leaks after AMI is implemented than before.

- In the most recent literature reviewed (Brueck, et al, 2020), participating utilities in a Water Research Foundation research effort recommended that utilities with conservation mandates or requirements to reduce water consumption should provide pertinent information specific to the customer's water usage within the context of similar neighboring or community-wide properties. This understanding of peer water consumption can be used to inform customer behavior. This approach is similar to Tucson Water's primary drought response measure of "water use guidelines" in its Drought Preparedness and Response Plan.

Access to an AMI customer portal may change customer behavior. If a customer is interested in adjusting their use to save on bills or conserve water, but does not know the best route to do so, utilizing a customer portal in conjunction with information from the utility may help a customer choose how best to adjust their behavior to save water (Brueck, et al, 2018).

Customers may also choose to receive alerts when their consumption strays from their typical pattern or rises above a threshold quantity over a defined period of time. As noted before, this is useful when identifying leaks, but may also inform customers when their water use pattern changes (Wimberly et. al., 2018). Though this may not provide additional savings at the outset of AMI activation (unless the customer takes the opportunity for a one-time adjustment to their usage patterns), an automatic alarm system may help the customer continuously keep their usage low, thereby contributing to long-term water use efficiency.

Another consideration regarding customer portal effectiveness is the acceptance or use rate of such portals. Given that they are voluntary and require some level of setup on behalf of the customer, utilities report a moderate range of their use when they are first offered. The reviewed literature did not report on this metric, but in HDR's recent (2019-2020) experience supporting other utilities through AMI procurement, we have observed AMI vendors stating use rates of customer portals typically being within the range of 20-35% of total customer base, within the first few years of AMI deployment. There are exceptions to these averages with some utilities that have more mature programs and a longer tenure of customer portals reporting participation rates as high as the 60-80% range.

6.0 Updated Business Case Analysis

A detailed business case analysis was prepared in 2013 that explored the costs and benefits related to various meter reading options if implemented by Tucson Water over a 15-year planning horizon. This analysis has been revisited in light of the broader suite of AMI benefits discussed in the previous sections and to reflect updated costs. This updated analysis is comprised of two components:

- Quantitative Analysis. HDR updated the 2013 15-year present worth comparison of meter reading options, which considers both capital and operational costs. This allows for direct quantitative comparison between maintaining the current AMR approach versus transitioning to AMI.
- Qualitative Analysis. For those benefits that cannot be reasonably monetized, a brief qualitative analysis has been prepared.

These analysis elements are presented in the following sub-sections.

6.1 Quantitative Analysis

The results of the 2013 business case analysis were documented in the form of present worth (PW) comparisons of meter reading options, as summarized in Table 2.

Table 2. 2013 Present Worth Costs for Meter Reading Alternatives (in $ million)

	Hybrid System: Manual Read and AMR	All AMR	Hybrid System: 50% AMR, 50% AMI	All AMI
Meter Reading O& M Costs (per year)	4.4	3.5	2.4	1.5
Equipment Purchase and Installation	22	45	49	52
Present Worth of Annual O&M	53	42	29	18
Present Worth of Capital Costs	21	44	47	51
Sum of Meter Reading Present Worth	**74**	**86**	**76**	**69**
Other Functionality (per year)	0.42	0.30	0.21	0.12
Present Worth of Other Functionality	5.0	3.6	2.5	1.4
Sum of Total Present Worth	**79**	**89**	**78**	**70**

Source: Tucson Water AMI Strategic Plan (July 2013); Table 6.

Most of the assumptions regarding AMR and AMI operational costs (e.g., number of meter readers, vehicle usage, annual AMI data hosting costs, etc.) approximately remain the same today. However, more refined information now exists for the projected capital costs associated with AMI, through an updated propagation study and cost estimate prepared by Mountain States Pipe & Supply (MSPS), the regional representative for Itron. Therefore, the updated quantitative business case analysis builds upon the prior evaluation by escalating costs from 2013 and incorporating revised assumptions regarding capital infrastructure needs. This is summarized in Table 3. Key assumptions in this analysis are:

- **Options considered**. Only two meter reading options are displayed: All AMR and All AMI. This focuses on addressing the primary current question of whether or not the business case exists to make the transition from the current meter reading program (which is effectively 100% AMR) to full AMI.
- **Deployment timeline**. The 2013 analysis assumed that the AMI data collection system would be installed over the first four-year period of the 15-year timeframe. That assumption is held constant in this updated analysis.
- **Cost escalation**. The starting point is the total PW established for the above two options in the 2013 analysis, escalated to 2021 dollars by applying a 25% escalation factor, based on the approximate average Engineering New Record Construction Cost Index (ENR-CCI) increase for the western portion of the US since 2013.
- **AMI Capital Costs**. These steps were taken to update the capital costs associated with AMI network infrastructure:

  - Subtraction of 2013 AMI capital costs. This includes lines 47-54 of the detailed cost assumptions presented in Appendix D of the 2013 AMI Strategic Plan, related to material and installation costs for 360 data collectors and 17 repeaters. These costs include provision for solar power. The costs were escalated to 2021 dollars before being subtracted from the previously-calculated total PW.
  - Addition of 2021 MSPS capital cost quote. This cost (prepared by MSPS July 30, 2021) reflects full system-wide Itron Choice Connect AMI Network implementation, involving 147 collectors and 439 repeaters.
  - Poles. MSPS' network costs do not include costs associated with approximately 300 35-foot tall poles that will be needed in areas where other existing infrastructure cannot accommodate the collectors or repeaters necessary for full system coverage.
  - Electrical connection. All collectors and repeaters are assumed to be AC powered, and therefore costs are included for each site. This cost will be highly variable, as some sites will require a relatively simple connection to a nearby power source like a street light, whereas some new pole sites may require a dedicated power drop. An average cost of $2,000 per electrical connection was assumed, recognizing that some sites may cost significantly more due to local site conditions which were not analyzed in detail.
- **Remote Shutoff Valves**. To evaluate the cost impacts of potentially installing remote shutoff valves (RSVs), a line item has been included to account for this, assuming these are installed on 10,000 service connections that have a history of repeated turn-on and turn-offs. This unit cost can be variable, but in HDR's recent experience a typical cost is approximately $500, accounting for options where the RSV is integral to the meter, or cases where the RSV is separate from a short lay-length meter, which is used to avoid modifications to meter setters or customer piping.
- **Other Unmodified Costs**. There are many other costs that Tucson Water will incur when transitioning to AMI that were already included in the 2013 PW analysis and which were not modified as they were not likely to have changed significantly. Key items like this include:
  - **Annual AMI infrastructure costs**. This involves routine maintenance and service agreements related to the collectors and repeaters. The current MSPS quote cost is $120 per collector, versus the previously assumed cost of $125. Because these values are so close, no update to this element was included.
  - **Annual Data Hosting Fees**. Monthly cloud-based data hosting services were included in the 2013 analysis, including costs related to a customer portal. No updates were obtained as part of this work, and so the prior cost was retained.
  - **Endpoint Upgrades**. Based on meter data provided by Tucson Water, there are currently approximately 17,000 endpoints (i.e., transmitter units) that would need to be replaced with Itron's 100W endpoint in order to be compatible with the AMI system, as opposed to just operating on AMR. Such upgrades were already accounted for in the 2013 PW analysis, and so those assumptions were held constant and no updates were deemed necessary.

Table 3. Updated Present Worth Costs for Meter Reading Alternatives (in $ million)

	All AMR	All AMI
2013 Present Worth (in 2013 dollars)	89.0	70.0
2013 Present Worth (escalated to 2021 dollars; 25%)	111.3	87.5
(Subtract 2013 AMI Network Capital Costs)	---	(3.9)
Add 2021 AMI Network Capital Costs (MSPS Quote)	---	5.6
Add Poles (300 poles @ $3,000 ea)	---	0.9
Add Electrical Installation (586 sites @ $2,000 ea)	---	1.2
Add Remote Shutoff Valves (10,000 connections @ $500 ea)	---	5.0
Sum of Total Present Worth (in 2021 dollars)	**111.3**	**96.3**

While this analysis indicates that AMI network capital costs have increased relative to the assumptions used in the 2013 evaluation, particularly when mounting pole and electrical costs are included, the present worth of transitioning to full AMI is still less than that of continuing with operation of full AMR, by approximately $15 million, over a 15-year life cycle. This is due to the higher operational costs associated with AMR.

6.2 Qualitative Analysis

Many of the benefits associated with AMI, as presented in detail in Sections 3 and 4, are significant but not readily monetized. As such, they are considered in a qualitative fashion in Table 4, which assigns a "benefit score" relative to the current meter reading approach (AMR). A "benefit score" of High (H) denotes a significant benefit provided by AMI, or a substantial difference in capabilities between AMR and AMI. By contrast, a "benefit score" of Low (L) represents a marginal benefit or difference.

Benefits associated with consumption data receive high scores, based mainly on the increased granularity of data provided by AMI, and the near real-time ability of it to be accessed and communicated to the Utility and to customers. The benefits associated with operational/environmental considerations do not score as high. Some of these benefits area a function of reduced field staff time needed to obtain meter readings. While AMI is vastly different than AMR in this regard, the scores reflect that field staff time is not completely eliminated, due to the need for ongoing maintenance of the AMI system hardware. And, in the case of reduced greenhouse gas emissions, although the amount of vehicle use is significantly decreased with AMI, the resultant emissions reduction is a fairly small fraction of the Utility's overall emissions.

Table 4. Qualitative Assessment of AMI Benefits Relative to AMR

Benefit	Relative Benefit (L/M/H)
Consumption Data	
Water Consumption Feedback	H
Water Loss and Leak Detection	H
Improved Meter Performance and Maintenance Efficiency	M
Improved Customer Service	H
Modified Rate Design	M
Operational/Environmental	
Operational Optimization	M
Improved Staff Safety	M
Greenhouse Gas Emission Reduction	L

L = Low; M = Medium; H = High

7.0 Recommendations and Potential Next Steps

Based on the enumeration of benefits and the updated business case analysis presented in this TM, transitioning to AMI outweighs the alternative of continuing to operate a full AMR meter reading system. Although additional capital costs are required to make the move to AMI, the benefits associated with AMI are significant and when viewed over a 15-year life cycle, they exceed the costs. Therefore, transitioning to AMI is recommended.

Potential next steps in Tucson Water's consideration of transitioning to AMI are:

- Conduct case studies regarding use of AMI to affect customer water use behaviors. As noted in Section 5, a literature review did not identify research that has documented directly the impacts of AMI on customer use behaviors. However, there are utilities that have used AMI for many years, including some with customer portals, that could be directly contacted and for which informal case studies could be conducted if Tucson Water wants to more fully understand their experiences, since those have not yet been clearly documented in the literature. Example utilities are included in Brueck, et al, 2020. Along these lines, the Utility should analyze information from the Flume pilot project to identify any customer behavioral changes that can be correlated to use of that system.
- Evaluate options regarding systems integration to best leverage AMI data. This evaluation did not include a detailed analysis of how the envisioned Itron Choice Connect AMI system would integrate with Tucson Water's customer information system and other platforms that are or will be part of the utility's ongoing transition to a digital utility. For example, integrations between the AMI system and the Utility's current online payment platform, Paymentus, have not been evaluated, though that will be an important part of implementation. However, at its core, an AMI system provides a repository of useful data that can be extracted and/or used by other systems for analytical and potentially operational purposes, yielding additional benefits to those focused upon in this review.

- Further analyze potential AMI benefits pertaining to Tucson Water's business processes associated with termination of service. As the Utility considers various policies surrounding this issue, AMI-related functions could be included in those evaluations. This would include a more in-depth examination of RSVs, options related to their deployment, and evaluation of return on investment for this feature.
- Consider broader range of AMI alternatives if the transition does not occur in the near future. Tucson Water has invested significantly to-date in infrastructure that will support implementation of the Itron Choice Connect AMI system. The business case evaluation (conducted both in 2013, and updated in this present effort) supports that transition. However, if such a transition is appreciably delayed into the future to the point where a significant portion of the presently-installed AMR infrastructure is near the end of it useful life, Tucson Water should revisit the alternatives analysis in more detail, accounting for the age of existing assets and the range of opportunities available in future years. Alternatives to the "fixed network" design of the Choice Connect system are available, such as cellular systems and options that would involve leveraging other communications providers' systems. Such options may warrant closer consideration if implementation of AMI does not occur for some time, as the costs of cellular systems may come down in the future.
- Advance AMI as a Capital Improvement Program (CIP) project. If Tucson Water elects to proceed with transitioning to AMI, one of the first steps will be to prepare a CIP request form. The information contained in this TM may be useful in describing the benefits of such a project and linking it to broader Utility goals. The projected cost information should be revisited at the time of advancing the AMI transition to a capital project, due to the current climate of rapidly increasing construction costs.

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Appendix I
ONE WATER 2100 POPULATION PROJECTIONS

TUCSON WATER
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One Water 2100 Master Plan

Tucson Water
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Technical Memorandum
POPULATION PROJECTIONS

FINAL | April 2020

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Technical Memorandum
POPULATION PROJECTIONS

FINAL | April 2020

This document is released for the purpose of information exchange review and planning only under the authority of Fair Yeager, 24 Apr 2020, Arizona PE 35903.

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Abbreviations

ACS	American Community Survey
CAP	Central Arizona Project
City	City of Tucson
Emp	employee
GIS	geographic information system
HU	housing unit
PAG	Pima Association of Governments
PCD	Planned Community Development
TAZ	Traffic Analysis Zone
Tech Park	University of Arizona Tech Park at Rita Road

Technical Memorandum

POPULATION PROJECTIONS

1.0 Introduction

This memorandum serves to document estimated population projections in Tucson Water's Service Area through the planning horizon of the One Water 2100 Master Plan. The analysis includes consolidation of various data sources including those from Pima Association of Governments (PAG), the US Census Bureau's American Community Survey (ACS), Arizona's Office of Economic Opportunity, discussions with City of Tucson (City) staff, and findings from prior land use planning research. The analysis results in a range of growth to provide the basis for further master planning.

2.0 PAG Estimates

PAG is the region's federally designated metropolitan planning organization and develops population projections, traffic data, and mapping in support of infrastructure planning. Projections from PAG, as described in this section, were used as the basis for the population projections. The PAG projections were confirmed through comparison to US Census Bureau data, as described in Section 3.0, and adjusted to account for known or anticipated growth as described in Sections 4.0 and 5.0. The adjusted projections are summarized in Section 6.0.

The PAG dataset includes residential (in terms of housing units) and non-residential (in terms of employees) estimates for 2018 and projections for 2045 by traffic analysis zone (TAZ) polygons, and it is indicative of demographic, development, and permitting trends in Pima County. A summary of the PAG estimates and projections for the City of Tucson is depicted in Figure 1, which indicates an increase of over 31,000 new housing units and 83,000 employees from 2018 to 2045.

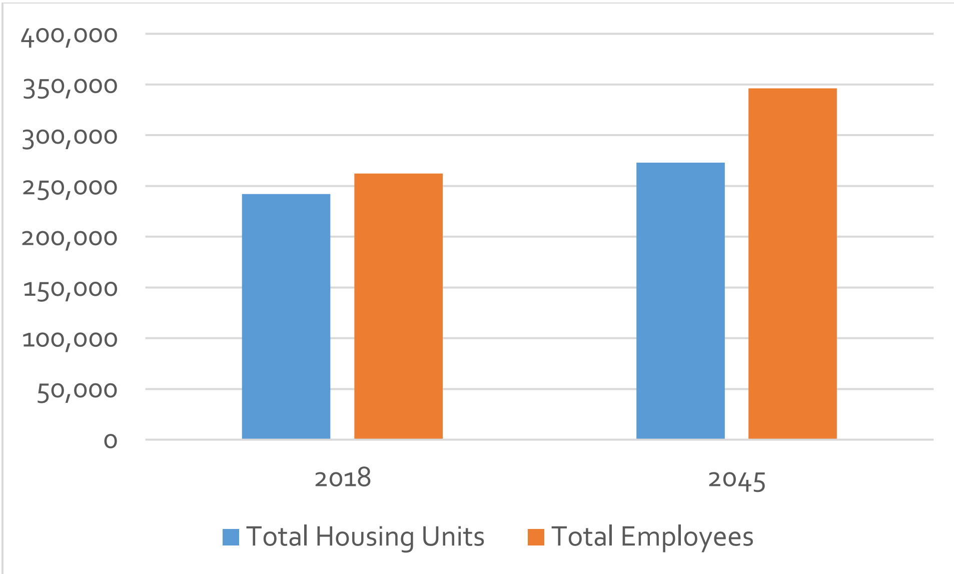


Figure 1 PAG Estimates and Projections of Residential and Non-Residential Growth for the City of Tucson

A spatial summary of PAG's projected growth by sub-area (as designated in the PAG dataset) within the City is shown in Figure 2. The numbers represent the increase in housing units (HU) or employees (Emp) from 2018 to 2045.

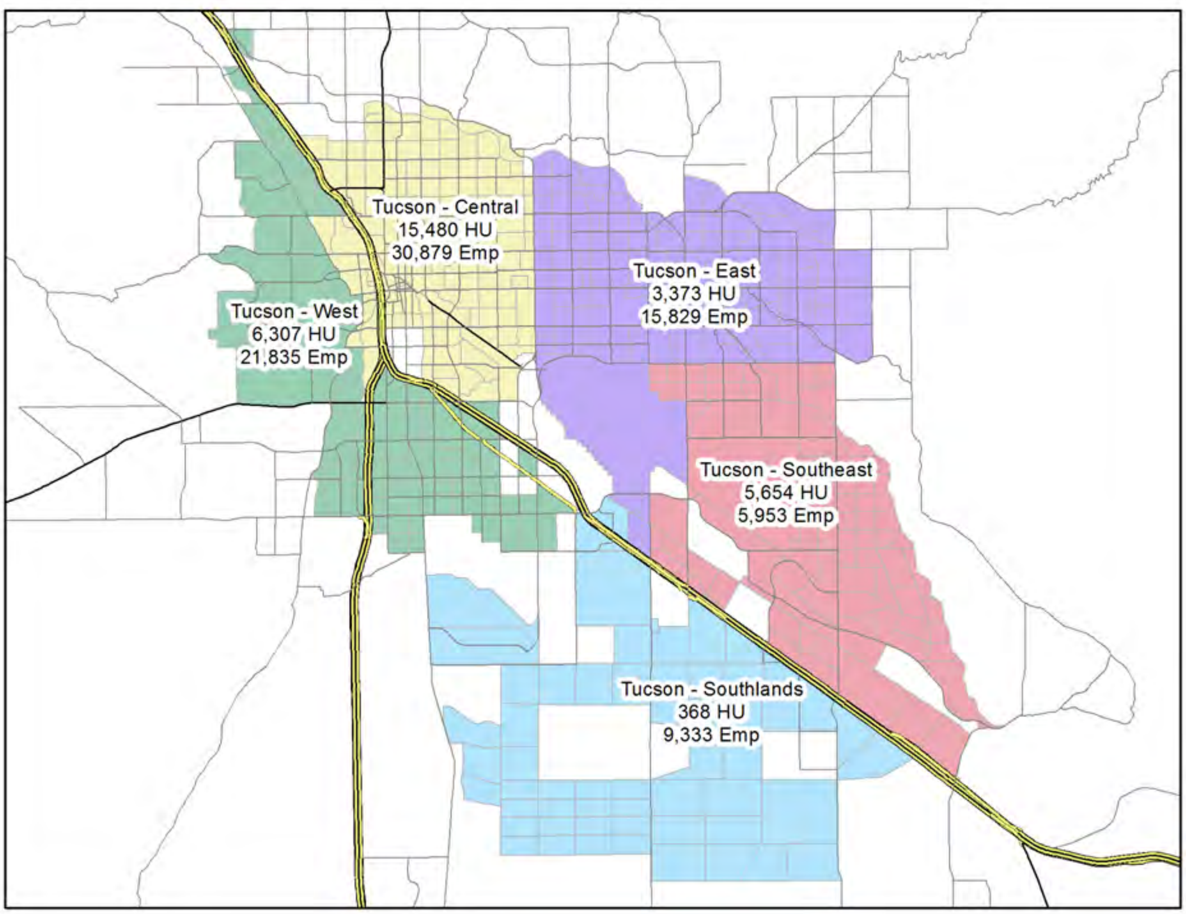


Figure 2 PAG Projections of Residential and Non-Residential Growth by PAG Sub-Area

To estimate growth within the Obligated Water Service Area, geographic information system (GIS) software was used to intersect TAZ polygons with the Obligated Water Service Area to obtain proportional counts of housing units or employees in partial TAZs. A summary of the PAG estimates and projections for the Obligated Water Service Area are shown in Figure 3, which indicates an increase of over 39,000 new dwelling units and 86,000 new employees from 2018 to 2045.

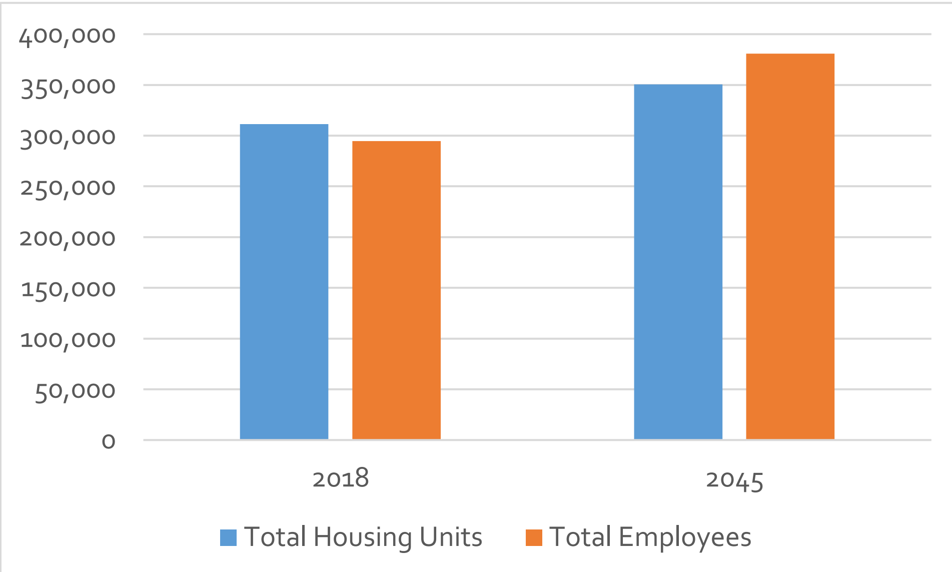


Figure 3 PAG Estimates and Projections of Residential and Non-Residential Growth for the Obligated Water Service Area

A detailed spatial representation of the residential (numbers of housing units) and non-residential growth (numbers of employees) by TAZ are shown in Figures 4 and 5, respectively. TAZs that are not colored are currently not planned for growth per the PAG projections.

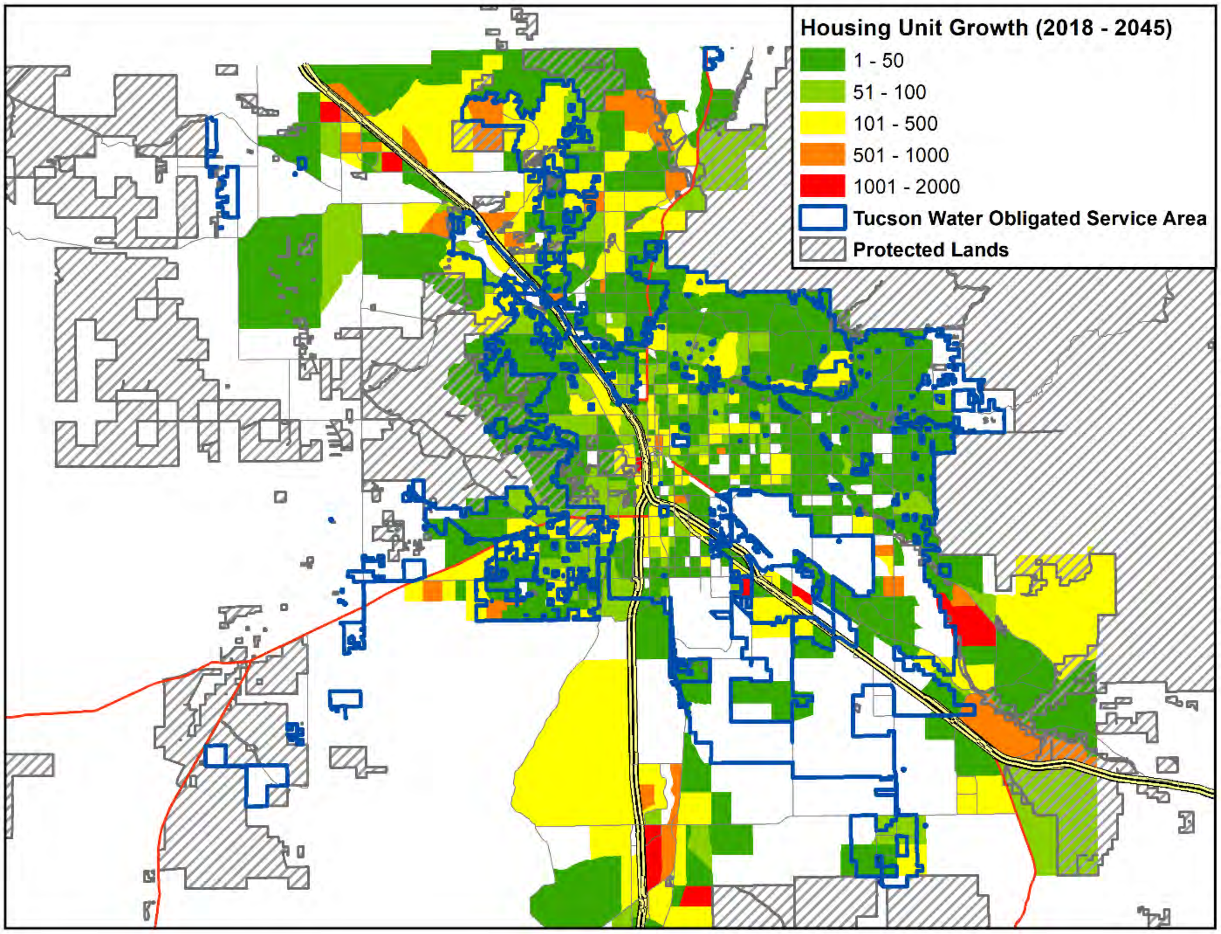


Figure 4 PAG Projections of Residential Growth by TAZ

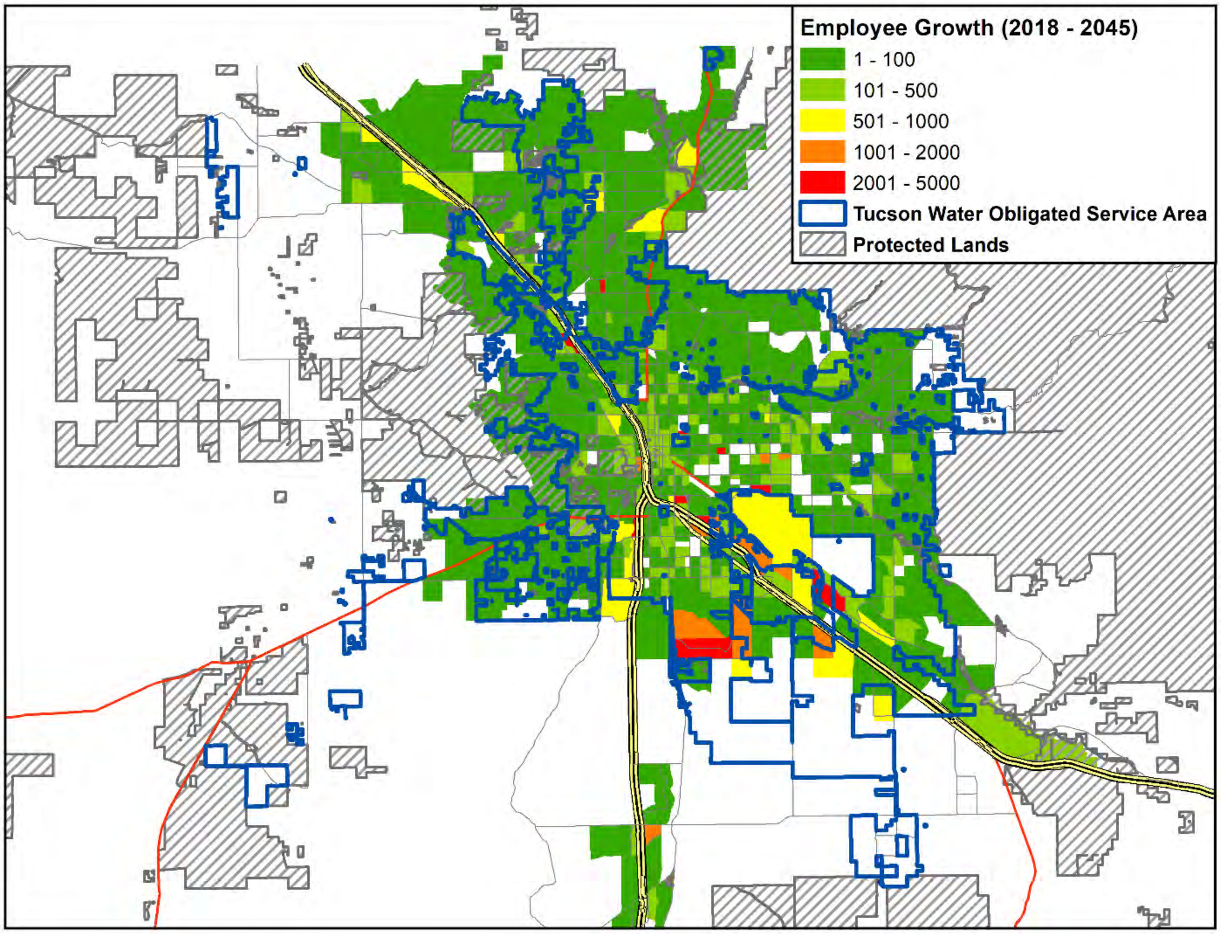


Figure 5 PAG Projections of Non-Residential Growth by TAZ

Population projections from the State of Arizona's Office of Economic Opportunity[1] were used to interpolate housing unit and population projections in 10-year increments from 2018 to 2045. The Office of Economic Opportunity projected annual population for Pima County in three scenarios: low, medium (baseline scenario), and high. The annual growth rates of these projections were used to estimate housing units from the PAG TAZ polygons that had been intersected with the Obligated Water Service Area. Consequently, housing units and population in the Obligated Service Area were calculated for 2025 and 2035 as well as low and high projections for 2025, 2035, and 2045.

The number of housing units was converted to population by applying a persons per occupied unit factor of 2.46 and vacancy rate of 5%, yielding a 2018 estimated population of 727,821. The equation is displayed below:

$$\text{Housing Units} \times \frac{2.46 \text{ people}}{\text{Housing Unit}} \times (1 - 0.05) = \text{Population}$$

[1] State of Arizona, Office of Economic Opportunity, Population Projections. Accessed December 11, 2019. https://population.az.gov/population-projections

Tucson Water provided the persons per occupied unit assumption from its 2018 Annual Water Withdrawal and Use Report[2] that is submitted to the Arizona Department of Water Resources and is an average for the Obligated Water Service Area; the vacancy rate was assumed based on current estimates in the housing market. Resulting housing unit and population growth is displayed in Figures 6 and 7, respectively.

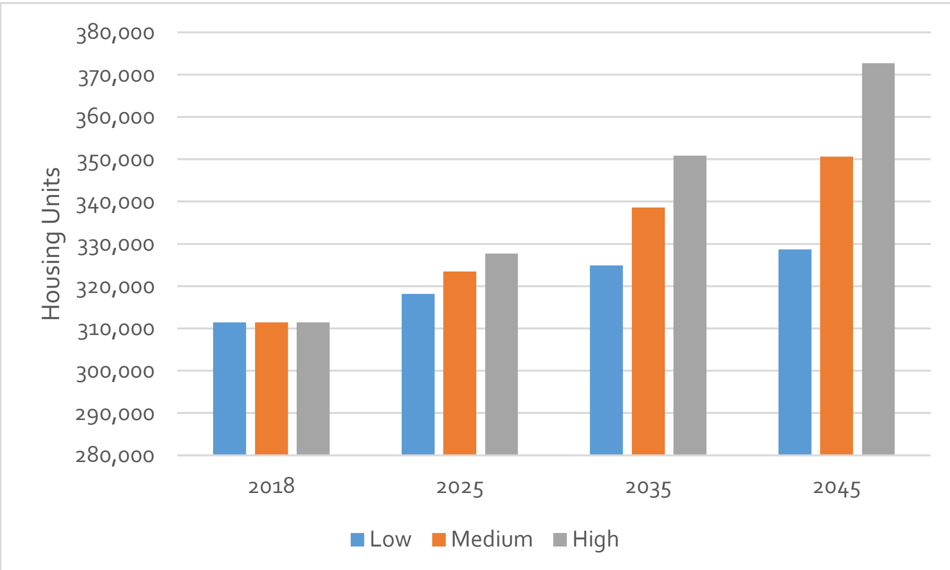


Figure 6 Housing Unit Projections in 10-Year Increments from 2018 to 2045 for the Obligated Water Service Area

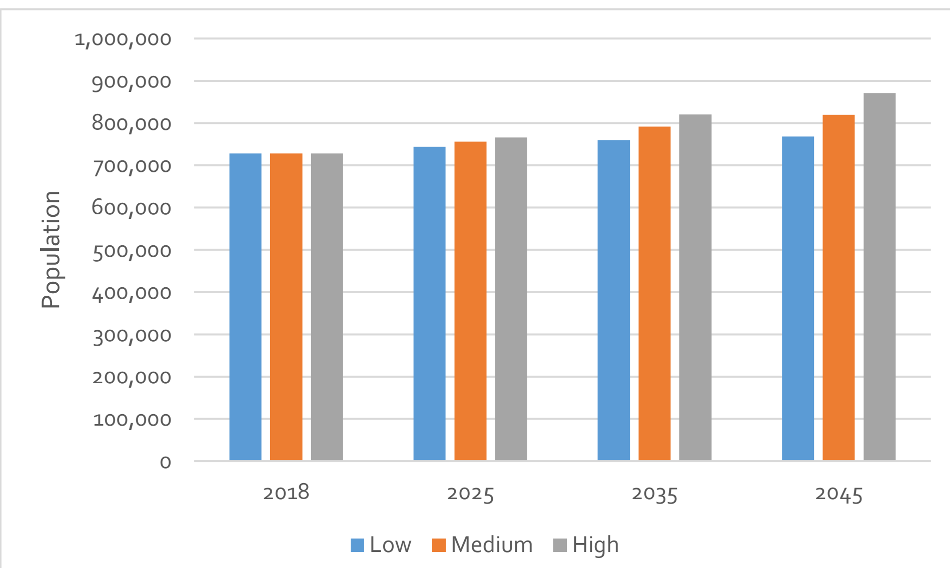


Figure 7 Population Projections in 10-Year Increments from 2018 to 2045 for the Obligated Water Service Area

[2] City of Tucson Water Department. *2018 Annual Water Withdrawal and Use Report*.

3.0 Comparison with American Community Service (ACS) Data

The 2018 PAG estimates were verified by comparing the PAG dataset with published 2018 ACS data[3] from the US Census Bureau. This was accomplished by intersecting census tract polygons with the Obligated Water Service Area to obtain proportional estimates of population and housing units from the ACS dataset and comparing the result to the number of housing units in the PAG dataset. The values were within 5% (see Table 1); therefore, they corroborate the 2018 PAG estimates.

Table 1 Dataset Comparison

Dataset	Housing Units
2018 ACS	297,360
2018 PAG	311,434

4.0 Adjustments to PAG Projections due to Known Planning Considerations

Based on known land use planning efforts, several areas within Tucson's Water Service Area are expected to grow above and beyond the PAG projections. These include:

- Houghton Road Corridor
- University of Arizona Tech Park at Rita Road
- Corona de Tucson

Each of these areas is discussed further in the following sections, and an overview map is displayed on Figure 8.

[3] US Census Bureau, 2018 ACS 5-year Estimates, Demographic and Housing Estimates (Table DP05). Accessed January 28, 2020. https://data.census.gov/cedsci/

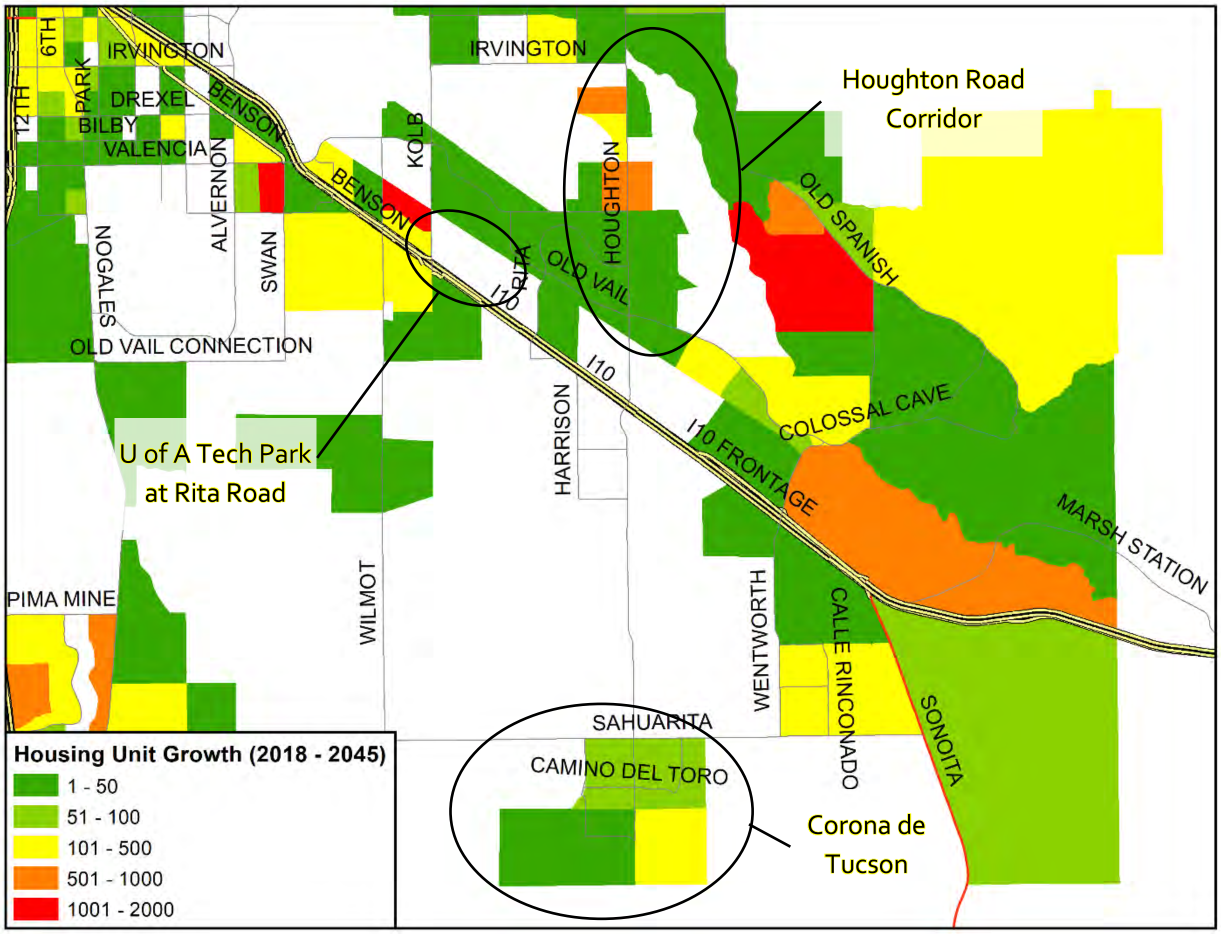


Figure 8 Overview Map of Houghton Road Corridor, University of Arizona Tech Park at Rita Road, and Corona de Tucson

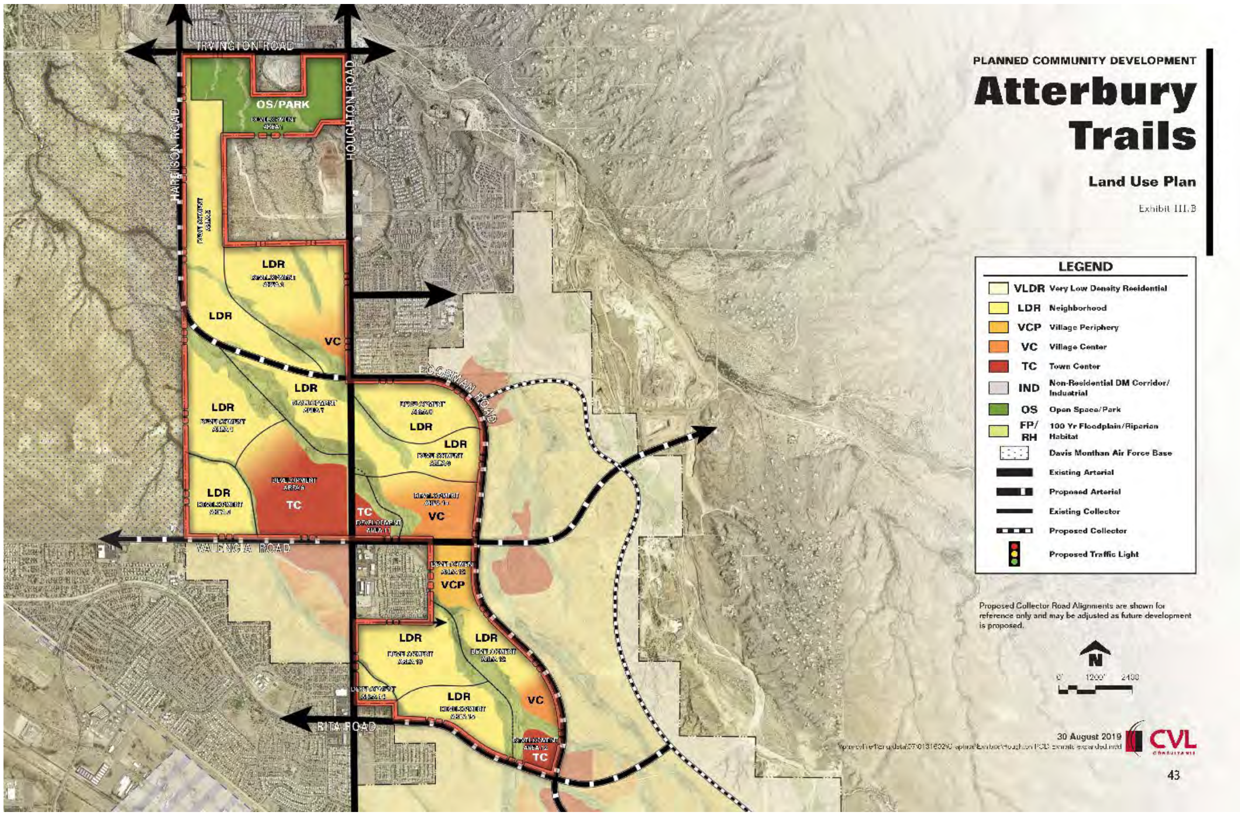
4.1 Houghton Road Corridor

The Houghton Road Corridor is located in southeast Tucson around Houghton Road, where extensive residential development is expected. PAG projected that approximately 4,000 housing units would be added to northwest Vail (immediately east of the Houghton Road Corridor) between 2018 and 2045; however, Tucson Water staff speculate that lack of water availability in Vail will hinder this growth and may be reallocated to Tucson's water service area.

Mayor and Council recently adopted the Atterbury Trails Planned Community Development (PCD) in November 2019[4], which provides an updated vision for land use planning within the Houghton Road Corridor. Based on the details provided in the PCD, about 9,500 housing units will be developed in this area by 2045 above and beyond the initial PAG projections. When adding these units, spatial density was considered by referring to the Land Use Plan (see Figure 9) in the PCD. Figure 10 compares maps of the Houghton Road Corridor that display the difference in housing units between 2018 and 2045 before and

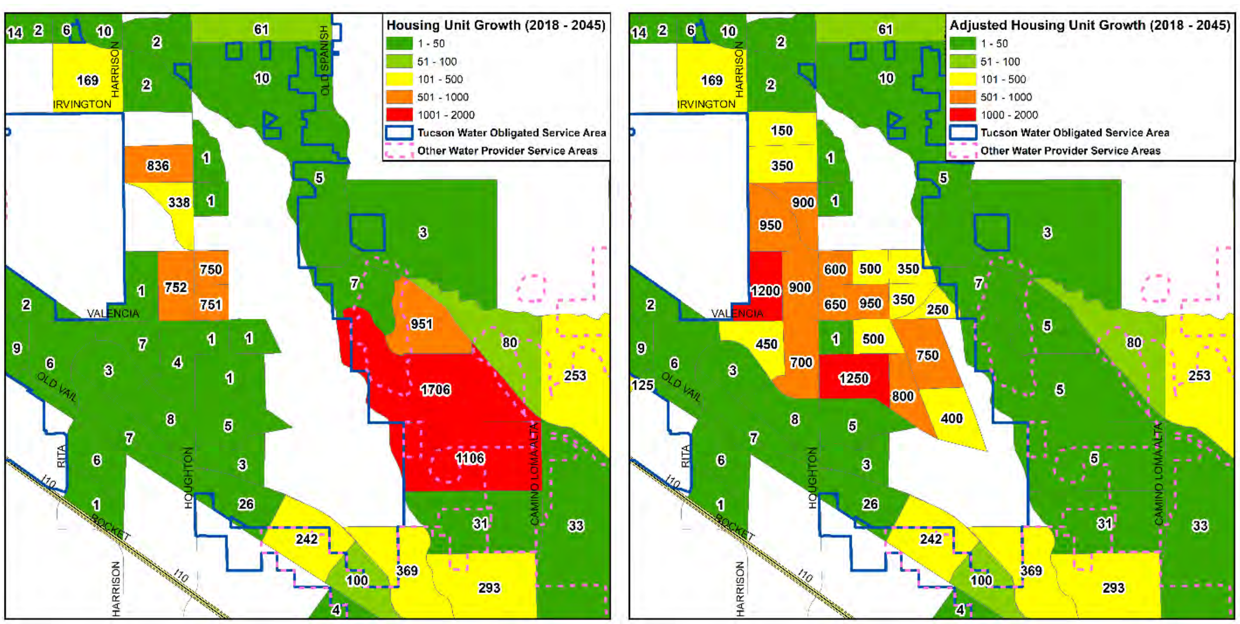
[4] CVL Consultants, Atterbury Trails Planned Community Development, Adopted November 19, 2019. https://www.tucsonaz.gov/files/pdsd/plans/Atterbury_Trails_PCD_FINAL_Adopted_by_MC_19NOV19.pdf

after adjustments were made. Employment projections remain unchanged from the base PAG projections; however, employees were spatially realigned to match the new land use plan as shown on Figure 11.



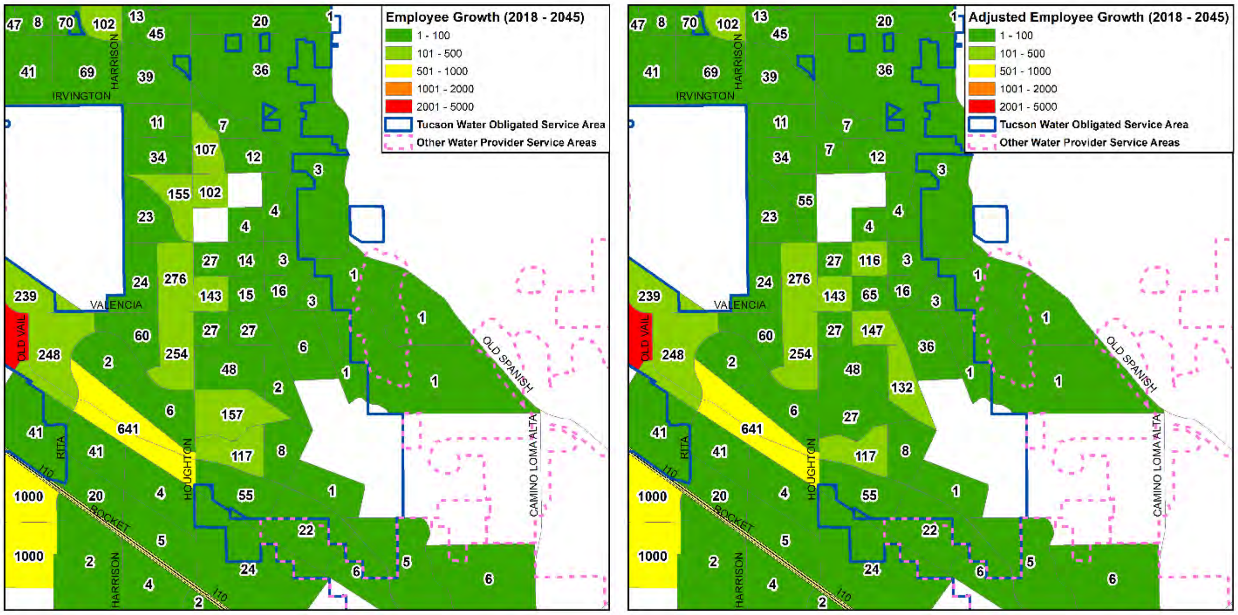
Source: Atterbury Trails Planned Community Development, November 2019.

Figure 9 Atterbury Trails PCD Land Use Map



Note: Base PAG projections are depicted on the left and adjusted projections are depicted on the right.

Figure 10 Adjustments to PAG Projections of Residential Growth in the Houghton Road Corridor and Vail



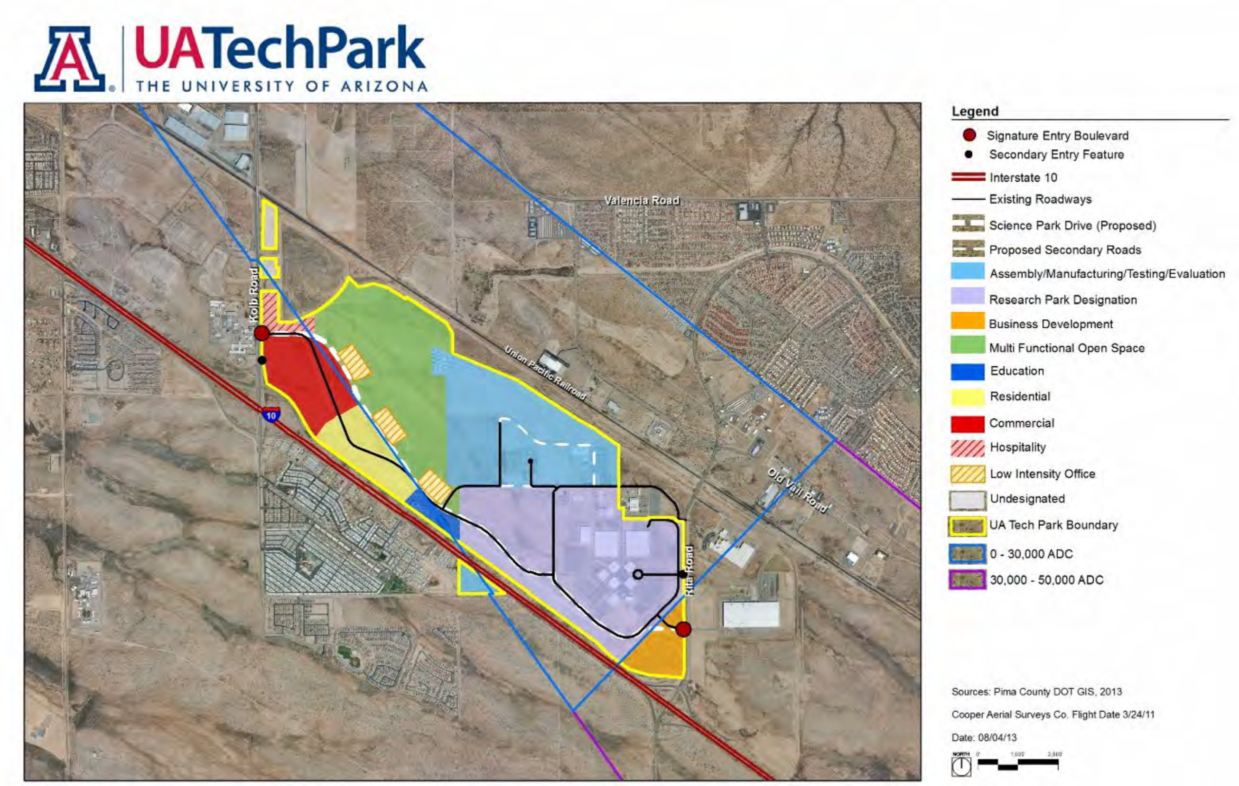
Note: Base PAG projections are depicted on the left and adjusted projections are depicted on the right.

Figure 11 Adjustments to PAG Projections of Non-Residential Growth in the Houghton Road Corridor

4.2 University of Arizona Tech Park at Rita Road

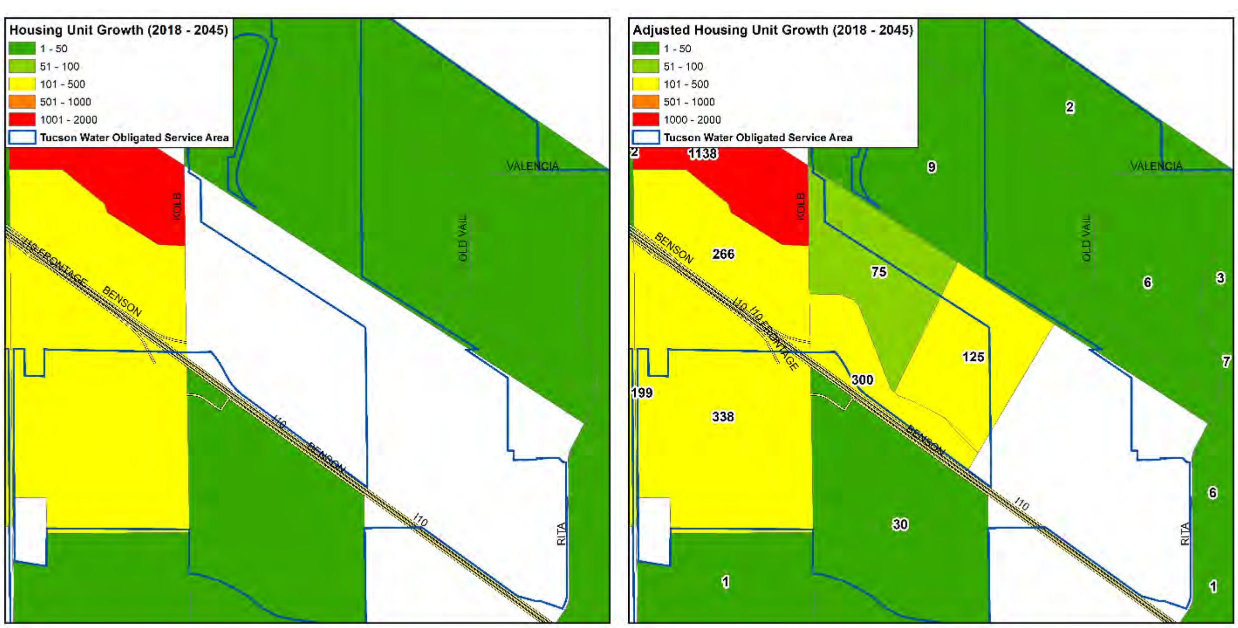
The University of Arizona Tech Park at Rita Road (Tech Park) has expressed interest in expanding within the Obligated Service Area. The proposed Tech Park expansion entails mixed-use development including retail, commercial, and residential uses along with a hotel. Figure 12 depicts the proposed land use[5] within the Tech Park's boundaries. According to the land use map, the area planned for residential use is approximately 90 acres, so it was assumed that 500 housing units would be added to the area between 2018 and 2045 and that these 500 units would be evenly distributed in that area. Figure 13 compares maps of the Tech Park that display the difference in housing units between 2018 and 2045 before and after adjustments were made.

[5] The University of Arizona. 2013. *UA Tech Park Land Use Plan Map*. https://techparks.arizona.edu/sites/default/files/UA%20Tech%20Park%20Land%20Use%20Map%208%207%202013%20%282%29.jpg



Source: UA Tech Park Land Use Plan Map, August 2013.

Figure 12 University of Arizona Tech Park at Rita Road Land Use Map

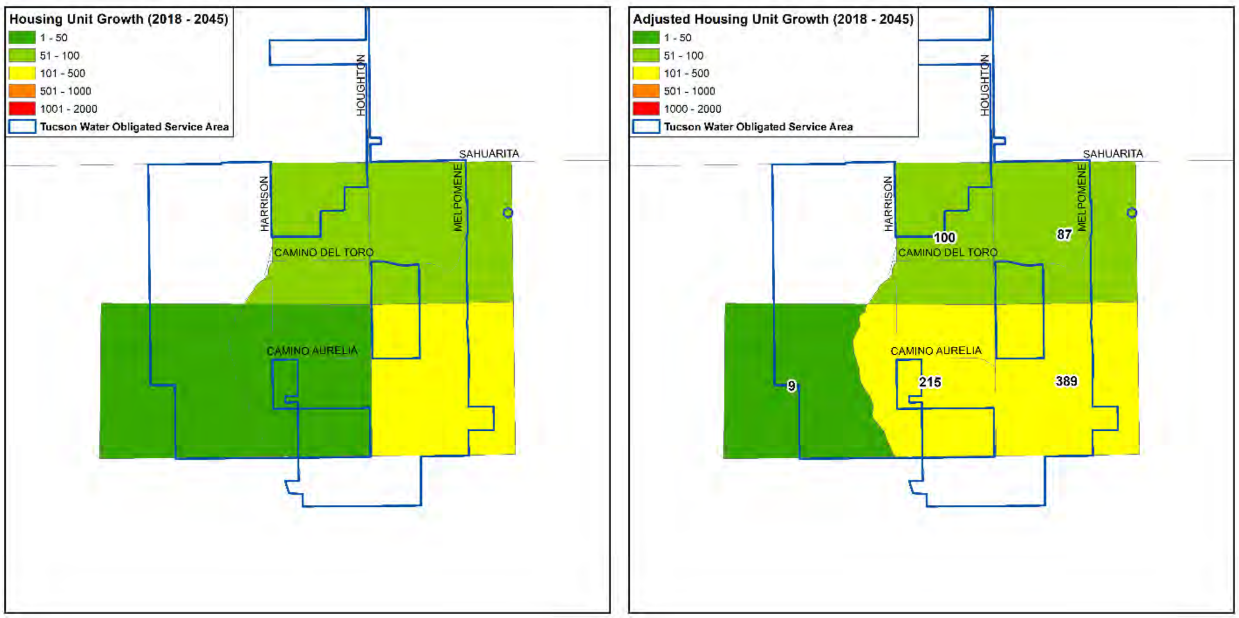


Note: Base PAG projections are depicted on the left and adjusted projections are depicted on the right.

Figure 13 Adjustments to PAG Projections of Residential Growth in the University of Arizona Tech Park at Rita Road

4.3 Corona de Tucson

Corona de Tucson is an isolated water system served by Tucson Water southeast of the City that is expected to be built out by 2035. Although PAG had already projected 588 additional housing units, Tucson Water staff expect a total of 800 units based on committed and planned development. It was assumed that the additional 212 units would be developed in the south-central area due to the available space. Figure 14 compares maps of Corona de Tucson that display the difference in housing units between 2018 and 2045 before and after adjustments were made.



Note: Base PAG projections are depicted on the left and adjusted projections are depicted on the right.

Figure 14 Adjustments to PAG Projections of Residential Growth in Corona de Tucson

5.0 Growth Beyond PAG Projections

5.1 Annexation

The City is planning to annex the following areas in the near term:

- Valencia Road and Kolb Road area: logistics and other non-residential uses are planned (Figure 15)
- State Land, bounded by Valencia Road, Swan Road, Alvernon Way, and Los Reales Road: residential development is planned with supporting commercial uses (Figure 16)

To estimate growth in the Potential Expansion Area polygons, GIS was used to intersect PAG TAZ polygons with the Potential Expansion Areas to obtain proportional counts of housing units or employees in partial TAZs. Inclusion of these areas in the projections results in an increase of almost 1,500 housing units and over 1,300 employees between 2018 and 2045.

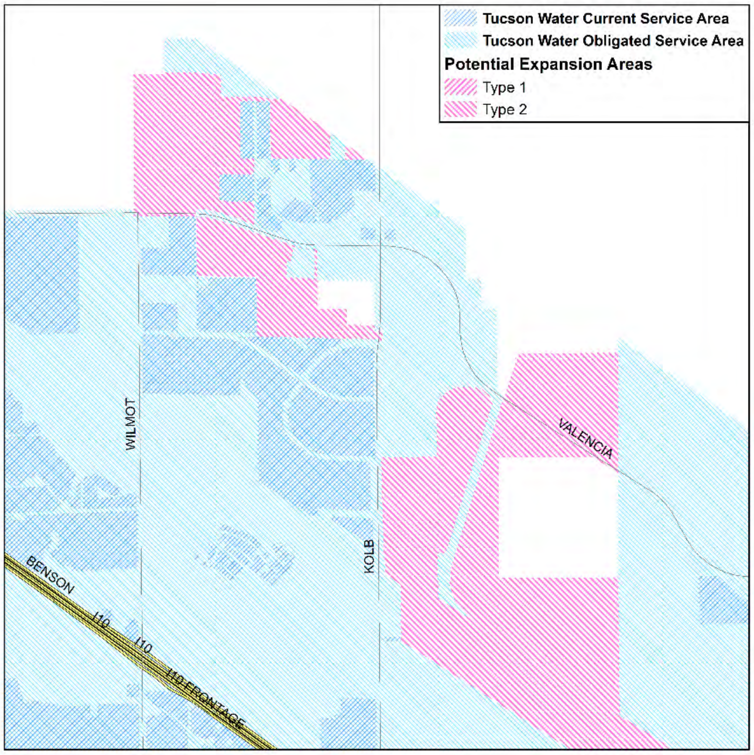


Figure 15 Potential Expansion Areas in Valencia Road and Kolb Road Area

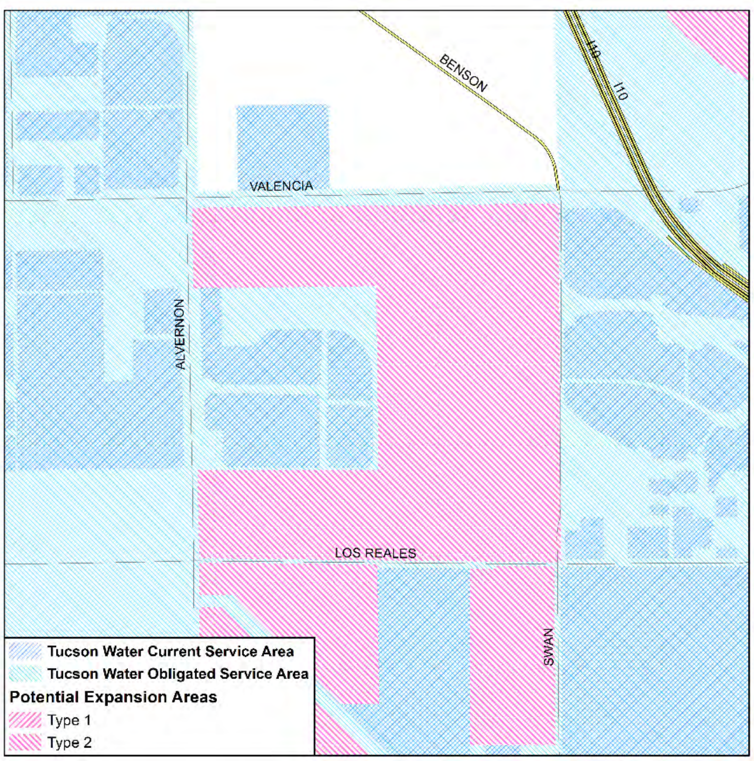


Figure 16 Potential Expansion Area of State Land Bounded by Valencia Road, Swan Road, Alvernon Way, and Los Reales Road

The City of Tucson may annex unobligated areas in eastern Tanque Verde (see Potential Expansion Areas in Figure 17) between 2045 and 2100. The same GIS intersection method that was described above was used to estimate the additional number of housing units and employees, resulting in 529 housing units and 175 employees.

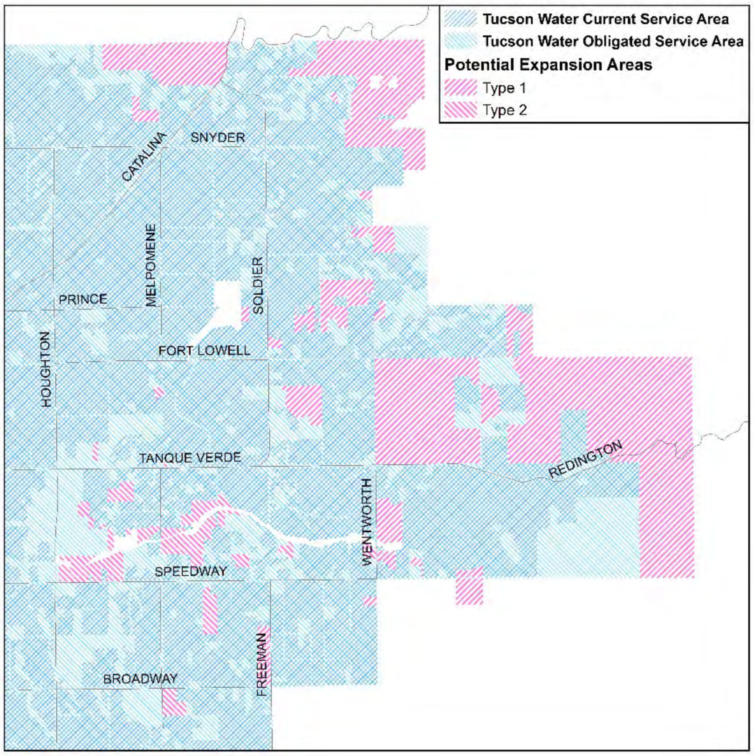


Figure 17 Potential Expansion Areas in Eastern Tanque Verde

5.2 Infill/Redevelopment

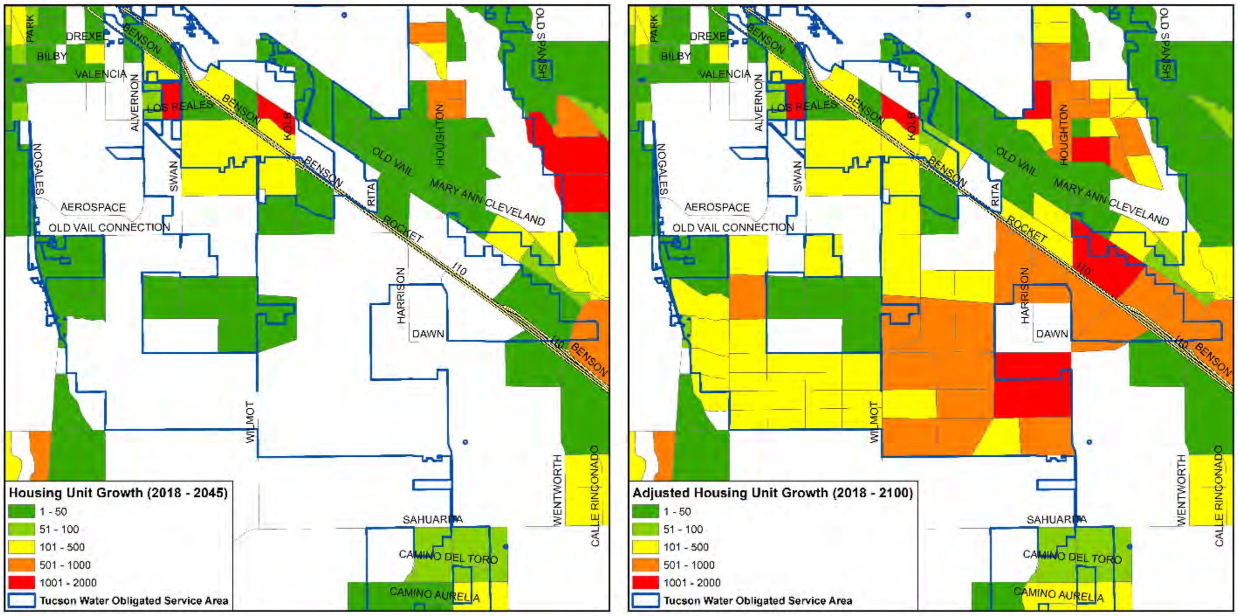
Based on discussions with City Planning and Development Services staff, residential infill and/or redevelopment within the water service area was accounted for in the planning period beyond the PAG projections (2045 – 2100). The following annual residential infill/redevelopment rates were included in the low, medium and high scenarios:

- Low growth scenario: 0%
- Medium growth scenario: 0.1%
- High growth scenario: 0.25%

These rates yielded about 20,000 additional housing units in the medium growth scenario, and over 46,000 additional housing units in the high growth scenario.

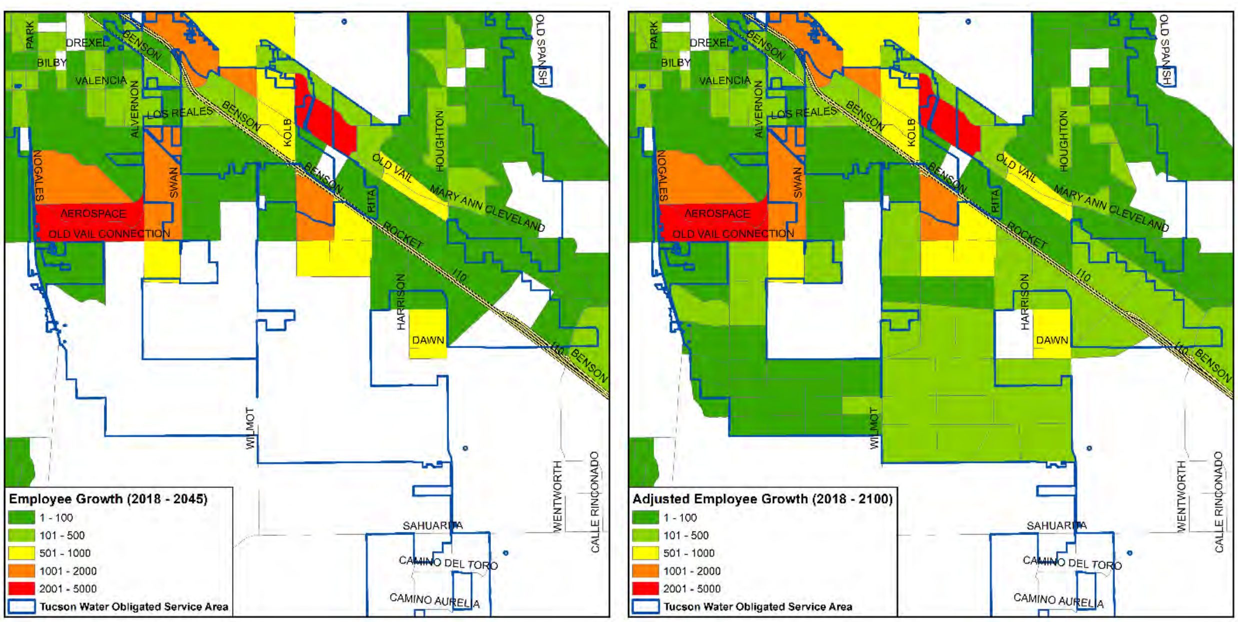
5.3 Southern Tucson

The Southlands is an area in southern Tucson (see Figure 2) that is anticipated to develop and contribute additional housing units and employees to the Obligated Water Service Area between 2045 and 2100. To project the number of housing units and employees in the Southlands, low density areas of Oro Valley were used as a surrogate to calculate baseline housing unit and employee densities. In addition, it was assumed that 15% of the available land area in the Southlands would be undevelopable floodplain and 20% would be reserved for right of way, leaving 65% of developable land area (approximately 25,000 acres). TAZs that were already built out or had significant non-residential development projected were also omitted. This led to additions of 22,682 housing units and 5,628 employees, which are displayed in Figures 18 and 19, respectively.



Note: Base PAG projections are depicted on the left and adjusted projections are depicted on the right.

Figure 18 Adjustments to PAG Projections of Residential Growth in the Southlands for 2100



Note: Base PAG projections are depicted on the left and adjusted projections are depicted on the right.

Figure 19 Adjustments to PAG Projections of Non-Residential Growth in the Southlands for 2100

6.0 Adjusted Projections

The baseline PAG projections were combined with the adjustments discussed in Sections 4 and 5 to calculate overall projections in the water service area through the planning horizon. The summary of cumulative housing units for low, medium, and high projections is displayed in Tables 2, 3, and 4, respectively.

The adjusted projections are summarized graphically in Figures 20 to 22. Similar to the prior population estimate and projections, the number of housing units was converted to population by applying a persons per occupied unit factor of 2.46 and vacancy rate of 5%.

Table 2 Cumulative Housing Unit Adjustments to PAG Data (Low)

Year	Base PAG	Houghton Road Corridor	UA Tech Park	Corona de Tucson	Annexations	Southlands	Infill and Redevelopment	Sum
2018	311,434							311,434
2025	317,788	3,114	246	106	483			321,737
2035	324,205	6,070	479	206	878			331,838
2045	327,772	8,888	479	206	1,391			338,736
2100	327,772	8,888	479	206	1,885	21,202	0	360,432

Table 3 Cumulative Housing Unit Adjustments to PAG Data (Medium)

Year	Base PAG	Houghton Road Corridor	UA Tech Park	Corona de Tucson	Annexations	Southlands	Infill and Redevelopment	Sum
2018	311,434							311,434
2025	323,460	3,170	250	108	492			327,480
2035	338,565	6,339	500	215	917			346,536
2045	350,654	9,509	500	215	1,488			362,366
2100	350,654	9,509	500	215	2,017	22,682	19,816	405,393

Table 4 Cumulative Housing Unit Adjustments to PAG Data (High)

Year	Base PAG	Houghton Corridor	UA Tech Park	Corona de Tucson	Annexations	Southlands	Infill and Redevelopment	Sum
2018	311,434							311,434
2025	327,963	3,214	253	110	499			332,039
2035	351,585	6,583	519	223	952			359,862
2045	373,871	10,139	519	223	1,587			386,339
2100	373,871	10,139	519	223	2,151	24,184	55,036	466,122

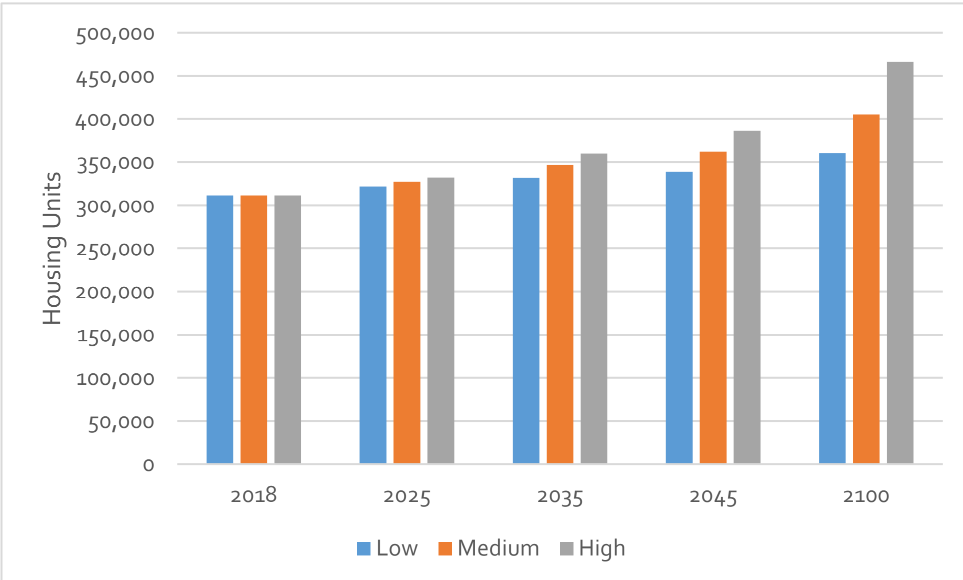


Figure 20 Adjusted Housing Unit Projections in the Water Service Area from 2018 to 2100

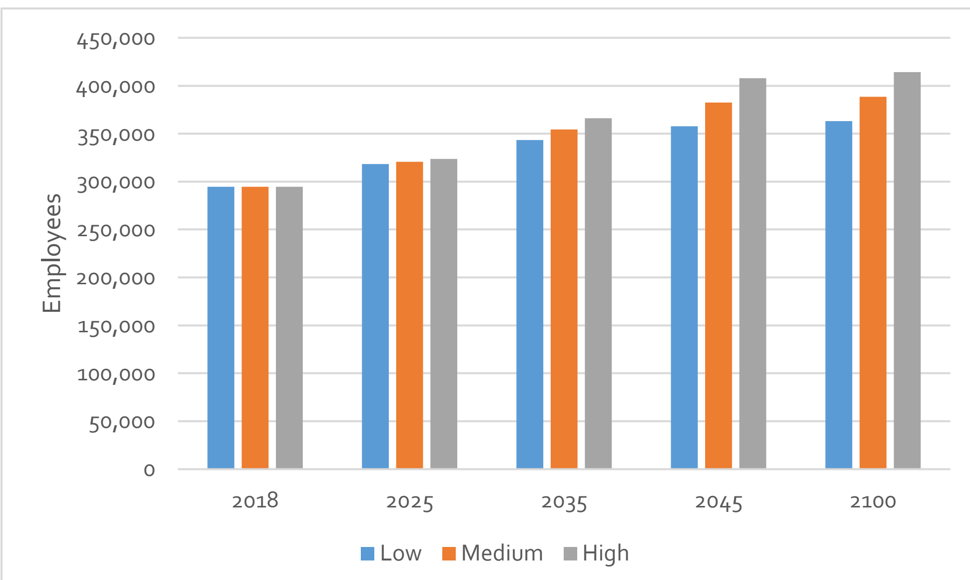


Figure 21 Adjusted Employee Projections in the Water Service Area from 2018 to 2100

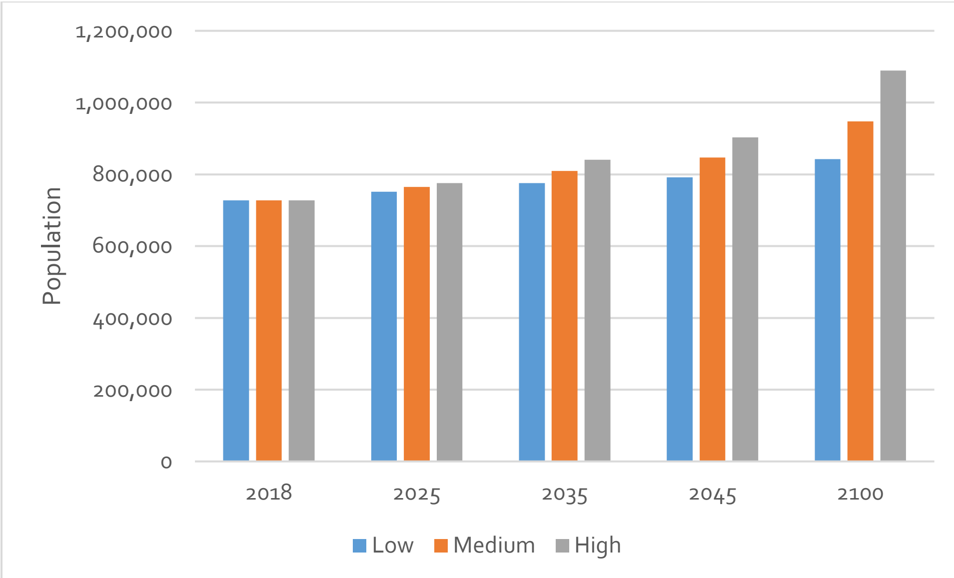


Figure 22 Adjusted Population Projections in the Water Service Area from 2018 to 2100

Spatial distributions of the adjusted housing unit and employee projections are displayed in Figures 23 and 24.

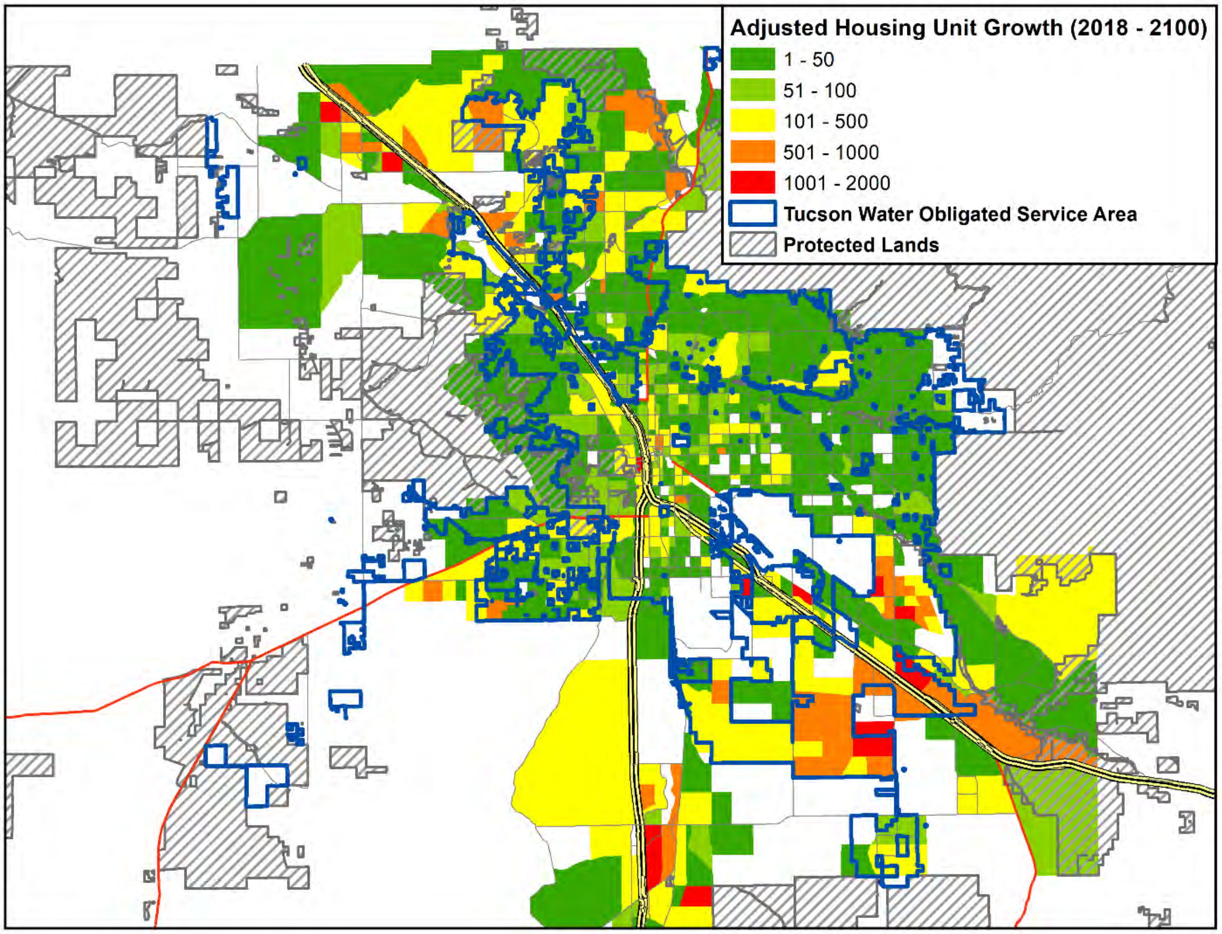


Figure 23 Adjusted PAG Projections of Residential Growth by TAZ

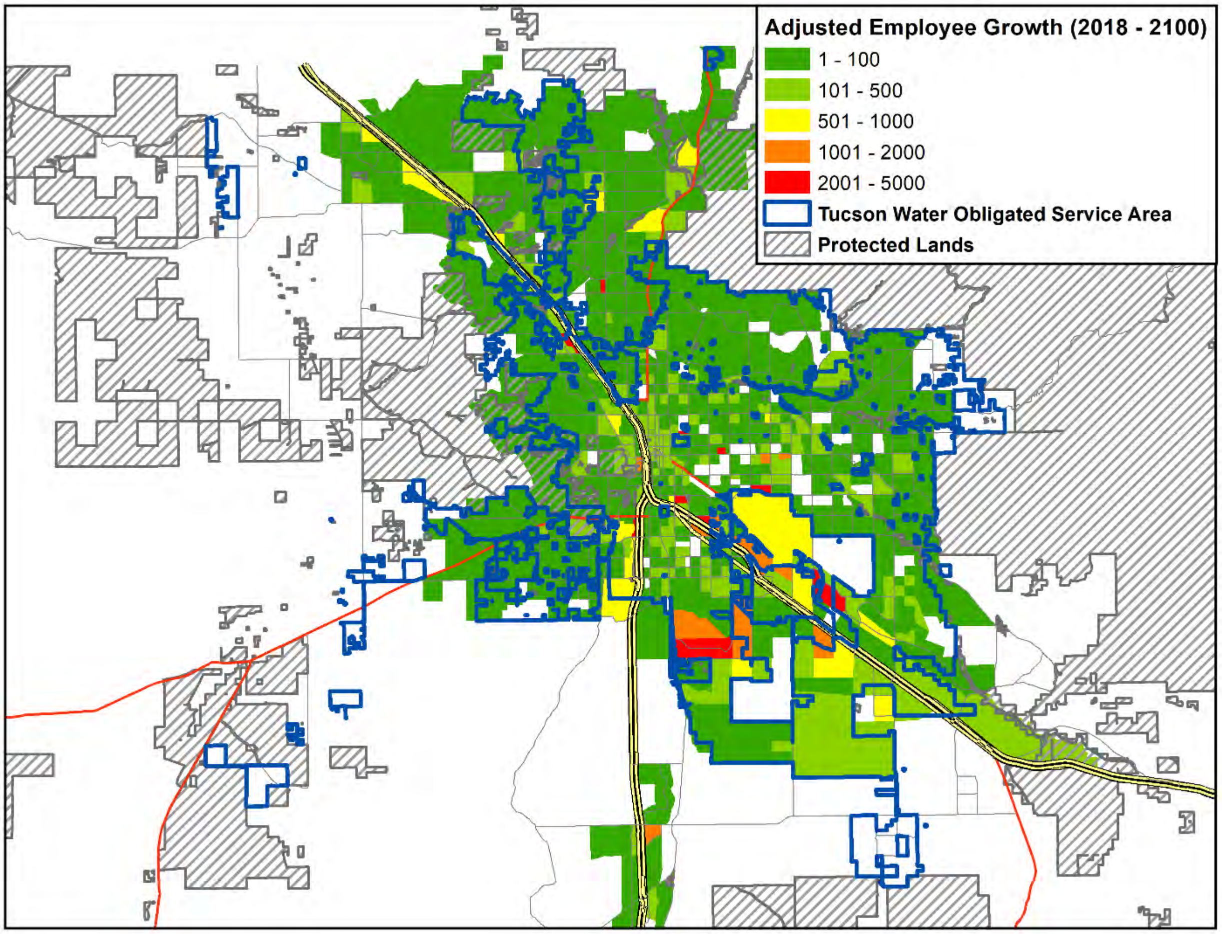


Figure 24 Adjusted PAG Projections of Non-Residential Growth by TAZ

7.0 Conclusion

Within the Tucson Water Obligated Service Area, population is expected to increase by over 200,000 people to an estimated total of 947,403 by 2100 in the medium growth scenario. The overall range of growth will be used to quantify future water demand that impacts both near-term capital planning and long-range supply planning.

For near-term planning purposes, PAG projections of dwelling units and employees with adjustments to account for known land use planning efforts will provide the basis for both residential and non-residential water demand projections. The spatial distribution of these demands will inform infrastructure capital requirements. Although long-term projections are less certain, estimates of the quantity and spatial distribution of additional dwelling units and employees will contribute to quantifying long-range water supply needs for both residential and non-residential customer classes.

Appendix J

ONE WATER 2100 LAND USE PLANNING

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Contents

Figures

Abbreviations

ADOT	Arizona Department of Transportation
af/yr	acre-feet per year
CAP	Central Arizona Project
EIS	Environmental Impact Statement
FHWA	Federal Highway Administration
HAMP	Houghton Area Master Plan
I-10	Interstate Highway 10
I-11	Interstate Highway 11
IGA	Intergovernmental Agreement
NWRRDS	Northwest Recharge, Recovery, and Delivery System
PAG	Pima Association of Governments
PCD	Planned Community Development

Technical Memorandum

LAND USE PLANNING

1.0 Introduction

On August 4, 2010, the Mayor and Council adopted a Water Service Area Policy[1] for Tucson Water that established a long-range planning area for the utility. It includes existing and potential future service areas, and areas where the utility has no plans to provide direct service. Water service is different from most City services in that water service is provided in areas outside the City of Tucson boundaries. The Water Service Area is further discussed in Section 2 below.

Although the utility has no plans to serve areas outside its service area, it works with other water providers on water supply and service matters of mutual benefit. For example, Tucson Water wheels (conveys) other providers' water to them and provides emergency interconnects to other water providers and vice-versa. Consequently, for Tucson Water's long-range planning purposes, it is important to consider where and how much growth may occur not only within the City of Tucson but in neighboring jurisdictions as well, including:

- Town of Marana
- Town of Oro Valley
- Pascua Yaqui Tribe Reservation and Trust Lands
- Unincorporated Pima County
- City of South Tucson

This memorandum summarizes where projected growth and development may occur by confirming adopted planning efforts and identifying development trends and new planning considerations in these areas. Land use planning impacts associated with regional transportation planning and potential releases of State Land are also discussed.

2.0 Planning Area

As noted, the City of Tucson established the utility's Water Service Area boundary in 2010 with the adoption of a formal Water Service Area Policy. The map on Figure 1 illustrates the extent of the current obligated Water Service Area, as well as potential areas of water service expansion, and non-expansion areas. The obligated service area includes areas within the City limits or contracted service areas that Tucson Water will serve in the future. The map is not intended to provide parcel-level guidance on water service availability, but rather meant to provide a general overview of Tucson Water's service in the region. All parcels within the City limits are eligible for water service. New requests for water service outside of the existing obligated

[1] City of Tucson, 2010, 2011 and 2013. "Resolution No. 21602" and subsequent amendments "Resolution No. 21753" and "Resolution No. 22080." Accessed July 25, 2019. https://www.tucsonaz.gov/files/water/docs/Resolution_21602.pdf.

Water Service Area require a water availability request, and staff review of the specific parcel(s) in question. The obligated Water Service Area may also be modified through approved City of Tucson annexations or by direction of the Mayor and Council.

The current Water Service Area spans several jurisdictions, with about 42% of the geographic area lying within the City of Tucson and nearly 53% in unincorporated Pima County. Marana (4%), Oro Valley (1%), South Tucson and Pascua Yaqui lands (less than 1% each) round out the Water Service Area. The Town of Oro Valley is also a wholesale customer of Tucson Water, and other potable wheeling agreements are in place with Metro Water District, Vail Water, and the Pascua Yaqui Tribe. The utility wheels reclaimed water to the Town of Oro Valley, Metro Water District, Pima County, and other smaller water providers.

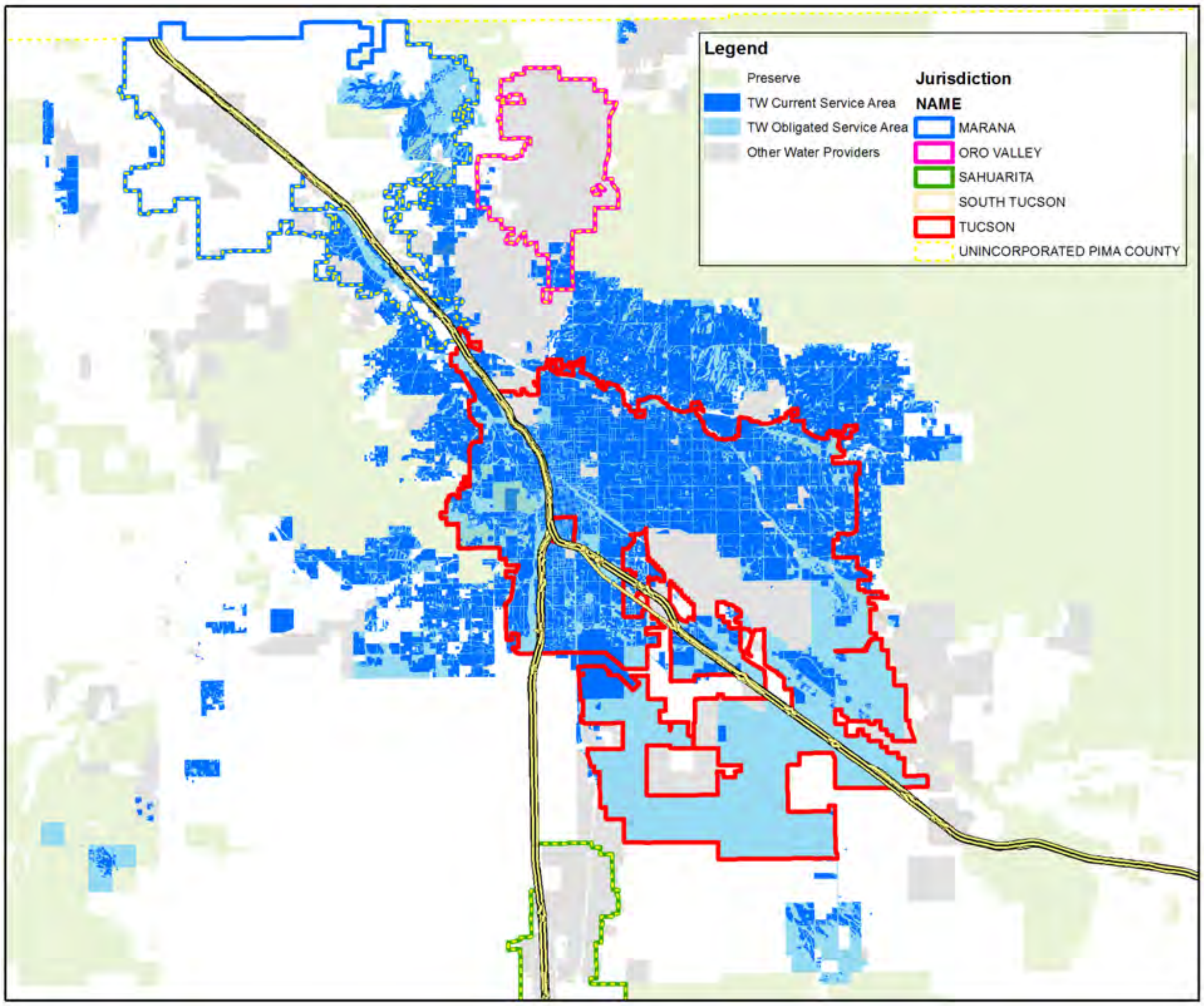

Figure 1 Tucson Water Service Area

3.0 Land Use Planning Considerations

3.1 City of Tucson

The City's current General & Sustainability Plan, *Plan Tucson*, was approved by voters and adopted by the Mayor and Council in 2013.[2] As shown on Figure 2, anticipated growth areas include the downtown core and major transportation corridors as the City pursues a strategy of transit-oriented development.

Extensive growth is expected in the Houghton Road corridor in southeastern Tucson. Planning and Development Services staff expect the area to develop over the next decade, with construction of about 5,000 housing units expected within master planned communities. Anticipated trends in the area include increased residential densities and more multifamily units, including townhomes.

Citywide, in addition to new single and multifamily housing units, the expanded construction of group quarters (e.g., student housing) is anticipated. Rezoning is expected at the northwest corner of Campbell Avenue and Speedway Boulevard for development of a 20-story residential building with ground floor retail.

Non-residential and residential infill development and redevelopment in the downtown area has been vertical in nature, where multi-story buildings are becoming more common. Non-residential development is occurring near the Tucson International Airport, where industrial uses, such as logistics and defense, are prevalent. The University of Arizona Tech Park at Rita Road has expressed interest in expanding within the obligated Service Area, which entails mixed-use development including retail, commercial, and residential uses along with a hotel. Although this area is currently supplied by private groundwater wells, future development may require additional water service from Tucson Water. Investors have also expressed interest in developing several hundred thousand square feet of medical marijuana greenhouses along Interstate Highway 10 (I-10) in the southern part of the City.

Additional anticipated projects or trends include:

- Residential redevelopment in the vicinity of Park Place Mall.
- Conversion of excess and unused commercial properties (i.e., "big box" retail spaces) to other uses such as entertainment or fitness centers.
- Redevelopment of the Grant Road corridor as roadway reconstruction is completed.
- Redevelopment potential of the northwest and southwest corners of the Oracle Road / River Road intersection.
- Conversion of closed and now vacant Tucson Unified School District sites to other uses including housing. For example, the Corbett Elementary School site on 29th Street west of Wilmot Road is planned for housing (eight to ten housing units per acre), and the Julia Keen Elementary School site on Ellington Place and Palo Verde Avenue was converted to a community garden.
- Strong growth and redevelopment along the Speedway Boulevard corridor, although zoning issues may be a hurdle for development in this area.
- Infill growth along Broadway Boulevard from Euclid Avenue to Country Club Road after roadway expansion is completed that will double the intensity of current uses.
- Potential development of lands immediately east of I-10 and south of Grant Road by the Pascua Yaqui Tribe.

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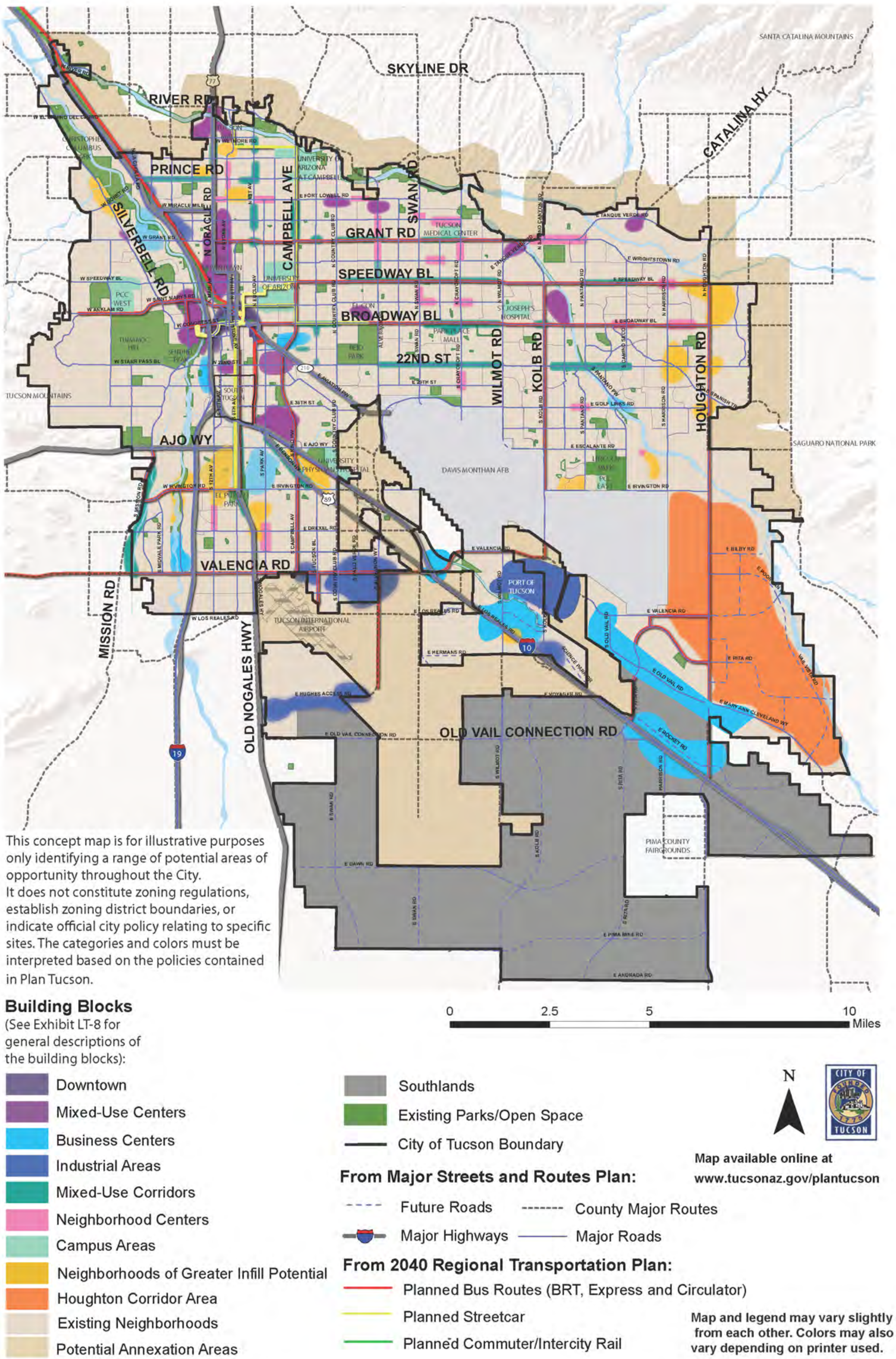
[2] City of Tucson. 2013. *Plan Tucson: City of Tucson General & Sustainability Plan 2013*. https://www.tucsonaz.gov/pdsd/plan-tucson.



Source: Plan Tucson, November 2013.

Figure 2 City of Tucson Future Growth Scenario Map

In addition to development and redevelopment within City limits, growth in potential annexation areas must be considered. The City relies upon *Plan Tucson* and the Water Service Area Policy for guidance relative to potential annexations. Areas planned for annexation in the near-term include the following:

- Valencia Road and Kolb Road area: logistics and other non-residential uses are planned
- State Land, bounded by Valencia Road, Swan Road, Alvernon Way and Los Reales Road: residential development is planned with supporting commercial uses

3.2 Pima County

Pima County's current Comprehensive Plan, *Pima Prospers*, identifies three growth areas[3] as illustrated in orange on Figure 3:

- Flowing Wells Focused Development Investment Area
- Southwest Focused Development Investment Area
- Tucson International Airport/I-10 Economic Development Area

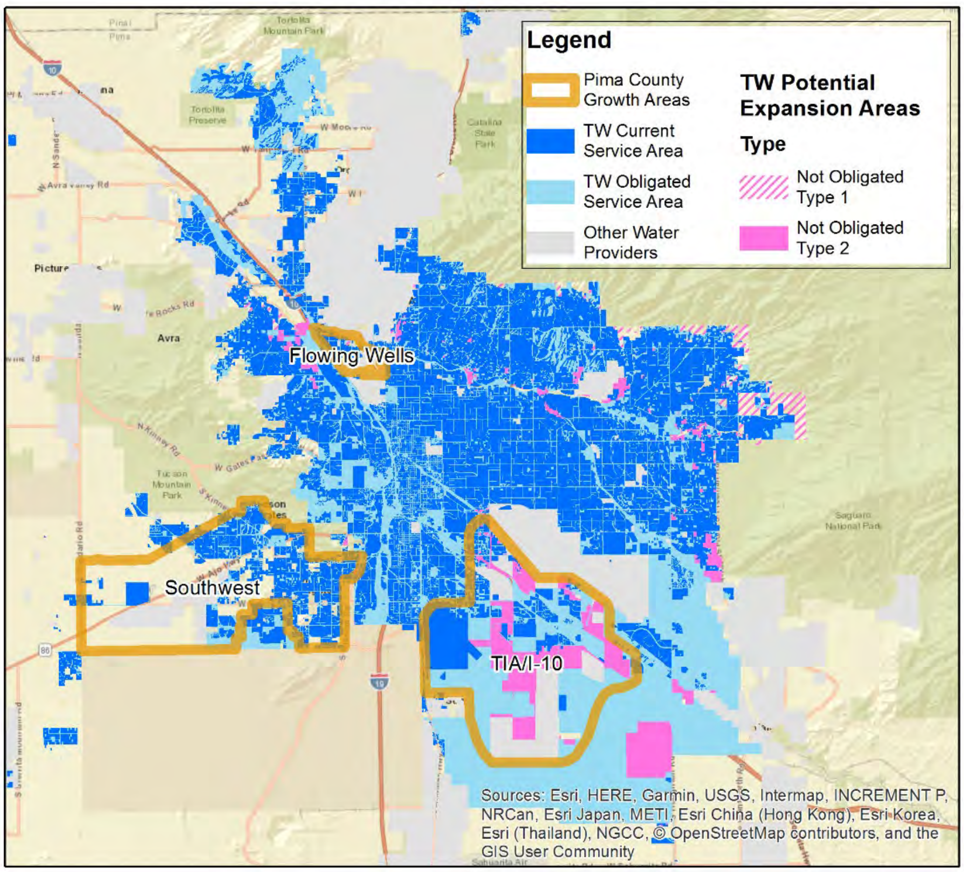


Figure 3 Pima County Focused Development Investment Areas

Less than half of the Flowing Wells growth area is within the Tucson Water Service Area. The County expects redevelopment in this area, and infill is occurring as well. The County has recently reduced parking

[3] Pima County. 2015. *Pima Prospers: Comprehensive Plan*. http://webcms.pima.gov/government/pima_prospers/

requirements for non-residential developments, which may increase the potential for infill by encouraging the redevelopment of former parking areas.

In the Southwest growth area, only the Star Valley subdivision lies within the Tucson Water Service Area. Star Valley's County-approved Specific Plan calls for about 7,000 residential units in addition to supporting commercial development and public uses. Approximately 10% of the residential units will be multifamily, and much of the remaining residential units will be low density (five housing units per acre). There are about 1,600 existing customers within this area.

More than half of the Tucson International Airport/I-10 growth area is within the Tucson Water obligated Service Area, and additional portions of the growth area are designated as potential expansion areas. The County anticipates primarily non-residential development in this region. In particular, logistics uses are expected near the airport. Commercial development is expected in the vicinity of Pima County Fairgrounds as County wastewater service is extended into the area.

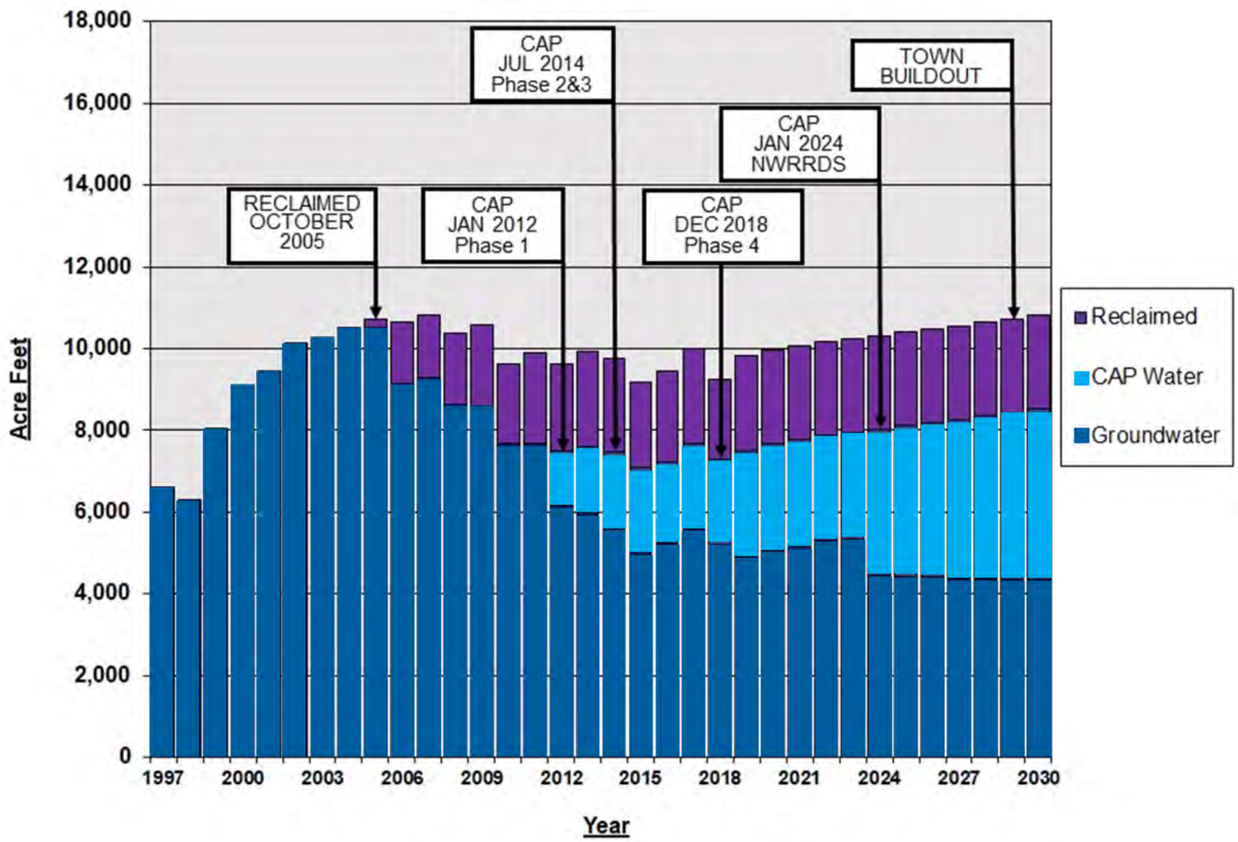
Development of the South Kolb property in the Airport/I-10 growth area will be guided by an approved Specific Plan and Amendment. The property, located near Davis-Monthan Air Force Base east of Kolb Road and south of Valencia Road, will support commercial and industrial uses. A portion of this property is within Tucson Water's obligated Service Area, and the remainder is within the potential expansion area. City of Tucson annexation of the area is anticipated.

Other County areas within the Tucson Water obligated Service Area where growth is expected include the Santa Rita Ranch and Santa Rita Mountain Ranch subdivisions. These areas are near Houghton Road and Sahuarita Road, and each development has an approved Specific Plan. Santa Rita Ranch on the east side of Houghton Road is planned for about 6,100 housing units; there are approximately 1,020 existing customers. Santa Rita Mountain Ranch on the west side of Houghton Road is planned for 1,320 housing units, with roughly 600 current customers in the area.

3.3 Town of Oro Valley

The Town of Oro Valley owns and operates its own water utility, but it also receives water from Tucson Water. Oro Valley receives about 2,100 acre-feet per year (af/yr) of recovered Central Arizona Project (CAP) water that Tucson Water wheels through its distribution system to several connection points in the town. Oro Valley also pays for the delivery of reclaimed water from Tucson Water to support its reclaimed water system and customers.

Oro Valley completed its General Plan update in 2016. More recently, the Oro Valley has been collaborating with Pima Association of Governments (PAG) to update its population projections. Oro Valley is now expecting to reach buildout no later than 2030 as shown on Figure 4.



Source: *Peter Abraham, Town of Oro Valley, email message forwarded to author, August 14, 2019.*

Figure 4 Oro Valley's Historic and Projected Water Use by Source of Supply

Oro Valley expects to continue utilizing its CAP wheeling agreement with Tucson Water and may increase its annual wheeling capacity to approximately 2,600 af/yr per the agreement. Oro Valley is jointly working with Marana and Metro Water District on the Northwest Recharge, Recovery, and Delivery System (NWRRDS). This large-scale capital project will deliver an additional 4,000 af/yr of Oro Valley's CAP allotment by 2024. With respect to reclaimed water use, Oro Valley is making full use of its entitlement and is not planning to expand its reclaimed water system.

Much of Oro Valley's recent growth is due to single-family residential development in neighborhoods along La Cholla Boulevard, with smaller lots of about 6,000 to 8,000 square feet. Although some multifamily housing is planned along the Oracle Road corridor, the current political climate in Oro Valley is not favorable to this type of development. Overall, Oro Valley is expecting about 2,300 to 2,800 more single-family units to reach build out.

Oro Valley is promoting job growth with non-residential development, and such growth is expected in the commercial area north of Tangerine Road on Innovation Park Drive as well as along Oracle Road. In general, non-residential development has been limited to two- or three-story buildings, and this trend is expected to continue. Like other parts of the greater Tucson area, Oro Valley has been experiencing long-term vacancies of former big box stores, and planners are considering mixed-use redevelopment of these parcels.

Oro Valley is also considering annexing an 880-acre State Land parcel in unincorporated Pima County on Tangerine Road. However, other entities are also interested in this land, and ownership has not yet been determined. If Oro Valley is successful in annexing the parcel, it would likely be developed into 6,000 to 8,000 square-foot residential lots.

3.4 Town of Marana

Marana owns and operates its own water and wastewater utilities, but much of the existing service area is concentrated in the land area west of I-10 and does not included the entire Town of Marana limits. Other water providers also serve customers in Marana; of these, the Tucson Water Service Area is the largest encompassing just less than 20% of the Town of Marana's land area.

The Town of Marana is currently updating its General Plan and expects to complete it prior to the end of 2019. The largest development in Marana within Tucson Water's long-range planning area is Dove Mountain. While the approved Specific Plan projected over 9,100 housing units, the area is not developing to that density level. Roughly 5,600 housing units have been platted, and about 4,600 of those have been developed to date. Marana anticipates about 1,200 more homes will be developed in this area, bringing the total to about 5,800 housing units. In addition, a 35-acre parcel on the northwest corner of Dove Mountain Boulevard and Twin Peaks Road is currently used for parking but is expected to be developed with large-scale commercial uses.

Just east of Dove Mountain, the Saguaro Ranch subdivision is developing at lower densities than originally planned. About 90 housing units are permitted in this area. To the south, the Tapestry subdivision is primarily planned for medium density residential uses. This subdivision is approved for about 850 housing units with just under 200 units in the platting process. It may also include a resort.

On Silverbell Road north of Ina Road, a commercial development called Marana Gateway is planned. Although a conditional use permit would allow a building up to 90 feet in height, the Town of Marana anticipates it would not be permitted for more than four stories.

Marana is also expecting multifamily development near this project just south of Crossroads Park. While this area is not within Tucson Water's planning area, the Town of Marana may seek service in the form of wheeling from the City. Another multifamily project planned within the Tucson Water Service Area is along Aerie Drive between Ina Road and Thornydale Road. This project may include a few hundred units.

Other areas planned for development include:

- Parcels near the movie theater along Arizona Pavilions Drive and Cortaro Road.
- Expansion of a medical marijuana facility on Ina Road, including 240,000 square feet of greenhouses and 10,000 square feet of office space.

3.5 City of South Tucson

The City of South Tucson is a small community of about one square mile that is surrounded by the City of Tucson and is fully served by and completely within the Tucson Water Service Area. It is just south of downtown Tucson and is east and north of I-10 and the I-10/I-19 junction. About half of the developable area is zoned for residential uses, about 40% is zoned for commercial uses, and the remaining area is zoned for industrial uses. A large majority of the housing stock consists of rental units with an estimated occupancy rate of approximately 90%.

South Tucson expects redevelopment of the residential corridor along 5th Avenue from the northern city limit to 36th Street with increased densities and potential for multifamily projects. The multifamily developments may reach three stories in height.

The southeast area of South Tucson includes undeveloped and underused parcels, where commercial and retail uses may ultimately replace industrial uses. Along the City's eastern boundary, City staff expects the former El Paso and Southwestern railroad right-of-way to transition to a "greenway" corridor with native plants.

3.6 Pascua Yaqui Tribe Reservation and Trust Lands

The Pascua Yaqui Tribe Reservation is located southwest of downtown Tucson, west of the I-19 and south of Ajo Highway. The City entered into a water service agreement[4] with the Pascua Yaqui Tribe in 2011 that included:

- Wheeling the Tribe's CAP allocation through City CAP storage facilities and back to the Tribe
- Storage of the Tribe's CAP allocation and other water in City underground storage facilities
- Purchase of CAP long term storage credits

The City also delivers potable water to approximately 600 residential and commercial customers located on the Pascua Yaqui Reservation.

In September 2019, the City's Mayor and Council approved an intergovernmental agreement (IGA) with the Tribe.[5] The IGA places just over 14 acres of Tribe-owned land within the City near the southeast intersection of the I-10 and Grant Road in trust. The Tribe has jurisdictional oversight of the land with this designation. The Tribe's plans to redevelop the parcel have not been finalized although there is potential to construct a gaming facility. The IGA permits Tucson Water to provide potable water service if the building or project meets the City's rainwater or greywater harvesting standards and if it is not developed as a gaming facility; the Tribe would need to provide water from its own resources if a gaming facility is ultimately developed.

4.0 State Land

The Arizona State Land Department (State Land) holds title to over 9,000,000 acres of land throughout the state. It may lease or sell the land for the benefit of the state's public schools. In the last several years, State Land has sold about 5,000 acres per year on average.[6] There are large tracts of State Land within the Tucson Water Service Area, and a few are planned to be released for development within the planning horizon of this Master Plan update.

Several State Land parcels near the intersection of Houghton and Valencia Roads could be released and developed in about 20 to 30 years, per State Land staff. This area is located within the City's adopted Houghton Area Master Plan[7] (HAMP) area, and land use guidance is provided by that plan. When parcels are rezoned, greater land use planning definition is provided, which may include changes to the HAMP conceptual land use map. When the HAMP was developed, such changes were envisioned provided they adhered to the underlying HAMP planning framework.

A roughly 360-acre site at the southwest corner of this intersection (yellow polygon on Figure 5) is planned for four housing units per acre in the southwestern portion, and for eight to 15 housing units per acre plus

[4] City of Tucson, 2011. "Resolution No. 21691." Accessed November 8, 2019.
[5] City of Tucson, 2019. "Resolution No. 23085." Accessed November 5, 2019.
[6] Arizona State Land Department, Accessed August 7, 2019. https://land.az.gov/about
[7] City of Tucson, Houghton Area Master Plan, Adopted June 7, 2005. Accessed October 22, 2019. https://www.tucsonaz.gov/files/pdsd/pdfs/HAMP-FULL.pdf

supporting commercial uses in the northeastern portion of the site. In all, approximately 3,000 housing units may be developed in this area.

The northwest, northeast, and southeast areas of the Houghton Road and Valencia Road intersection (orange area on Figure 5) encompasses roughly 1,700 acres. This area is part of a proposed Planned Community Development (PCD) that includes a mix of low-density residential (majority of the use), medium- and high-density residential, and supporting commercial uses near the arterial roadways. The proposed PCD land use plan includes a Town Center that has been largely shifted from the northeast to the northwest of the Houghton Road/Valencia Road intersection.

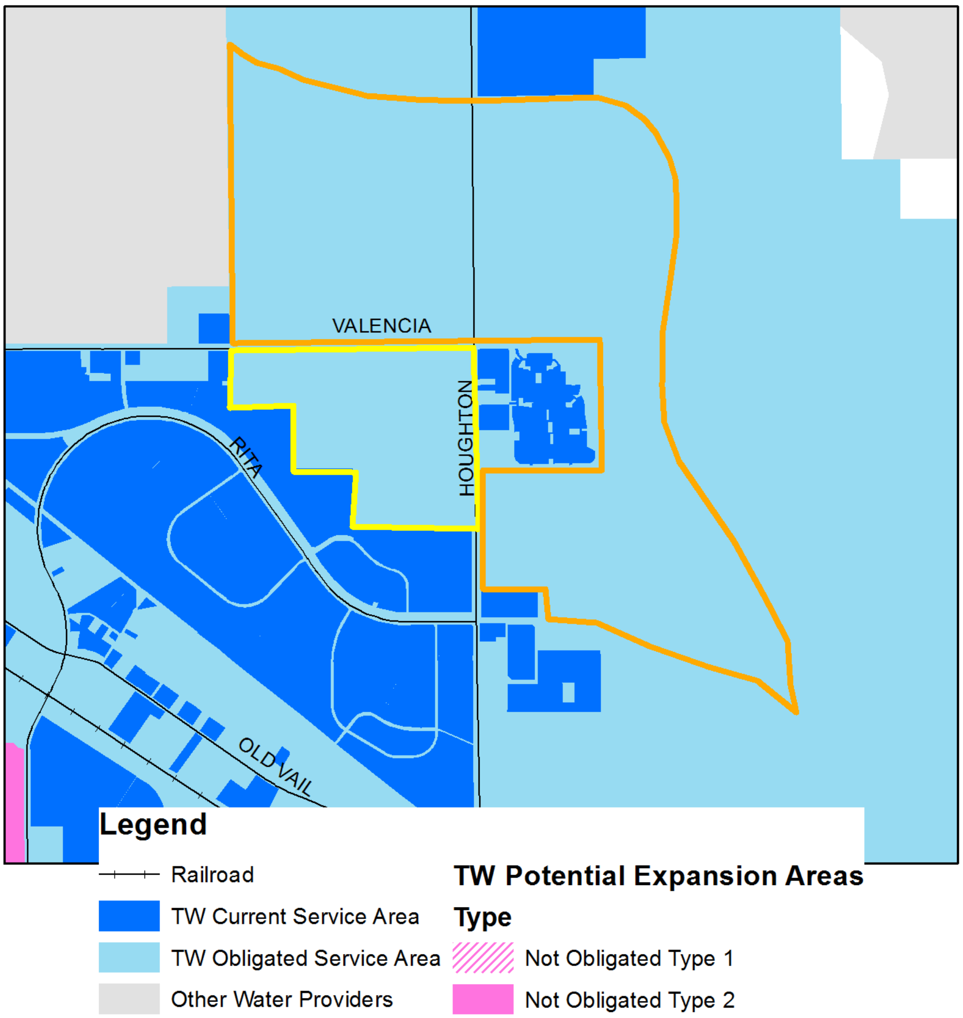


Figure 5 State Land Holdings near Houghton and Valencia Roads

Other areas of State Land that are actively being rezoned or are under consideration for near-term sale include:

- Approximately 880 acres east of Thornydale Road spanning north and south of Tangerine Road as described in Section 3.3; however, this area in not within the Tucson Water Service Area.
- Approximately 1,500 acres north of I-10 near East Mary Ann Cleveland Way.
- Approximately 480 acres bounded by Valencia, Swan, Alvernon and Los Reales Roads that would require annexation by the City of Tucson. This may develop at six housing units per acre with

supporting commercial uses on Valencia Road. The City is progressing with annexation of this area as previously noted.

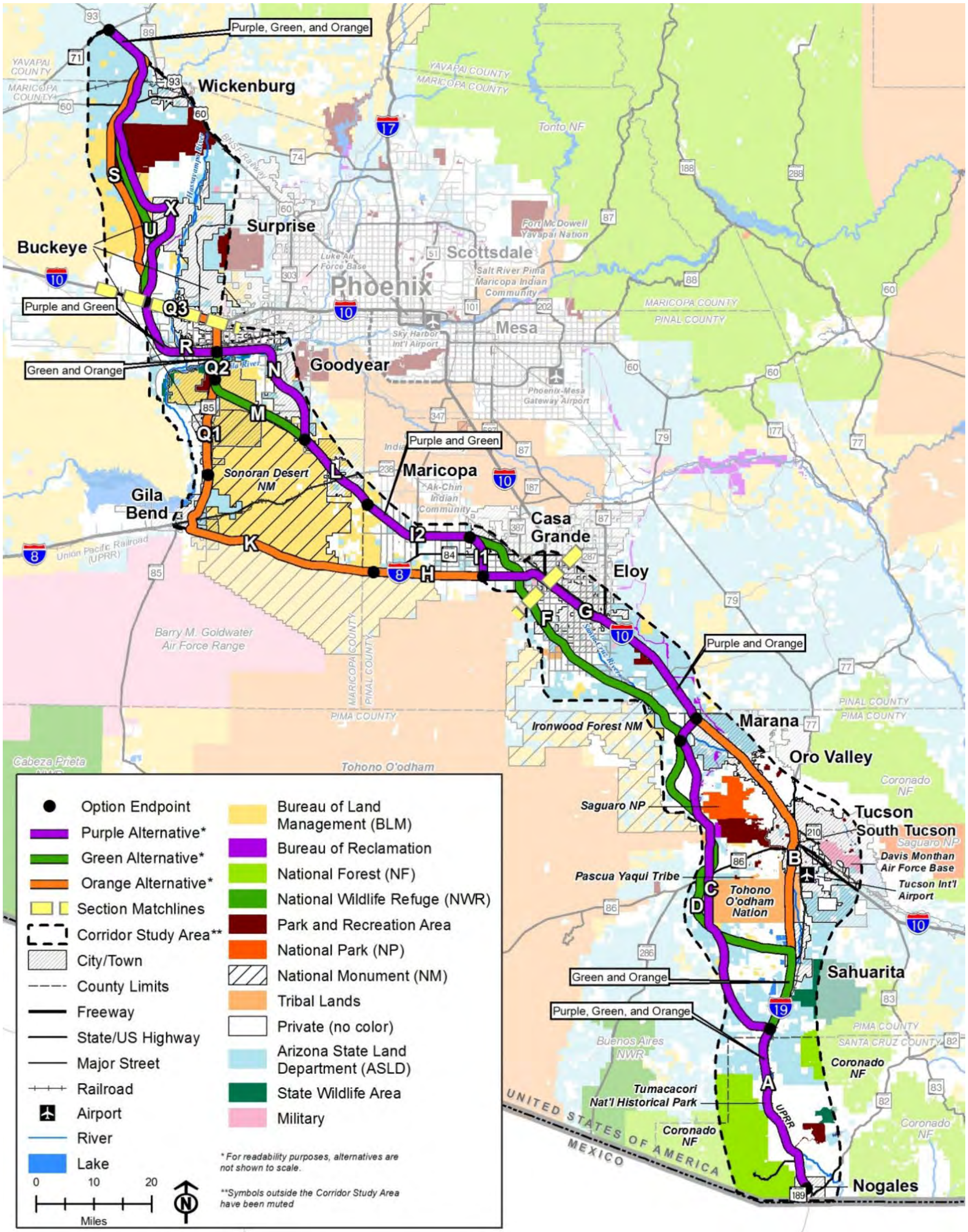
- 86 acres east of Kolb Road near Irvington Road that are expected to be developed as low- and medium-density residential.

5.0 Regional Transportation Planning

5.1 Interstate Highway 11

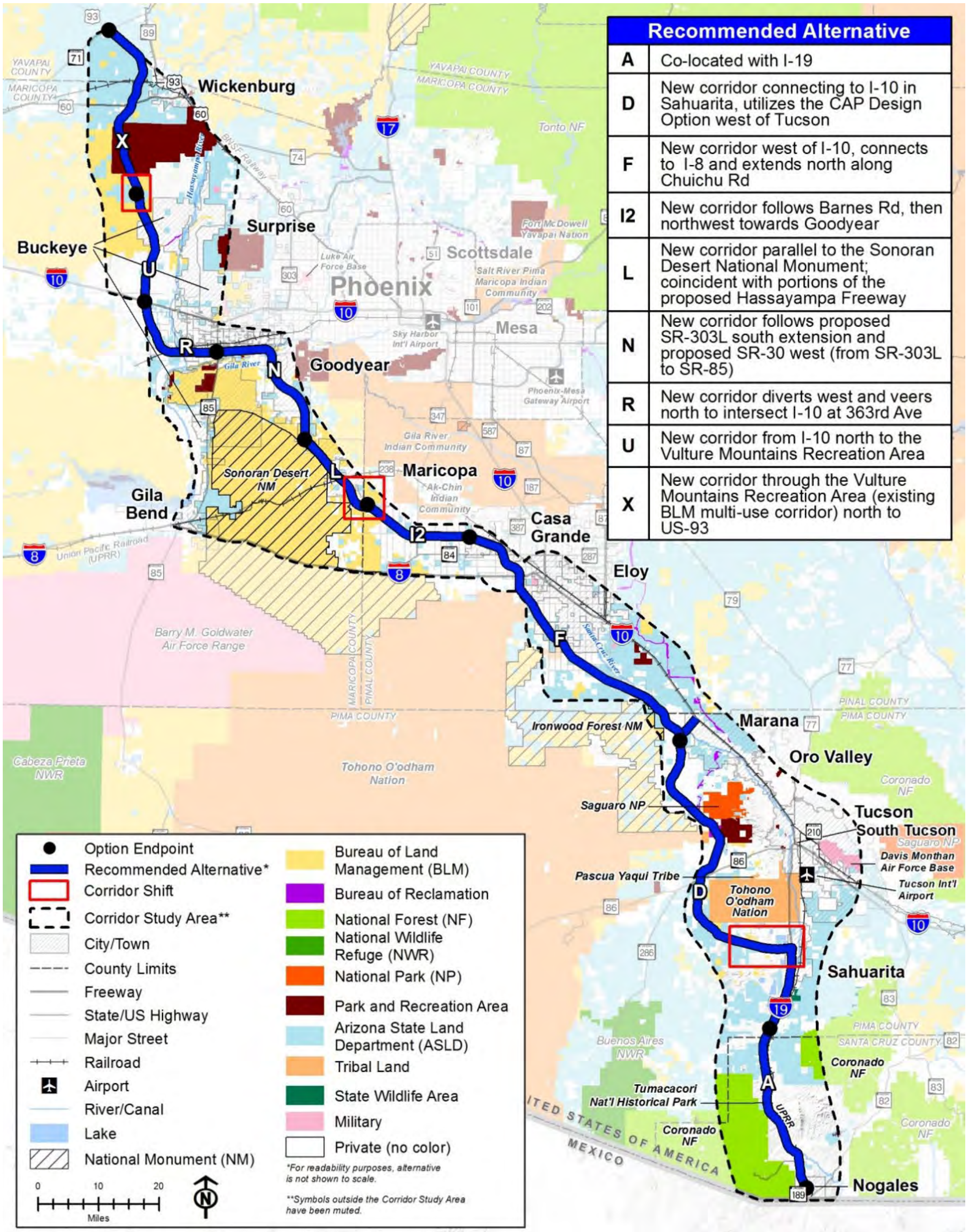
Interstate Highway 11 (I-11) is a north-south freeway that is being planned from Nogales to Wickenburg, AZ. It is part of a series of freeway and other transportation infrastructure improvements in the western U.S., known as the CANAMEX corridor, that will connect Canada and Mexico. As part of the planning process, the Federal Highway Administration (FHWA) and Arizona Department of Transportation (ADOT) published a Draft Tier 1 Environmental Impact Statement (EIS) in March of 2019. The EIS identifies three alternative alignments and a Recommended Alternative as shown in Figures 6 and 7.[8]

[8] Federal Highway Administration and Arizona Department of Transportation. 2019. *Interstate 11 Corridor Draft Tier 1 Environmental Impact Statement and Preliminary Section 4(f) Evaluation.* http://i11study.com/Arizona/Documents.asp.



Source: Interstate 11 Corridor Draft Tier 1 Environmental Impact Statement and Preliminary Section 4(f) Evaluation, March 2019.

Figure 6 I-11 Corridor Alternatives



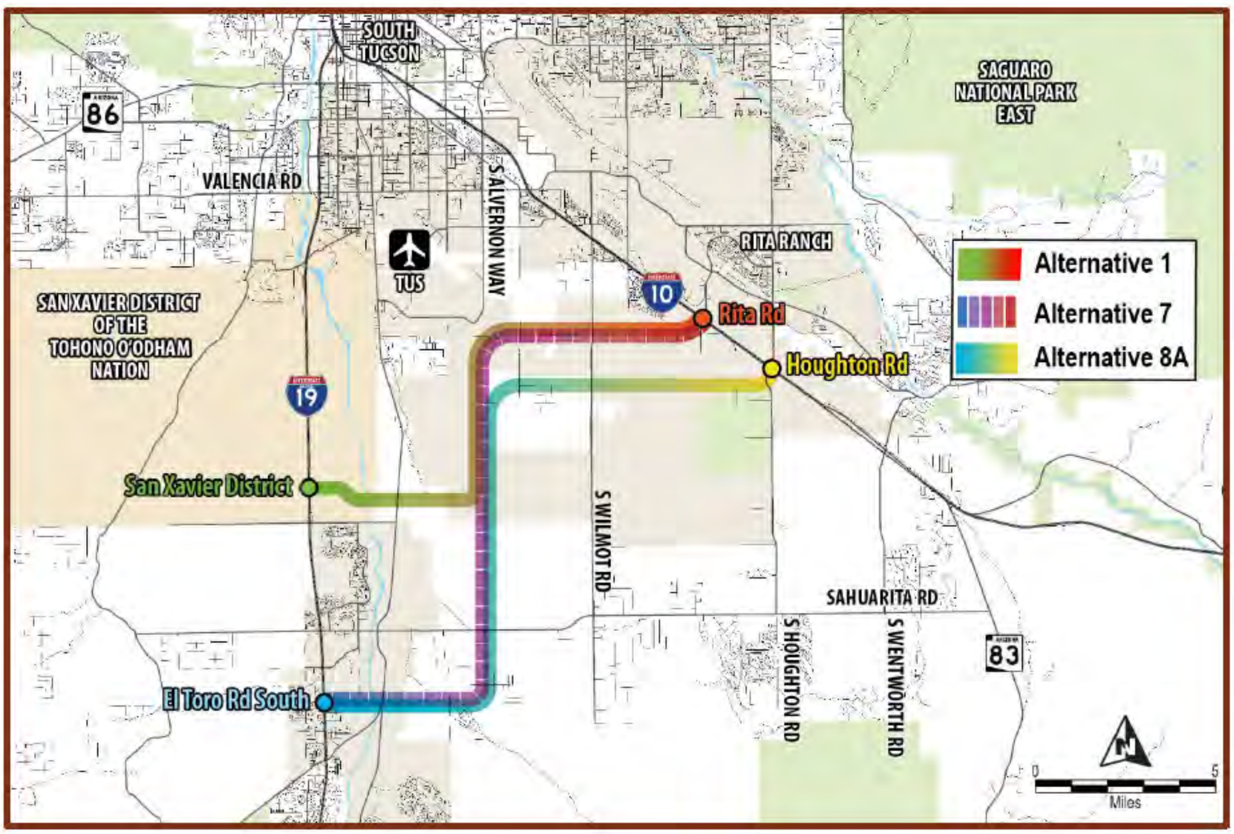
Source: Interstate 11 Corridor Draft Tier 1 Environmental Impact Statement and Preliminary Section 4(f) Evaluation, March 2019.

Figure 7 I-11 Recommended Alternative

The Recommended Alternative travels through Avra Valley west of Tucson, where Tucson Water has large-scale operational recharge and recovery facilities. The Tucson City Council has opposed the Recommended Alternative for environmental and economic reasons.[9] A Final Tier 1 EIS addressing comments and questions is expected to be available in 2020. If the project progresses as planned, construction in the Tucson area may not occur until 2040 or later. There is potential to construct a regional roadway prior to this timeframe, which may occur within the next 10 to 20 years.

5.2 Sonoran Corridor

ADOT has completed a study of alternatives[10] for the Sonoran Corridor, which is planned to connect I-19 and I-10 south of the Tucson International Airport. The project is intended to provide access to existing and future employment centers, and three alternatives are being considered, as shown on Figure 8. In northern parts of the corridor area, non-residential development is expected; while in the southern parts, residential development may occur in and near Sahuarita. The southern study area is also near the Pima Mine Road Recharge Facility.



Source: ADOT Corridor Selection Report, June 2019.

Figure 8 Sonoran Corridor Alternatives

[9] Craig Smith, "Tucson City Council joins I-11 Opposition," June 20, 2019, https://www.kgun9.com/news/local-news/tucson-city-council-joins-i-11-oppositio.

[10] Arizona Department of Transportation. 2019. *Sonoran Corridor Tier 1 Environmental Impact Statement: Corridor Selection Report*. https://azdot.gov/docs/default-source/transportation-studies/sonoran-corridor-selection-report.pdf?sfvrsn=2.

ADOT expects to select an alternative in 2020, and a project specific environmental study would follow. These efforts can span up to a decade; therefore, project implementation is not likely to occur for about 12 to 15 years depending on availability of funding. Portions of this corridor will pass through the Tucson Water Service Area.

6.0 Conclusion

Within the Tucson Water Service Area, growth will occur as infill development and redevelopment in the mostly built-out areas, and as larger-scale new growth in primarily undeveloped or underdeveloped areas. In the mostly built-out areas, infrastructure maintenance and upgrades are key planning considerations. In new growth areas, water demand, infrastructure upgrades, and new infrastructure must be considered. As per adopted long-range land use plans, new growth is expected in the following areas:

- Buildout of the Dove Mountain subdivisions and surrounding areas in Marana with supporting commercial development;
- Development of master planned residential communities with supporting commercial uses along the Houghton Road corridor in the southeastern portion of the City;
- Expansion of non-residential development south of Tucson International Airport along the planned Sonoran Corridor and around the Pima County Fairgrounds; and
- Non-residential development along the 1-10 corridor from Kino Parkway to Rita Road.

Tucson Water will continue to coordinate with local jurisdictions and water providers, as well as regional planning agencies, and will monitor growth and development trends that may impact its systems and operations.

Appendix K

ONE WATER 2100 WATER USE PROJECTIONS

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
WATER USE PROJECTIONS

FINAL | September 2021

Jacobs

Tucson Water
One Water 2100 Master Plan

Technical Memorandum
WATER USE PROJECTIONS

FINAL | September 2021

This document is released for the purpose of information exchange review and planning only under the authority of Fair Yeager, 3 September 2021, Arizona PE 35903.

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Abbreviations

ADWR	Arizona Department of Water Resources
AF	acre-feet
AF/yr	acre-feet per year
AOP	Advanced Oxidation Process
AWS	Assured Water Supply
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAVSARP	Central Avra Valley Storage and Recovery Project
CAWCD	Central Arizona Water Conservation District
DCP	Drought Contingency Plan
GIS	Geographic information system
GPCD	gallons per capita day
gpd	gallons per day
LTSC	Long-term storage credit
M&I	Municipal and Industrial
mgd	million gallons per day
PFAS	per- and polyfluoroalkyl substances
SAVSARP	Southern Avra Valley Storage and Recovery Project
SF	square feet
TARP	Tucson Airport Remediation Project
TAZ	Traffic Analysis Zone
TCE	trichloroethylene
WSA	Water Service Area

Technical Memorandum

WATER USE PROJECTIONS

1.0 Introduction

This technical memorandum documents Tucson Water's water resources portfolio along with accompanying analyses of the utility's existing water demands and water production summaries. It also highlights customer consumption trends including calculation of unit demands, summarizes demand projections, and shows the water system supply versus demand balance through the One Water 2100 master planning horizon.

2.0 Water Resources Portfolio

Tucson Water has a diverse water resources portfolio consisting of surface water (Colorado River water delivered via the Central Arizona Project [CAP] canal), groundwater, treated groundwater, reclaimed water, harvested rain, and stormwater sources.[1] Each of these supply sources has its own set of delivery and use restrictions based on regulatory and contractual obligations that impact how they can be used to meet the water service area needs. Tucson Water combines these varied water resources to strategically meet the needs of its unique service area.

The City of Tucson established the utility's Water Service Area boundary in 2010 with the adoption of a formal Water Service Area Policy. The map shown as Figure 1 illustrates the extent of the current obligated Water Service Area, as well as potential areas of water service expansion and non-expansion areas. The obligated service area includes areas within the City limits or contracted service areas that Tucson Water will serve in the future. The map is not intended to provide parcel-level guidance on water service availability, but rather meant to provide a general overview of Tucson Water's service in the region. All parcels within the City limits are eligible for water service. New requests for water service outside of the existing obligated Water Service Area require a water availability request and staff review of the specific parcel(s) in question. The obligated Water Service Area may also be modified through approved City of Tucson annexations or by direction of the Mayor and Council.

The current Water Service Area spans several jurisdictions with about 42 percent of the geographic area lying within the City of Tucson and nearly 53 percent in unincorporated Pima County. Marana (4 percent), Oro Valley (1 percent), South Tucson and Pascua Yaqui lands (less than 1 percent each) round out the Water Service Area. The Town of Oro Valley also has an agreement with Tucson Water to deliver a specified amount of the Town's CAP water via Tucson Water's infrastructure; other potable wheeling agreements are in place with Metro Water District, Vail Water, Marana, and the Pascua Yaqui Tribe. The utility wheels reclaimed water to the Town of Oro Valley, Metro Water District, Pima County, and other smaller water providers.

[1] Note: Harvested rain and stormwater sources are not metered.

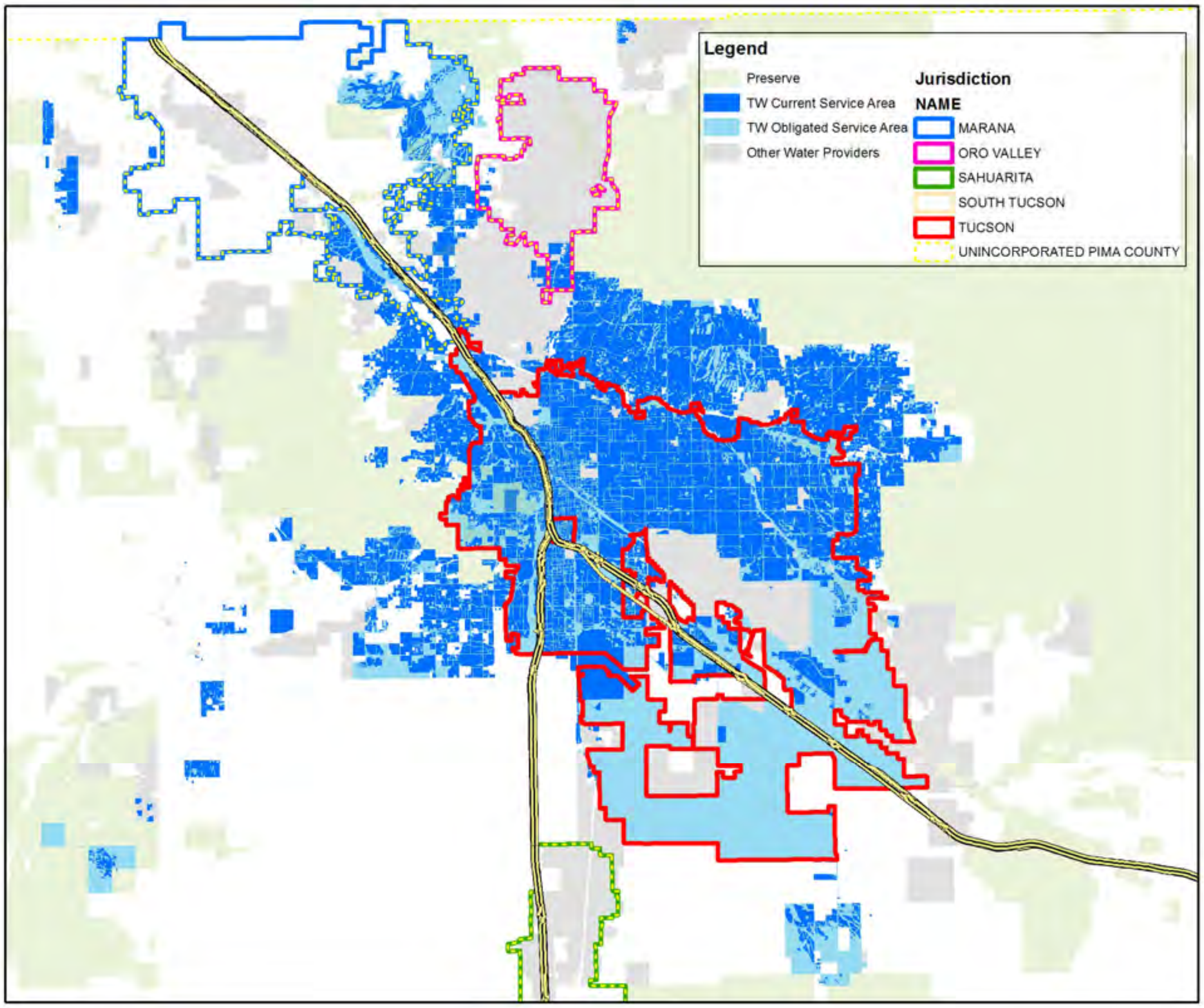

Figure 1 Tucson Water Service Area

On October 16, 2014, the Arizona Department of Water Resources (ADWR) approved the most recent City of Tucson Designation of Assured Water Supply (AWS). The resulting Decision and Order identified the portfolio of physically and legally available water supplies including the future responsibilities of Tucson to maintain its Designation. Table 1 summarizes the components of the 2014 Designation.[2]

Table 1 2014 Assured Water Supply Designation

Supply Source	Average Annual (acre-feet [AF])
Groundwater	**31,761.16**
Replenished by Central Arizona Groundwater Replenishment District (CAGRD)	12,500
Incidental Recharge	6,213.82
Allowance	12,537.60

[2] Arizona Department of Water Resources, City of Tucson Designation of Assured Water Supply (AWS No. 2014-002, DWR No. 86-400957.0001), Decision and Order, October 2014.

Table 1 2014 Assured Water Supply Designation

Supply Source	Average Annual (acre-feet [AF])
Remediated water	509.74
Recovered Water	**145,012.98**
Long Term Storage Credits (LTSCs)	2,068.98
CAP water recovered within the area of hydrologic impact of storage	90,000
CAP water recovered outside the area of hydrologic impact of storage	45,966
Effluent stored and recovered inside the area of hydrologic impact of storage	6,978
Effluent	**6,078**
Total 2024 Supplies	**182,852.14**

2.1 Groundwater

Tucson is a "member service area" of the Central Arizona Groundwater Replenishment District (CAGRD). CAGRD functions as a department within the Central Arizona Water Conservation District (CAWCD), the entity responsible for the management, operation, and maintenance of the CAP. CAGRD was created by the state legislature in 1993 to perform a groundwater replenishment function in the State of Arizona within the three-county CAP service area. Membership in the CAGRD provides a mechanism for its members to meet increasing service area demands without pumping groundwater in excess of allowable limits, thereby maintaining consistency with the State's AWS Rules. For Tucson, CAGRD membership represents a "safety net" in water supply management. Tucson Water's current supply portfolio is sufficient for meeting system demands without utilizing the CAGRD replenishment capabilities. However, should Tucson Water encounter an unexpected circumstance requiring an increase in local supply, it could respond with a commitment to that need and exercise its access to CAGRD replenishment capabilities, if necessary, until a long-term renewable resource strategy is put in place for that need.

Incidental Recharge is defined in the AWS Rules as an amount of water that is recharged to the groundwater aquifer as a result of Tucson Water's routine production and distribution of supply to its end users. ADWR determines the allowance according to a factor (4 percent), which is multiplied by Tucson Water's previous year's total water demand.

When the AWS Rules were established, water providers were granted a fixed volume of groundwater (Allowance). In Tucson's case, this volume is the total volume of water provided to its customers from any source during calendar year 1994 multiplied by a factor of 15. Once this water is pumped, the Allowance is no longer available.

Tucson also has access to a special class of groundwater (remediated water as noted on Table 1) through its Tucson Airport Remediation Project (TARP) Water Treatment Facility in conjunction with the Advanced Oxidation Process (AOP) Water Treatment Facility. This groundwater receives additional treatment for the removal of trichloroethylene (TCE), 1,4-dioxane, and per- and polyfluoroalkyl substances (PFAS). Due to elevated PFAS levels, Tucson Water shut down the facility on June 21, 2021. Tucson Water is planning to add additional treatment capacity and work with appropriate regulatory agencies to eventually redirect this supply from the potable system to the reclaimed system in two phases:[3]

- Construct a gravity-fed outfall to deliver treated water to the Santa Cruz River in October 2021

[3] Jeff Biggs, meeting with Jaimie Galayda and Fair Yeager, August 3, 2021.

- Construct a 1.5-mile pipeline to connect directly to the reclaimed system east of 12th Avenue by early 2022

Although not included in its current Designation of AWS, Tucson holds Type 1 non-irrigation grandfathered groundwater rights on land owned in Avra Valley. These rights total about 1.2-million AF and serve as a backup supply. In the future, Tucson may make a request to ADWR to include these rights in its designation; ADWR will consider the amount of groundwater to include consistent with groundwater management goals.

2.2 Colorado River Water

The CAP water supply is managed and delivered by the CAWCD. The CAP is designed to deliver approximately 1.5-million AF of Colorado River water each year to Maricopa, Pinal, and Pima Counties. Tucson has access to 144,191 AF/yr of CAP supply, which is the largest municipal allocation in the state. As noted in its current AWS, 144,172 AF are from its subcontract with CAWCD, and an allocation transfer with Flowing Wells Irrigation District completed in 2015[4] added 19 AF.

There is a specific priority system related to the use of Arizona Colorado River water numbered 1 through 6 with the first priority rights being the most senior (most protected). For example, first priority rights are established in the Supreme Court Decree of Arizona v. California. Fourth priority rights are held by water users with contracts, Secretarial Reservations, or other rights established by the United States after September 30, 1968. The CAP holds primarily Fourth Priority rights. Priority of entitlement has a direct relationship to availability of this resource during periods of shortages within the Colorado River Basin.

Delivery priorities are also assigned within the CAP allocations. The highest priority water is associated with Municipal and Industrial (M&I) and Indian water allocations ("Firm" water). Agricultural allotments and CAP Excess Water/Recharge supplies have lower priority assignments ("Non-Firm" water). Non-Firm supplies are more susceptible to being affected by shortage conditions or drought conditions on the Colorado River system. Tucson's CAP supply is a combination of an original M&I allocation, reallocation of previously uncontracted M&I priority water, and transfer of M&I priority water from Flowing Wells Irrigation District.[5]

Tucson Water's CAP allocation is managed through its recharge and recovery operations, which have sufficient capacity to recharge and recover the City's full allocation on an annual basis. The program is summarized below:

- Central Avra Valley Storage and Recovery Project (CAVSARP)
  - Recharge capacity = 100,000 AF/yr
  - Recovery capacity = 70,000 AF/yr
- Southern Avra Valley Storage and Recovery Project (SAVSARP)
  - Recharge capacity = 60,000 AF/yr
  - Recovery capacity = 60,000 AF/yr
- Pima Mine Road Recharge Project/Santa Cruz Well Field
  - Recharge capacity = 30,000 AF/yr
  - Recovery capacity = 11,100 AF/yr in fiscal year 2020-2021 and 19,000 AF/yr in fiscal year 2021-2022

2.3 Long-Term Storage Credits

LTSCs are the legal mechanism by which Tucson can recover recharged CAP water by using its wells. When the Colorado River experiences decreased flow conditions within its watershed, a "shortage" may occur. A

[4] City of Tucson, 2015. "Resolution No. 22344." Accessed April 17, 2020.
[5] Ibid.

complex set of agreements and laws determine how the shortages are distributed among the seven Basin States of Arizona, California, Nevada, New Mexico, Utah, Colorado, and Wyoming. Shortages within the State of Arizona are assigned in accordance with a set of agreements with the Arizona users.

The replacement of the shortages is built around a regulatory framework that provides the legal authority to replace the reduction in water delivery with access to alternative water rights. For the past several decades, Tucson has been recharging CAP water and has accumulated 472,740 AF of LTSCs through 2020.[6] ADWR will issue a LTSC that quantifies Tucson's right to pump the LTSC out of the ground. Having the right to pump (or recover) LTSCs must be accompanied with a physical mechanism (wells) to pump the LTSC from the groundwater aquifer.

In addition to recharging CAP water, Tucson has accumulated 35,560 AF of effluent recharge credits.[7] These credits may also be used for potable deliveries to customers. Based on current customer water use (approximately 95,000 AF), Tucson Water has enough LTSCs accrued via CAP recharge and effluent recharge to provide water to its customers for over five years.

2.4 Reclaimed Water

Tucson Water has implemented strategic efforts to locally reuse and recharge reclaimed water through an intergovernmental agreement with Pima County. In addition, recharge efforts result in the accumulation of LTSCs that contribute to Tucson's long-term AWS. These credits can be recovered through any well that is permitted and designated through the ADWR as a recovery well as noted above. Reclaimed water, therefore, presents a very reliable and flexible component of the Tucson Water's available resources.

3.0 Existing Water Use Patterns

This section summarizes three years of recent customer consumption via billing data and also documents trends of potable customer consumption based on customer class (residential versus non-residential) for use in subsequent water demand projections.

3.1 Billing Data Analysis

Tucson Water has nearly 240,000 potable and reclaimed water accounts, where each meter is read on a monthly basis. A summary of customer account statistics for 2018 is shown in Table 2.

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[6] Dee Korich, email message to Jaimie Galayda, and Fair Yeager, August 3, 2021.

[7] Ibid.

Table 2 2018 Customer Account Summary

Customer Type	Potable Customers	Reclaimed Customers
Residential	221,854	608
Non-Residential	14,538	384
Wheeling	6	40
Total	**236,398**	**1,032**

Notes: Excludes construction water meters and meters that did not record any usage for any given year.

Tucson Water also maintains daily water production records in a database that is capable of generating monthly summaries in tabular form with associated graphics. However, meter read dates vary among accounts within each month and do not necessarily align with the date ranges in the monthly production data summaries. To more accurately compare monthly consumption with monthly production data, the consumption data needs to be adjusted to match production data timeframes. To achieve this consistency, the average daily use was calculated in the monthly read period and the averages by calendar month were aggregated.

The results of the 2016, 2017, and 2018 potable water billing analyses are shown in Figures 2 through 4 and are presented in million gallons per day (mgd). The actual use equates to consumption during the read month as documented in Tucson Water's billing system, and the adjusted use is the estimate of consumption associated within each calendar month between read dates. Tucson Water's average monthly production is also shown along with an estimate of average demand; Tucson Water calculates demand as water produced plus the change in storage volume. During most months, the adjusted billed rates correlate with average monthly production values.

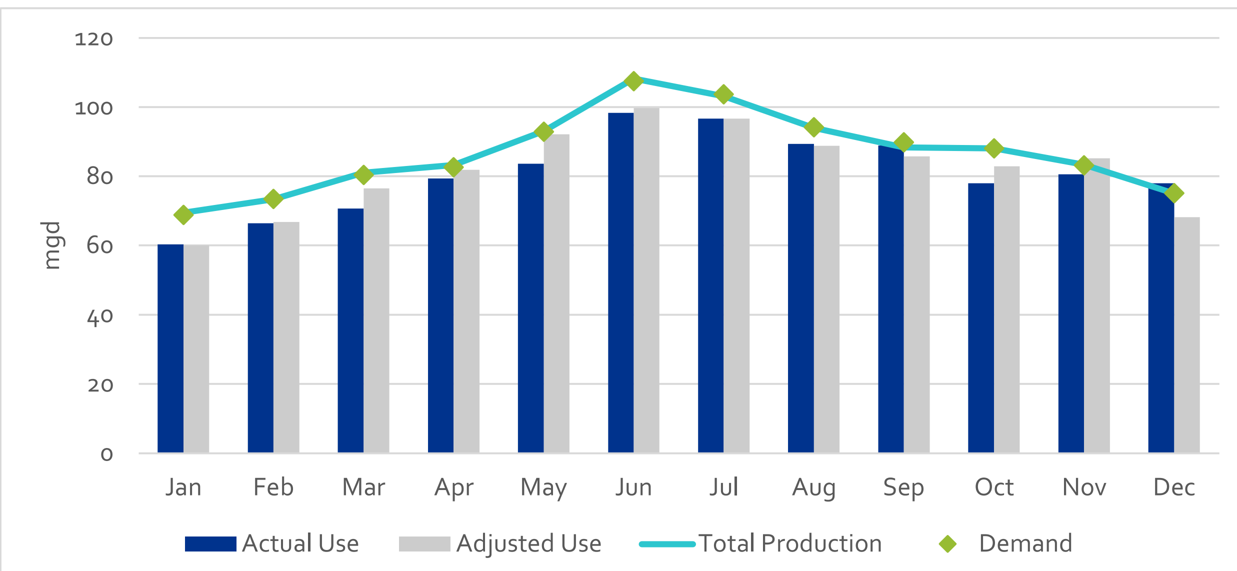


Figure 2 2016 Potable Water Production and Consumption Comparison

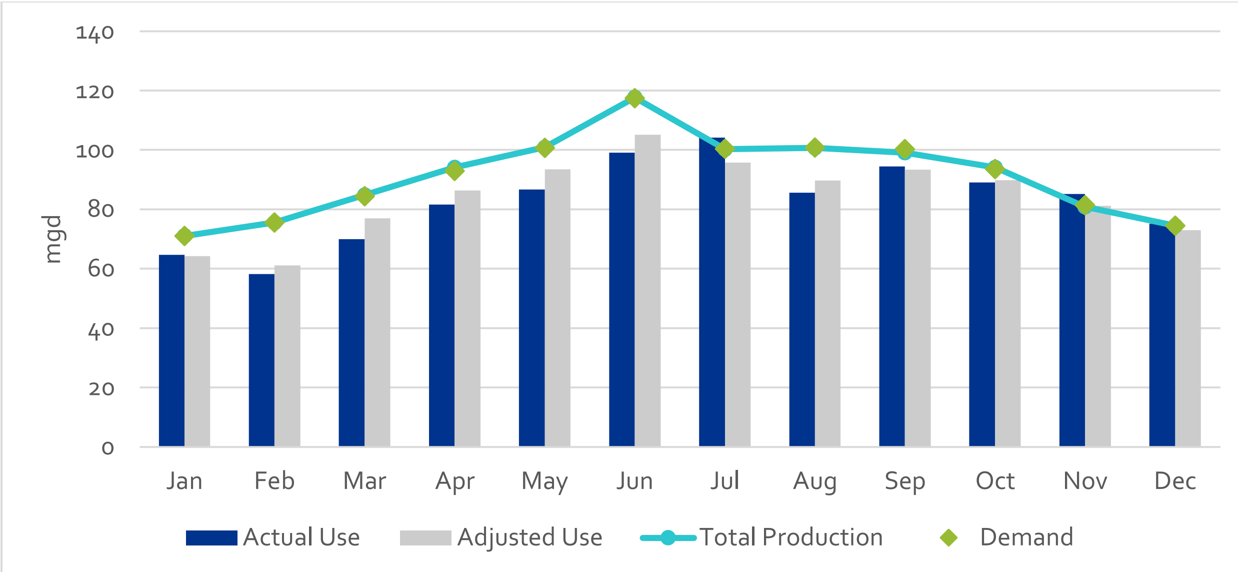


Figure 3 2017 Potable Water Production and Consumption Comparison

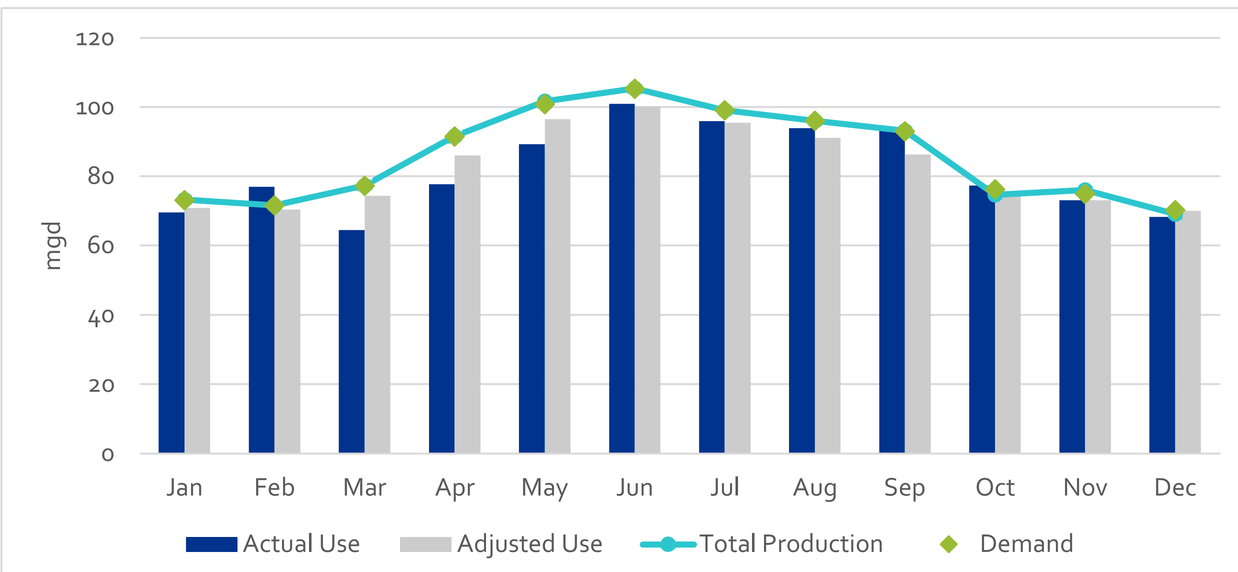


Figure 4 201 Potable Water Production and Consumption Comparison

A summary of the analysis of reclaimed water customer use and annual production is provided in Appendix A.

3.2 Non-Revenue Water

Non-Revenue or lost-and-unaccounted for water is the difference between metered demand and production less any known unmetered uses. Recent non-revenue water percentages that Tucson Water reported to ADWR are presented in Table 3. An average of 8.7 percent of non-revenue water will be applied to future potable demand projections.

Table 3 Non-Revenue Water

Year	Non-Revenue Water (%)
2016	8.00
2017	9.87
2018	8.20
Average	**8.69**

Source: Tucson Water

A summary of annual potable water production and customer consumption from the billing database is presented in Figure 5; the difference between the two provides an estimate of non-revenue water.

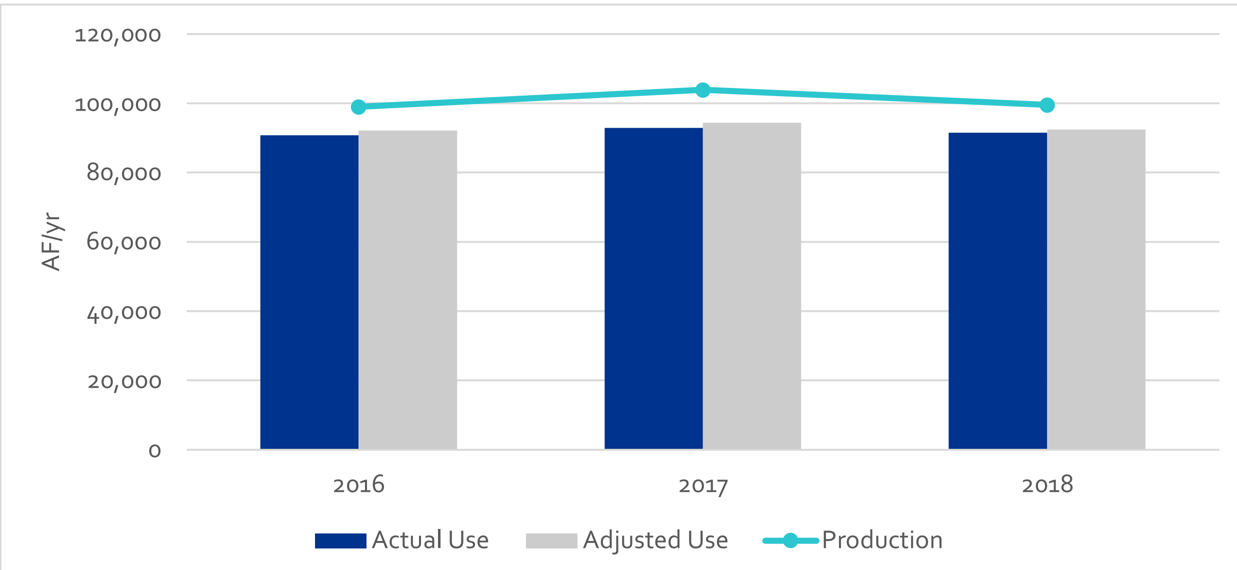


Figure 5 Annual Potable Water Production and Consumption Comparison

3.3 Peaking Factors

A peaking factor is the multiplier that translates average day demand to maximum day demand or to peak hour demand. These factors are often used in a hydraulic model to represent a condition when the system is most stressed or to substantiate diurnal patterns for extended period simulations. Because the consumption data are only available in monthly increments, the average day to maximum day peaking factors are calculated from Tucson Water's production data in mgd. Recent calculated maximum day peaking factors are shown in Table 4.

Table 4 Maximum Day Peaking Factors

Year	Annual Average Production (mgd)	Maximum Day Production (mgd)	Maximum Day Peaking Factor	Maximum Day Production Date
2016	86.7	126.4	1.5	19 June 2016
2017	91.2	136.4	1.5	28 June 2017
2018	85.8	115.4	1.3	4 June 2018

3.4 Customer Consumption Trends

Over 90 percent of Tucson Water's potable accounts are residential; but from a volumetric perspective, this customer class represents just over 70 percent of consumption. From 2016 to 2018, annual customer consumption by class has been consistent as summarized below:

- Residential volume: 72 percent
- Non-residential volume: 25 percent
- Wheeling volume: 3 percent

Graphical representations of consumption by month are summarized on Figures 6 through 8.

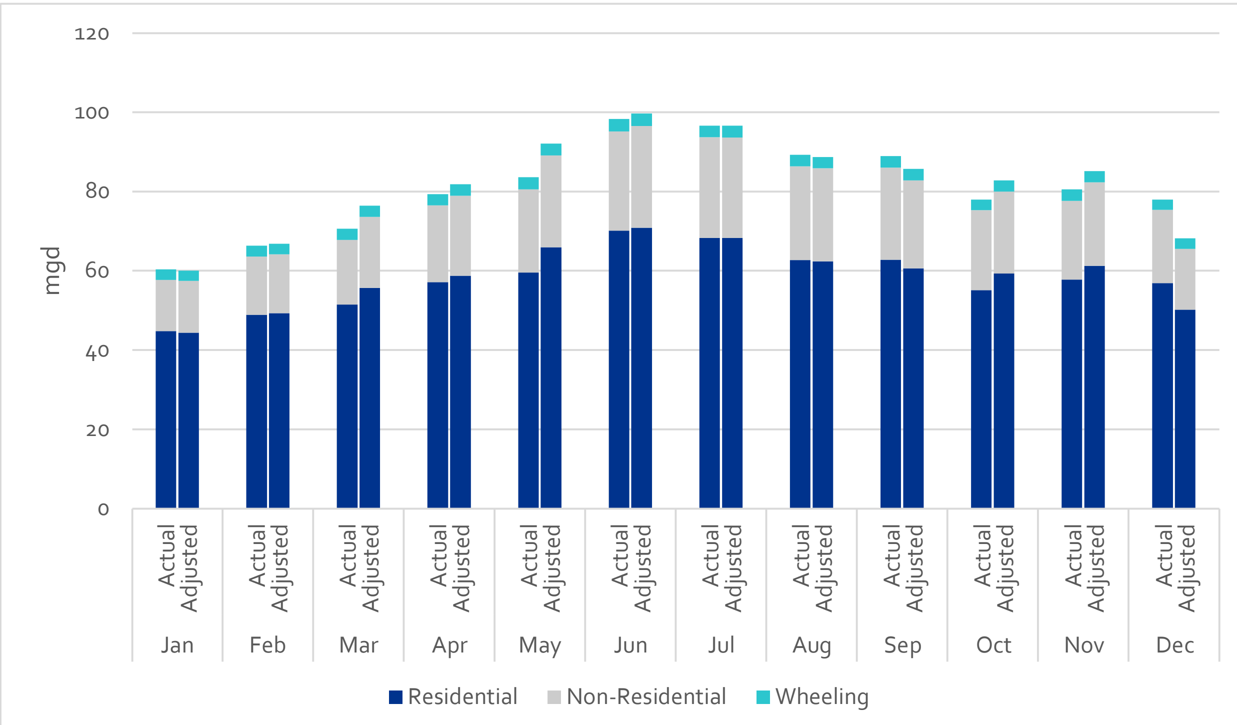


Figure 6 2016 Potable Water Consumption by Customer Type

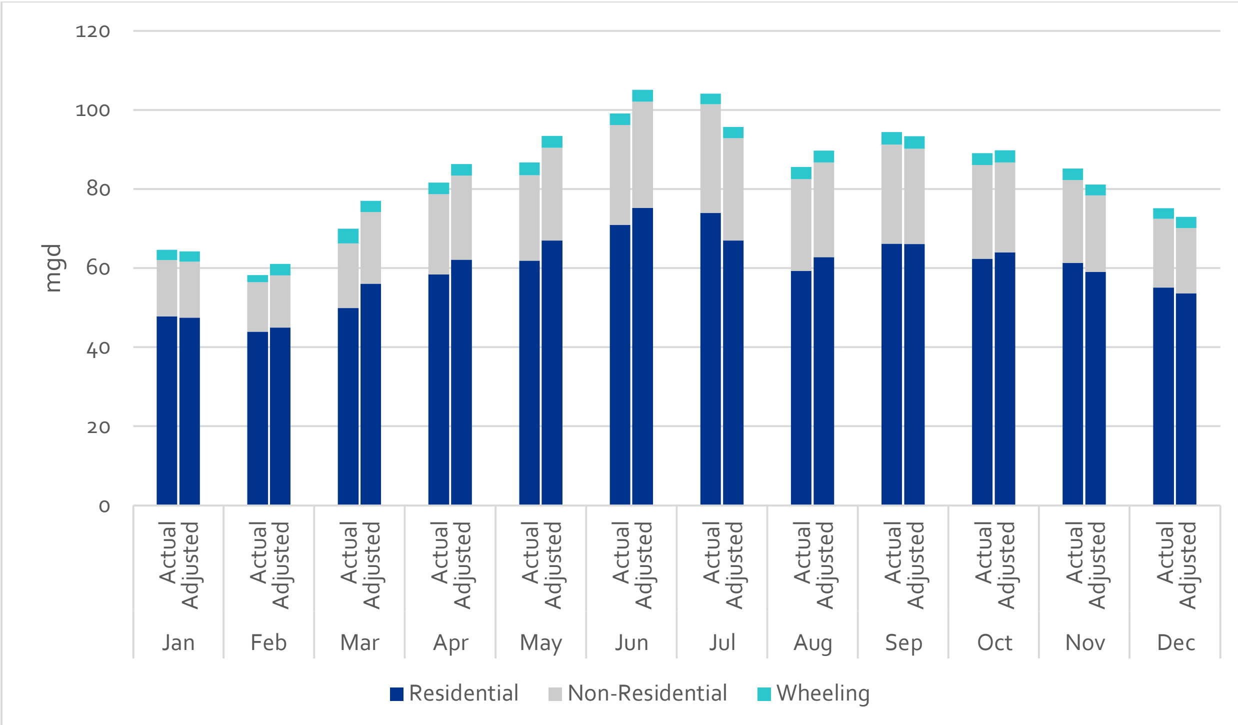


Figure 7 2017 Potable Water Consumption by Customer Type

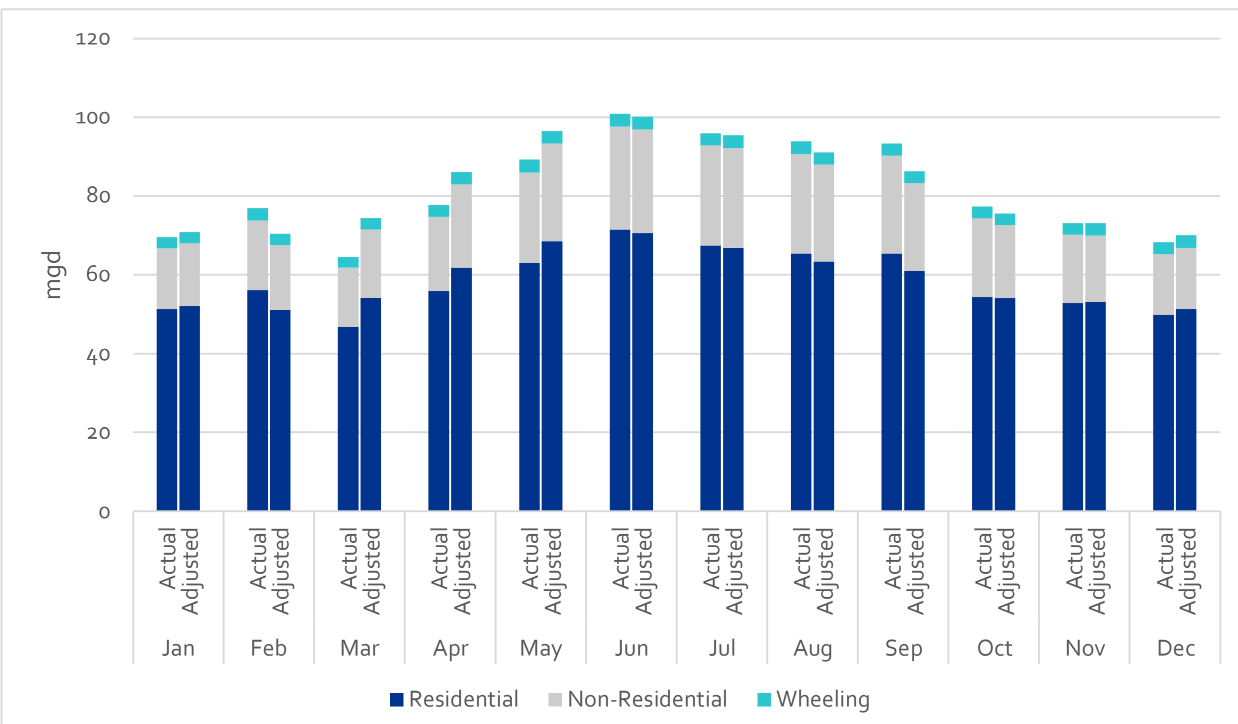
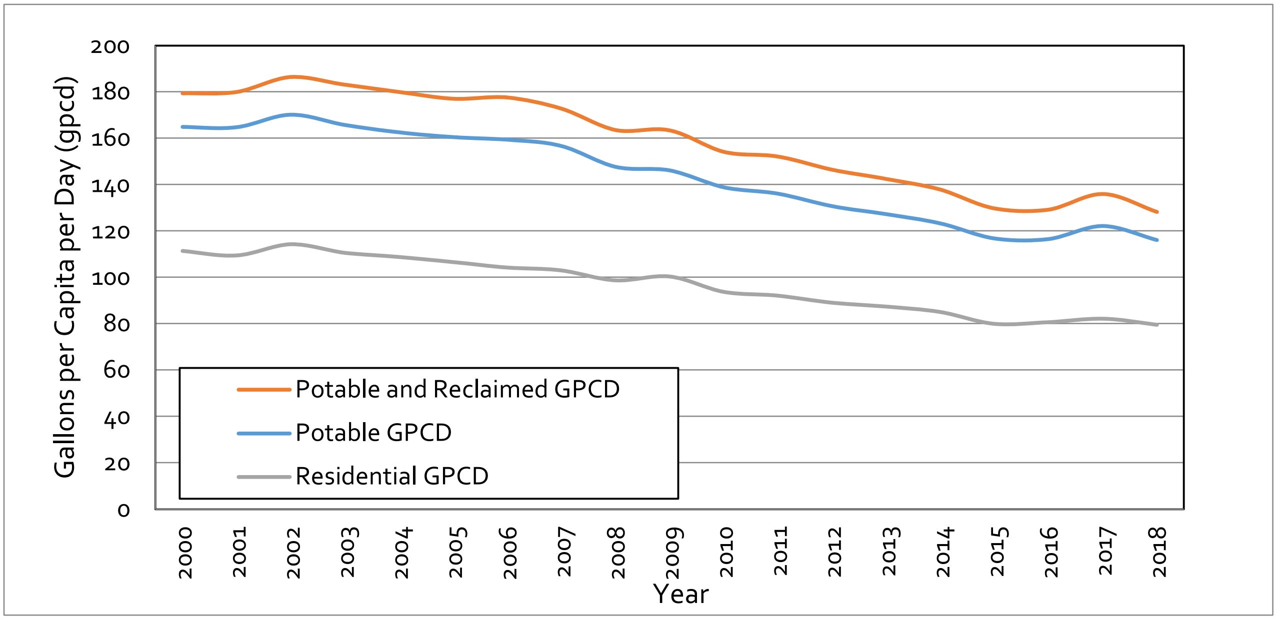


Figure 8 2018 Potable Water Consumption by Customer Type

Tucson Water has been tracking per capita consumption for decades. As shown on Figure 9, the utility has been experiencing a downward trend that has been flattening in recent years.



Source: Tucson Water

Figure 9 Water Service Area Gallons per Capita per Day Trends

In addition to summarizing customer use within the service area, the accounts were geocoded to provide a spatial location of customer demand to calculate unit demands by customer class and support hydraulic modeling.

The meters were geocoded to parcel centroids based on service address where 99 percent of the meters (over 245,000) were matched to a spatial location. A snapshot of 2018 average annual potable customer consumption within each pressure zone or water service area (WSA) is summarized on Figure 10; it is normalized by the WSA geographic area, where red and orange areas use more water per acre than yellow or green areas.

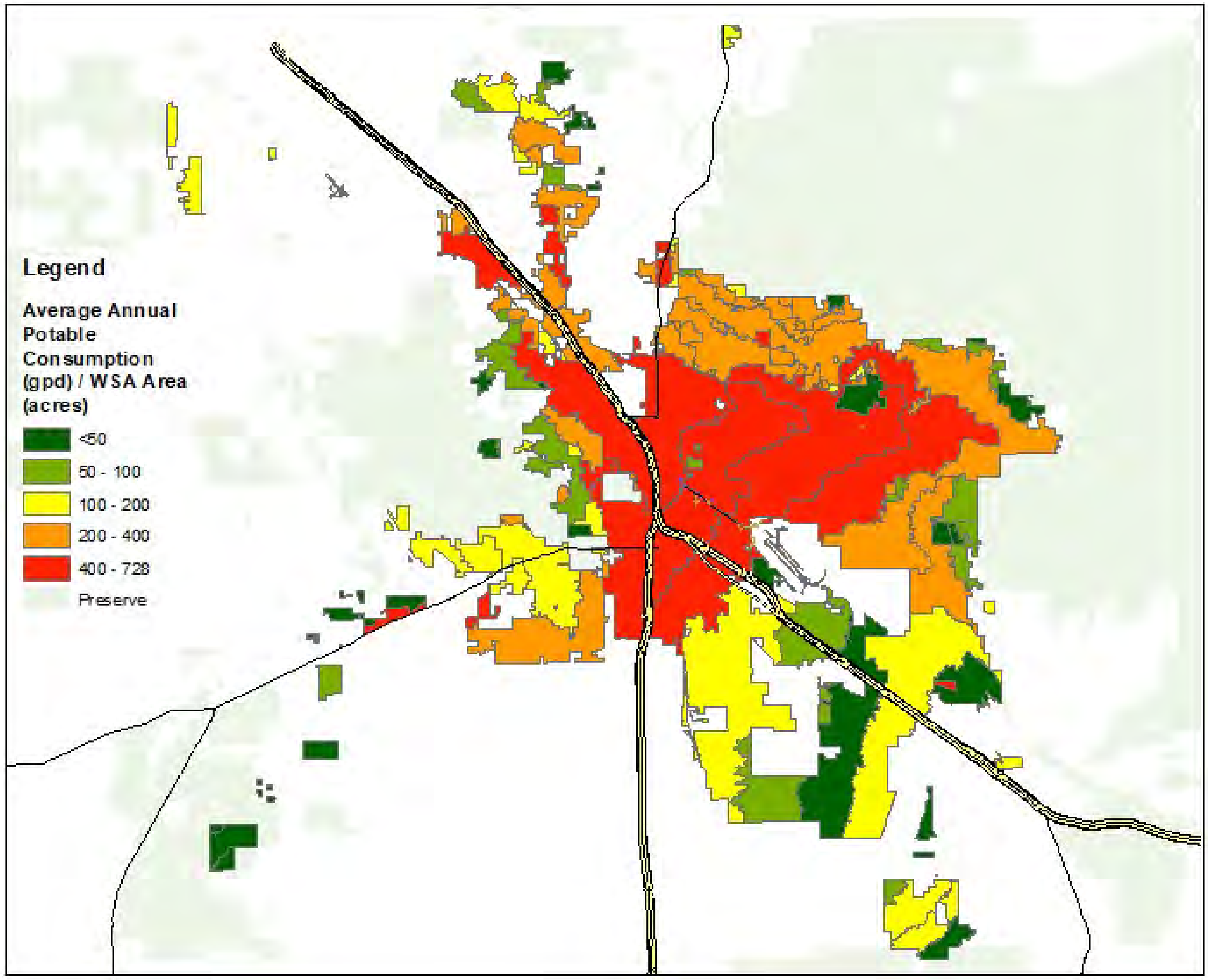


Figure 10 2018 Annual Average Potable Consumption Normalized by WSA Geographic Area

To develop potable water unit demands by customer type that align with the housing unit and employment projections in the accompanying One Water 2100 Master Plan Technical Memorandum entitled, "Population Projections," residential parcels were analyzed to determine groupings by parcel area. The following parcel areas were identified to further review single-family residential customer consumption:

- Up to 7,000 square feet (SF) (about 67,000 parcels)
- >7,000 SF – 10,000 SF (about 77,000 parcels)
- >10,000 SF (about 62,000 parcels)

Potable meters that were located within each respective parcel group were tallied to summarize average annual water use for 2016 through 2018 in gallons per day (gpd); meters that did not record any usage for any given year were excluded. The results are also summarized by use recorded within the billing system (read month) versus adjusted use to better capture use within each calendar year as shown below in Table 5.

Table 5 Unit Demands: Single-Family Residential

Parcel Area (square feet)	Actual Use (gpd/meter)			Adjusted Use (gpd/meter)			Meter Count
	2016	2017	2018	2016	2017	2018	
< 7,000	150	154	151	153	158	154	65,104
7,000 – 10,000	189	194	189	193	199	192	75,883
> 10,000	274	284	276	278	290	280	64,696
Total	**204**	**210**	**205**	**207**	**215**	**208**	**205,683**

Notes: Includes Class Codes: R (residential); R2 (duplex/triplex); L1, L2, L3, L4 (low income)
Includes water and irrigation service codes (WA and IR).
Does not account for non-revenue water.

Overall, the consumption per housing unit increases as parcel size increases. On average, single-family residential customers use just over 200 gpd/meter (or housing unit), which is very low compared to other water utilities. In comparison, it is common for customers to use over 300 gpd/housing unit in the Phoenix area. For purposes of future residential demand projections, a rate of 208 gpd/housing unit will be applied.

Multi-family residential customers are often master-metered and lack summaries of housing units per meter, making it difficult to develop unit demands for this customer class. A special analysis of this customer class was conducted and documented in an accompanying One Water 2100 Master Plan Technical Memorandum entitled, "Water Conservation Program Analysis & 10-Year Savings Projection." Per this memorandum, "the average water use in the multifamily sector is 128.8 gallons per unit per day."[8]

For non-residential unit demands, all non-residential meters that recorded usage during the analysis period were spatially selected; about 14,000 meters were included. Next, the traffic analysis zones (TAZs) that these meters fell within were selected to estimate the total headcount of existing employees. A summary of consumption per employee is summarized in Table 6; a rate of 59 gpd/employee will be applied for future non-residential demand projections.

Table 6 Unit Demands: Non-Residential

Year (Adjusted Use)	Consumption (gpd)	Consumption (gpd/employee)	Meter Count
2016	20,262,958	59	14,919
2017	20,847,508	60	14,977
2018	20,431,220	59	14,921

Notes: Includes water (WA) and irrigation (IR) service codes.
Does not account for non-revenue water.

4.0 Water Conservation and Climate Change

Tucson is required by ADWR to implement water conservation programs to reduce water use. Tucson Water has been very proactive on this front and currently implements several conservation strategies to comply with ADWR's requirements. These are further detailed in the aforementioned Technical Memorandum entitled, "Water Conservation Program 10-Year Savings Projection." The memorandum estimates that

[8] WaterDM, *Water Conservation Program 10-Year Savings Projection*, Final, August 2021.

Tucson Water may reduce water demand by a range of 7,055 AF to 16,931 AF[9] over the next ten years as summarized in Table 7; this estimate will be carried forward in the subsequent water demand projections.

Table 7 Conservation Program Savings Projection

Scenario	10-Year Water Savings Estimate (AF)	Average Savings per Year (AF)
High	16,931	1,693
Medium	11,661	1,166
Low	7,055	705

Tucson Water has also been developing long-range water resource plans that incorporate drought preparedness for more than two decades. An excerpt from Tucson Water's most recent plan, updated in October 2020,[10] notes that "climate change impacts in the southwest have increasingly shown that drought may be "the new normal", and not a temporary condition that we experience periodically. The goal of Tucson Water's long range water resource planning efforts is to mitigate the impacts of future supply uncertainty." An accompanying One Water 2100 Technical Memorandum prepared by HDR summarizes climate change impacts on not only the Colorado River basin, but also Tucson Water. These impacts will also be incorporated into the water demand projections presented in Section 5.

5.0 Water Demand Projections

5.1 System-wide Projections

Water demand projections for the planning horizon of this master plan update were calculated using the unit demands presented in Section 3.4 along with the growth projections (numbers of housing units and employees) summarized in the "Population Projections" Technical Memorandum. A summary of growth from the "Population Projections" Technical Memorandum is presented in Table 8.

Table 8 Cumulative Housing Unit and Employment Projections

Year	Housing Units			Employees		
	Low	Medium	High	Low	Medium	High
2018	311,434	311,434	311,434	294,481	294,481	294,481
2025	321,737	327,480	332,039	318,406	320,761	323,737
2035	331,838	346,536	359,862	343,269	354,324	365,952
2045	338,736	362,366	386,339	357,611	382,577	407,907
2100	360,432	405,393	466,122	363,036	388,380	414,095

The housing unit projections do not differentiate between single-family or multi-family, so the single-family unit demand was assumed for the projections. The equation to estimate water demand includes both

[9] Ibid.

[10] Tucson Water, *Drought Preparedness and Response Plan*, October 2020 Update. Accessed 20 Jan 2021, https://www.tucsonaz.gov/files/water/docs/Drought_Preparedness_and_Response_Plan_October_2020_update_FINAL.pdf

residential and non-residential unit demands and non-revenue water as described in Section 3.2 as shown below:

$$\text{Water Demand} = \left(\left(\text{Housing Units} \times 208\frac{\text{gpd}}{\text{housing unit}}\right) + \left(\text{Employees} \times 59\frac{\text{gpd}}{\text{employee}}\right)\right) \times 1.087$$

A summary of projected water demand is shown on Figure 11.

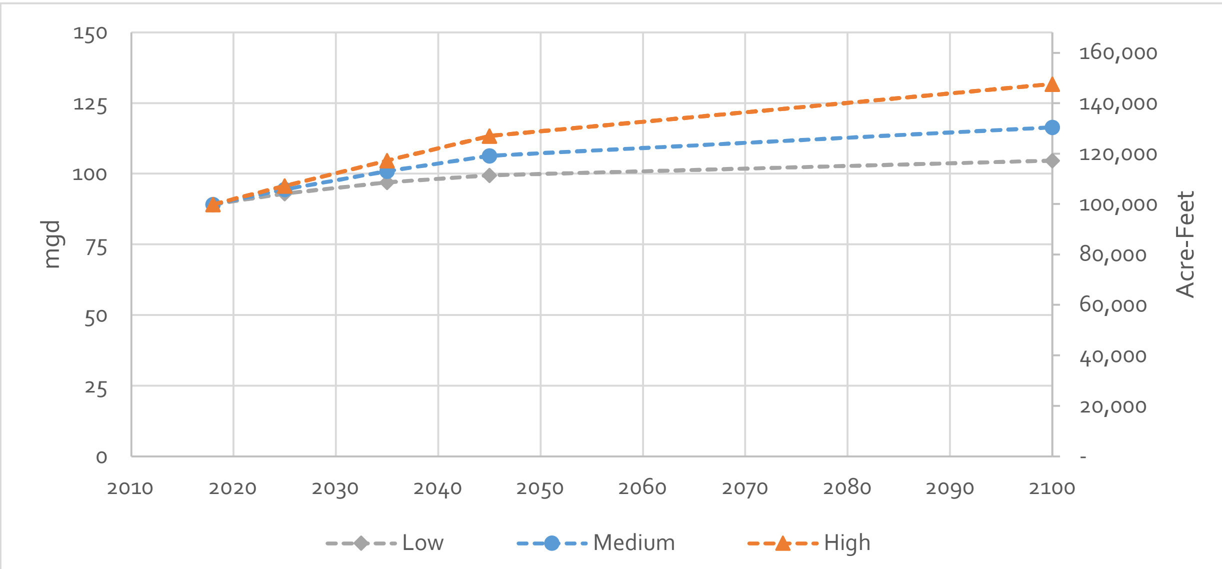


Figure 11 Projected Water Demand

Another projection was completed to account for the effects of conservation. As previously noted, the utility can expect savings ranging from 705 AF to 1,693 AF/yr (600,000 to 1,500,000 gpd) depending on the scenario. Although additional conservation measures may further reduce future customer consumption, the range of 600,000 to 1,500,000 gpd was applied over the planning horizon as an estimate beyond the 10-year timeframe was not available. The equation to estimate water demand with conservation measures includes both residential and non-residential unit demands, conservation savings, and non-revenue water as shown below:

$$\text{Water Demand including Conservation} = \left(\left(\text{Housing Units} \times 208\frac{\text{gpd}}{\text{housing unit}}\right) + \left(\text{Employees} \times 59\frac{\text{gpd}}{\text{employee}}\right) - \text{Conservation Savings gpd}\right) \times 1.087$$

Projected water demands accounting for conservation are shown on Figure 12.

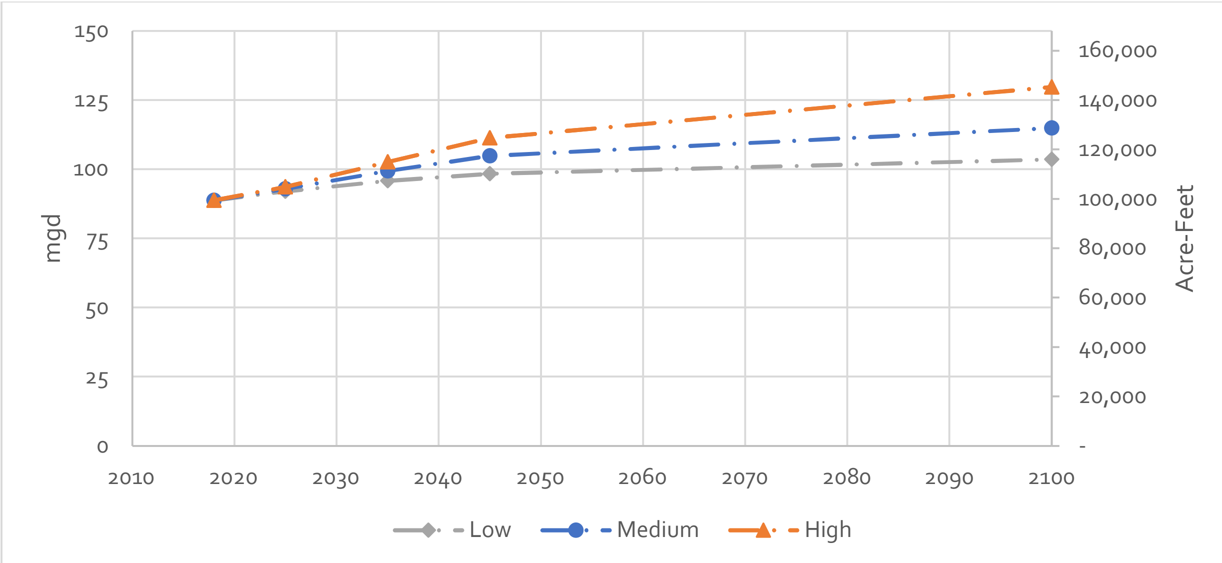


Figure 12 Projected Water Demand with Conservation Measures

Jacobs also incorporated estimated impacts due to climate change that were summarized in HDR's technical memorandum, "Climate Change: Impacts to Tucson Water and the Tucson Water Integrated Water Master Plan." Impacts were included in both the medium and high projections where a 1.5-percent water use increase was applied to the medium 2045 and 2100 projected consumption and a 3.0-percent increase was applied to the high 2045 and 2100 projected consumption. The low projection remained unchanged. The equation incorporating climate change impacts in the medium projection is shown below; the medium multiplier of 1.015 is replaced with 1.030 for the high projection:

$$\text{Water Demand including Conservation and Climate Change}_{medium} = \left(\left(\text{Housing Units} \times 208\frac{\text{gpd}}{\text{housing unit}}\right) + \left(\text{Employees} \times 59\frac{\text{gpd}}{\text{employee}}\right) - \text{Conservation Savings}_{medium}\ \text{gpd}\right) \times 1.015_{medium} \times 1.087$$

Projected water demands incorporating conservation and climate change impacts are shown on Figure 13.

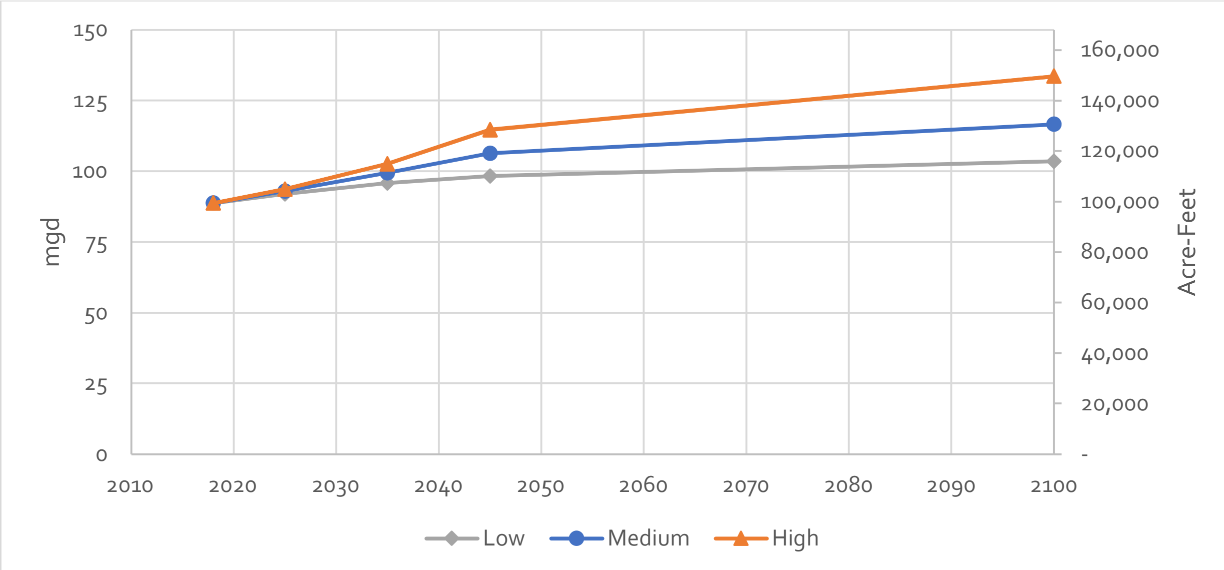


Figure 13 Projected Water Demand with Conservation Measures and Climate Change Impacts

In total, Tucson Water should plan for a range between about 116,000 AF and 150,000 AF of annual average demand by 2100. To estimate maximum day demands, a peaking factor of 1.5 as shown in Section 3.3 may be applied to the average demands noted above. Using this factor, the utility may experience peak day demands ranging from 155 to 200 mgd in 2100.

Although wheeled water does not impact water supply needs, it should be accounted for in customer demands to confirm that the distribution system is capable of conveying these needs. On average, Tucson Water has wheeled about 3 mgd (over 3,000 AF/yr) to customers; however, the distribution system should be capable of conveying the agreement amounts summarized in Table 9.

Table 9 Wheeling Agreement Summary

Entity	Agreement Volume (AF/yr)
Metro Water District	300
Oro Valley	2,600
Pascua Yaqui Tribe	500
Vail Water	1,857
Total	**5,257**

5.2 Projections by Water Service Area

In addition to developing system-wide water use projections, Jacobs estimated projected use by WSA to support facility capacity analyses. The methodology relied upon geographic information system (GIS) software to allocate projected growth from the TAZ polygons to each WSA. The steps included the following:

1. Intersecting TAZ polygons and WSA polygons to calculate the number of housing units and employees in each WSA. If a TAZ polygon was not completely within a WSA polygon, the

proportional number of housing units and employees were assigned based on TAZ area within the WSA. Any TAZs that were spatially outside of a WSA were assigned to the nearest WSA.

2. Joining each geocoded customer meter (including each customer's average annual potable water use from 2018) to its respective WSA based on spatial location. Any meter points that were spatially outside of a WSA were assigned to the nearest.
3. Exporting the tabular WSA information to a Microsoft Excel spreadsheet that included existing metered demands and the TAZ projections. Existing demands (2018) were summarized from customer meter records. Demands for 2045 and 2100 were calculated using the formulas in Section 5.1 that include conservation, climate change impacts, and non-revenue water. The spreadsheet calculations also included planned annexations and infill/redevelopment estimates that were added to fully developed WSAs. Annexations and infill/redevelopment were summarized in the Technical Memorandum entitled, "Population Projections."
4. Rejoining the tabular calculations from the Microsoft Excel spreadsheet to a new GIS geodatabase that provides projections by WSA tabularly and spatially.

The spatial summary of demand added to each WSA is presented on Figure 14 (demand added between 2018 and 2045) and Figure 15 (demand added between 2018 and 2100). A detailed tabular summary by WSA of existing metered demands and projections for 2045 and 2100 is available in Appendix B.

Regions (groups of pressure zones) within the service area that are estimated to have the largest increase in demand over the planning horizon are summarized in Table 10.

Table 10 Demand increases in Water Service Area Regions

WSA Region	Demand increase from 2018 to 2045 (mgd)	Demand increase from 2018 to 2100 (mgd)
A1	4.7	5.7
C1	4.5	8.6
B1	3.4	4.7
F1	3.3	4.5
C5	0.6	0.6
D1	0.5	1.4
K2	0.2	1.4

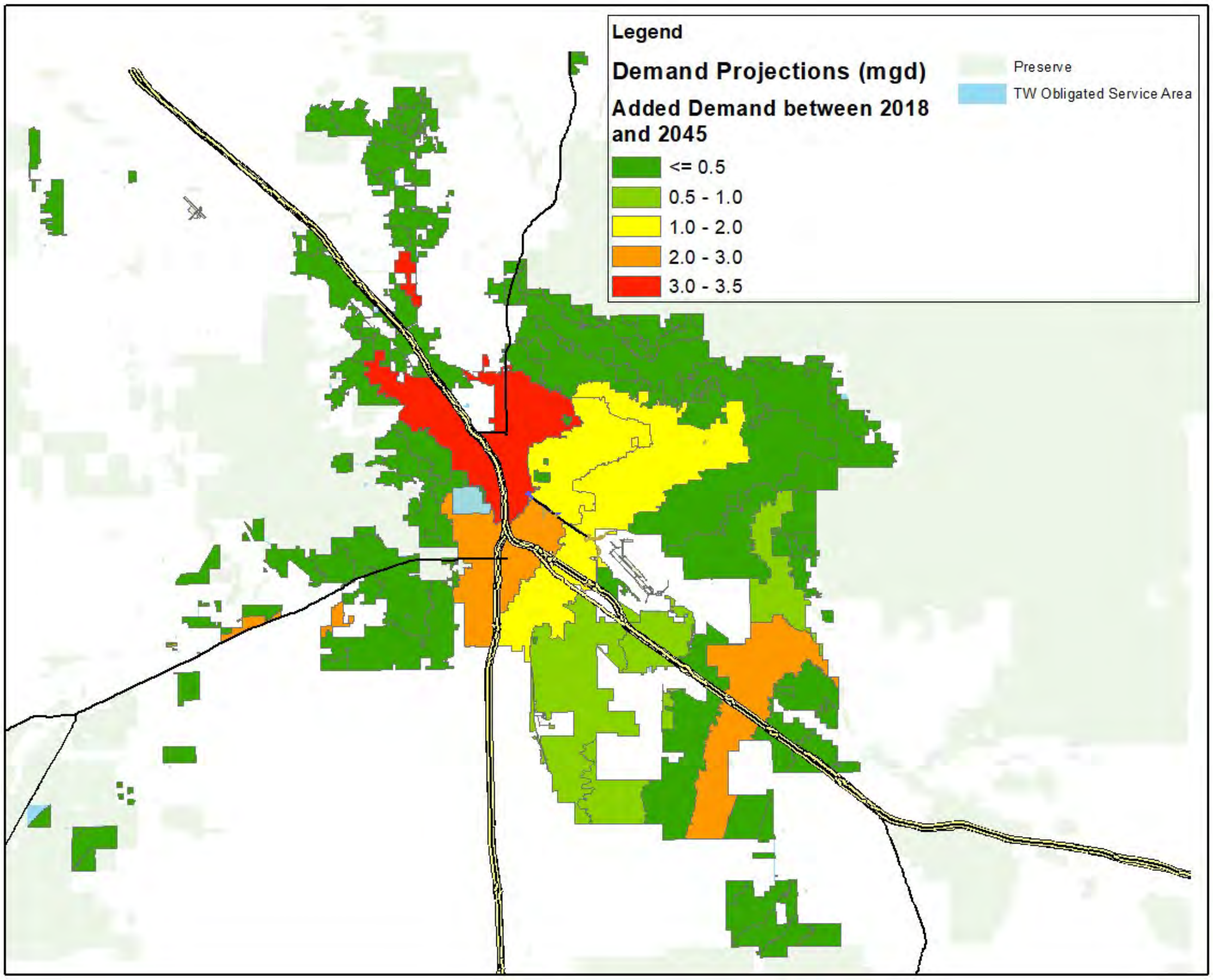


Figure 14 Demand added to Water Service Areas between 2018 and 2045

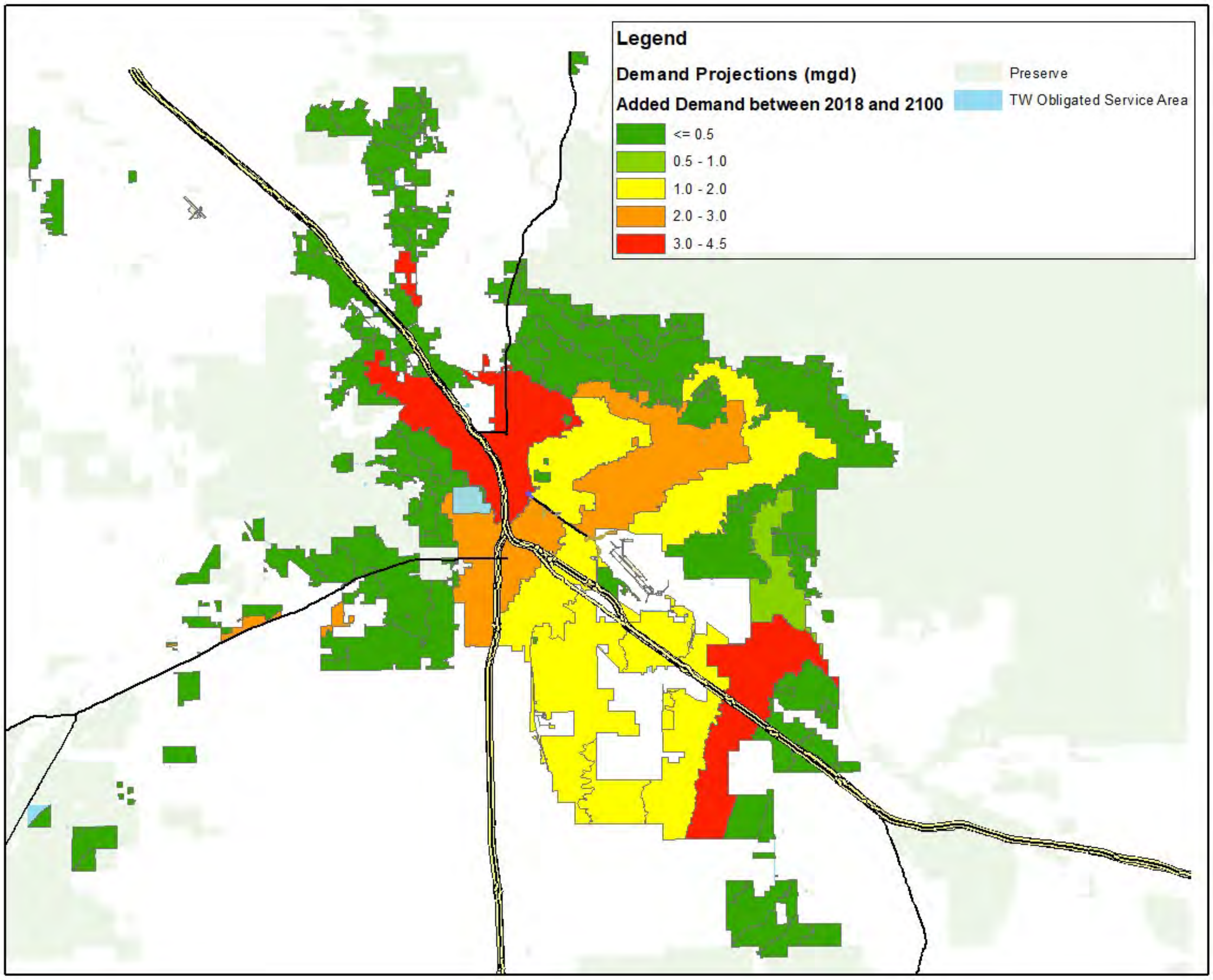


Figure 15 Demand added to Water Service Areas between 2018 and 2100

5.3 Projections by Traffic Analysis Zone

Jacobs also estimated projected use by TAZ to support subsequent planning efforts including hydraulic modeling, where Jacobs also used GIS software to support the analyses. The steps included:

1. Joining each geocoded customer meter (including each customer's average annual potable water use from 2018) to its respective TAZ based on spatial location.
2. Exporting the tabular TAZ information to a Microsoft Excel spreadsheet that included existing metered demands and TAZ projections. Existing demands (2018) were summarized from customer meter records. Demands for 2045 and 2100 were calculated using the formulas in Section 5.1 that include conservation, climate change impacts, and non-revenue water. Microsoft Excel calculations also included planned annexations and infill/redevelopment estimates that were added to fully developed TAZs. Annexations and infill/redevelopment were summarized in the Technical Memorandum entitled, "Population Projections."
3. Rejoining the tabular calculations from the Microsoft Excel spreadsheet to a new GIS geodatabase that provides projections by TAZ tabularly and spatially.

The spatial summary of demand added to each TAZ is presented on Figure 16 (demand added between 2018 and 2045) and Figure 17 (demand added between 2018 and 2100). A detailed tabular summary by TAZ of existing metered demands and projections for 2045 and 2100 is available in Appendix C. TAZs that did not add any demand for the period shown are omitted from each figure.

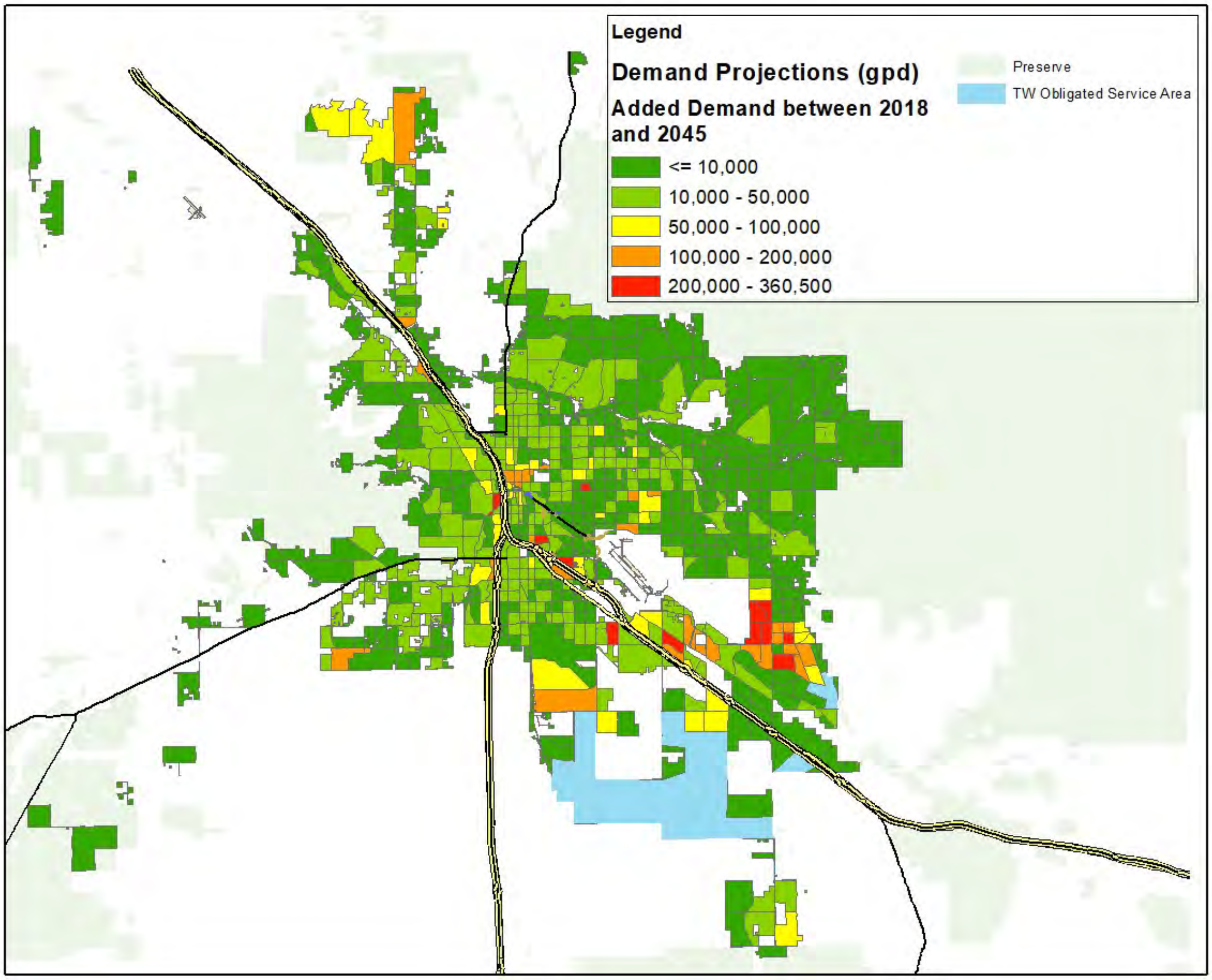


Figure 16 Demand added to Traffic Analysis Zones between 2018 and 2045

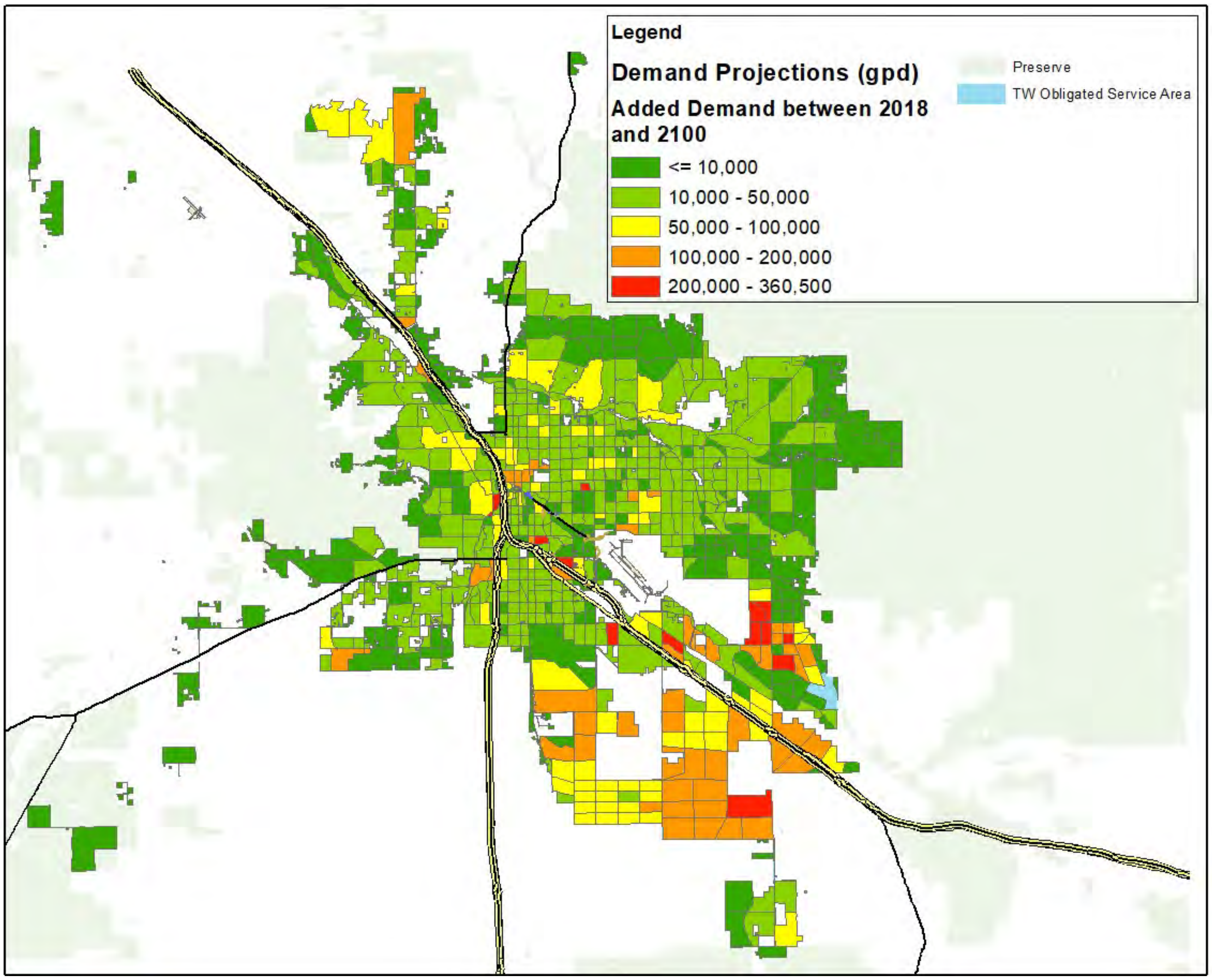


Figure 17 Demand added to Traffic Analysis Zones between 2018 and 2100

6.0 Supply / Demand Balance

The supplies considered for Tucson Water's long-term supply versus demand balance only include "wet water" supplies from the City's AWS for a conservative projection. These include supplies from the City's AWS and CAP subcontract as shown in Table 11.

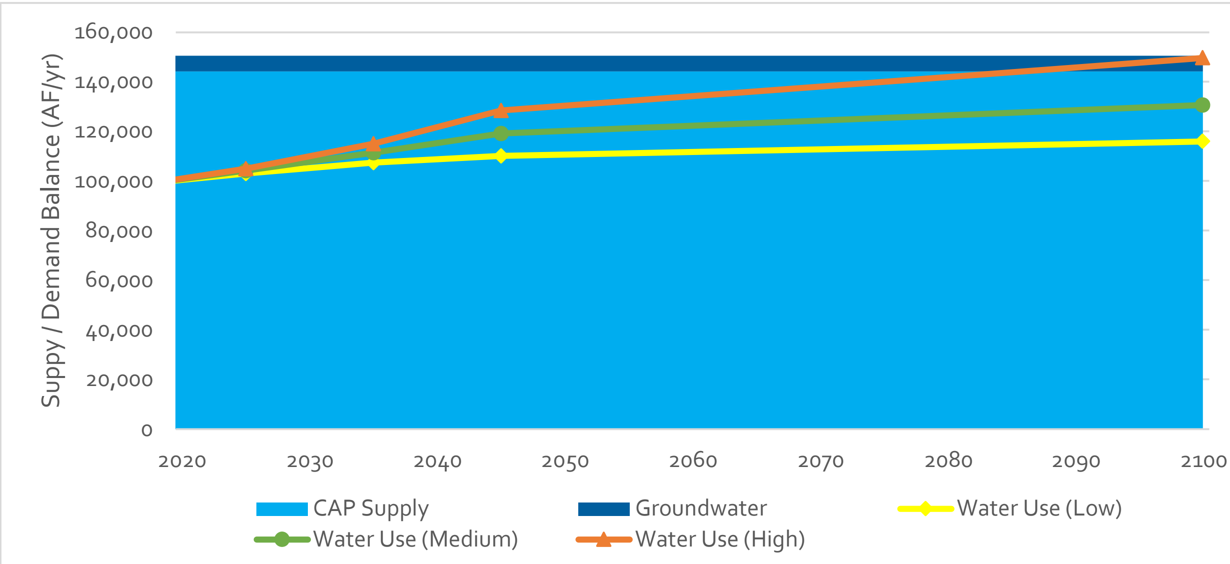
Table 11 Supply Summary for Supply / Demand Balance

Supply Source	Type	Annual Volume (AF/yr)
Groundwater	Incidental Recharge	6,213.82
Groundwater	Allowance	156.72 [a]
CAP Supply	CAWCD Subcontract	144,191
Total		**150,561.54[b]**

a - The groundwater allowance of 12,537.60 AF is not an annual allocation; the volume is spread equally over the 80-year planning horizon.

b - Only includes "wet water" supplies.

The overlay of Tucson Water's current supplies and projected service area water needs (including estimated effects of conservation and climate change and non-revenue water) are shown on Figure 18. The utility has more than adequate supplies for many years, which are further bolstered by its "paper water" supplies not shown on the figure, such as membership in the CAGRD and LTSCs, and other sources including reclaimed water, stormwater, and harvested rain.

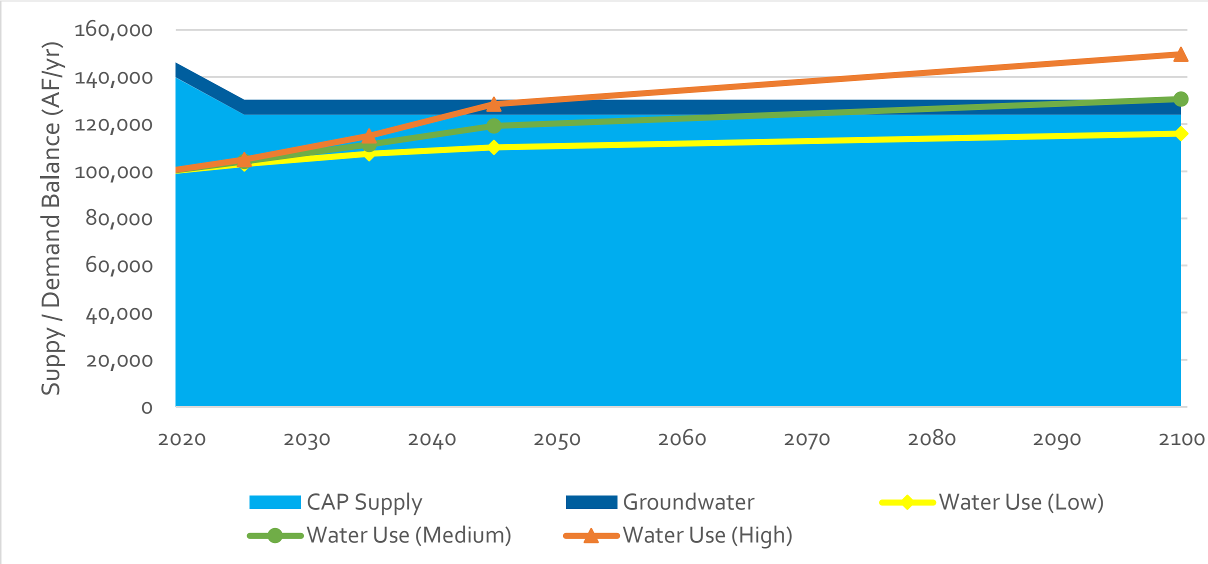


Note: Water use projections do not include wheeled water.

Figure 18 Supply / Demand Balance

To address the long-term drought conditions in the southwestern United States, Tucson Water has documented the impact of the 2019 Lower Colorado River Basin Drought Contingency Plan (DCP) in its recently published *Drought Preparedness and Response Plan*. The DCP outlines CAP delivery reductions in four tiers (zero through three) based on projected Lake Mead elevations; however, Tucson Water will not be impacted until Tier 3.

The resulting impact of Tier 3 reductions, which is the most severe, in Tucson Water's CAP supply and projected demands is shown on Figure 19.



Note: Bureau of Reclamation currently estimates a 20% probability of a Tier 3 shortage in 2025.

Figure 19 Supply / Demand Balance (Drought Contingency Plan Tier 3)

Despite the potential reduction, Tucson Water is well positioned with adequate supplies, both renewable and non-renewable, for decades. One of these supplies includes 1.2-million AF of groundwater rights in Avra Valley that Tucson Water may access as a backup (Section 2.1). As described in Section 2.3, Tucson Water has been accumulating LTSCs for many years. The utility will continue to store CAP water as long as the allocation or supply is greater than demand. These credits provide a mechanism for Tucson Water to deliver water to customers in times of water shortages. Figure 20 depicts the supply / demand balance under the medium water demand scenario with a Tier 3 CAP reduction in 2025. Figure 20 only includes groundwater resulting from natural recharge as summarized in the City's Designation of AWS and does not include the backup groundwater rights in Avra Valley. Under these conditions, the utility stops accumulating LTSCs in 2045, but there are ample credits available to support the demand beyond the master planning time frame.

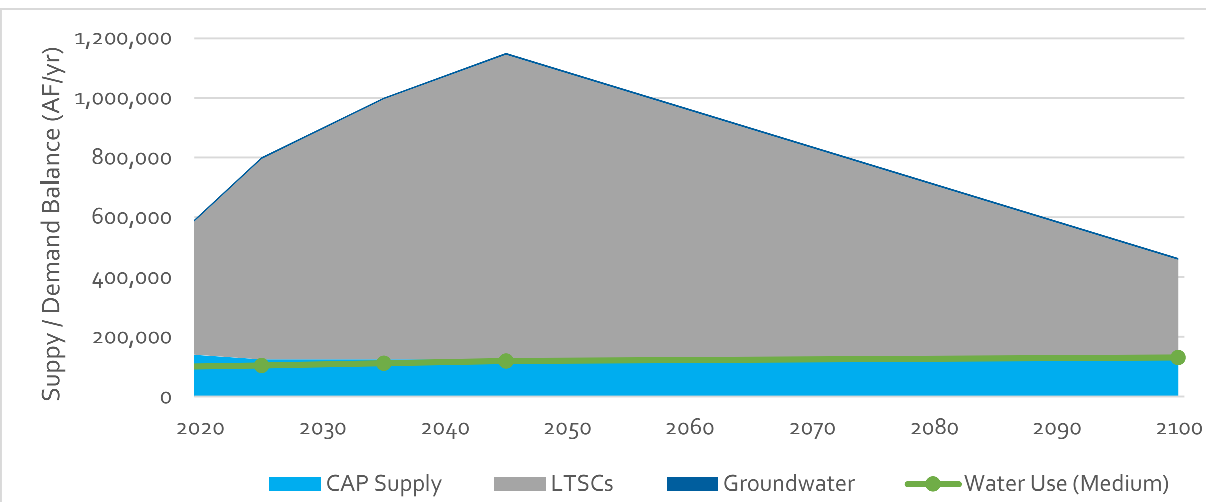


Figure 20 Supply / Demand Balance with LTSCs (Drought Contingency Plan Tier 3)

Graphics summarizing the high and low water demand scenarios are available in Appendix D.

7.0 Conclusion

Although water demands are projected to increase based on growth in the residential and non-residential customer sectors, Tucson Water has a robust and reliable water resources portfolio that will meet its customer needs for decades to come. Next steps include summarizing the spatial distributions of customer demands, including wheeled water, in tabular form to evaluate facility capacities (storage tanks, booster stations) by WSA and also applying the spatial distributions of customer demands by TAZ, including wheeled water, to apply to Tucson Water's hydraulic models. The tabular and hydraulic analyses will evaluate whether the existing infrastructure is capable of meeting these future demands and result in identification of future infrastructure required to resolve deficiencies or serve newly developed areas.

Appendix A

RECLAIMED WATER BILLING ANALYSIS

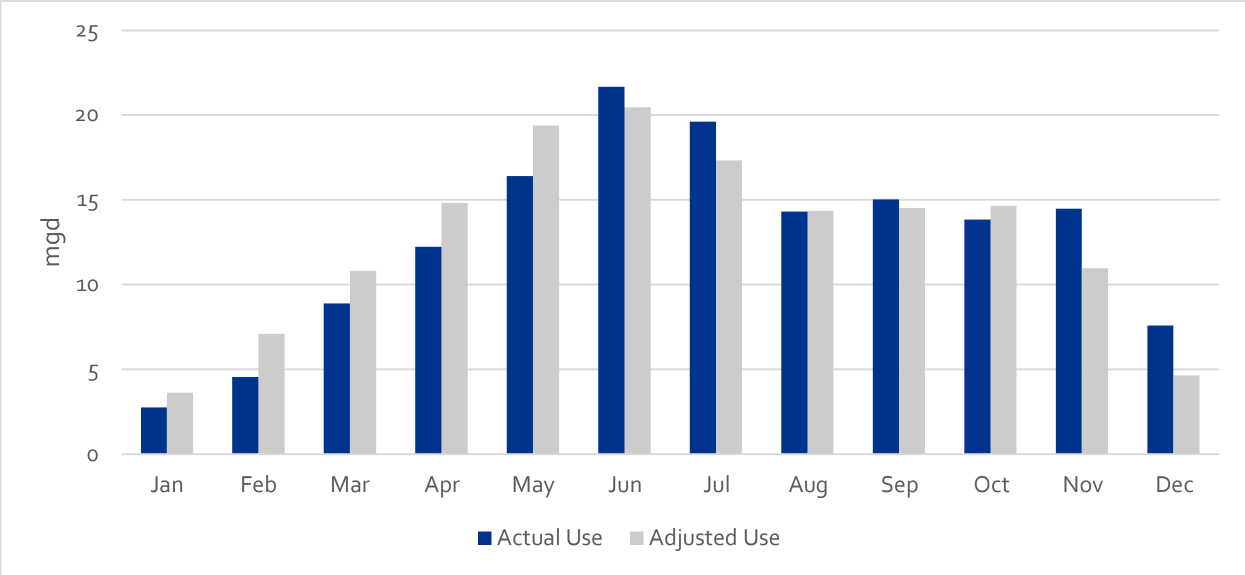


Figure A-1 2016 Reclaimed Water Consumption

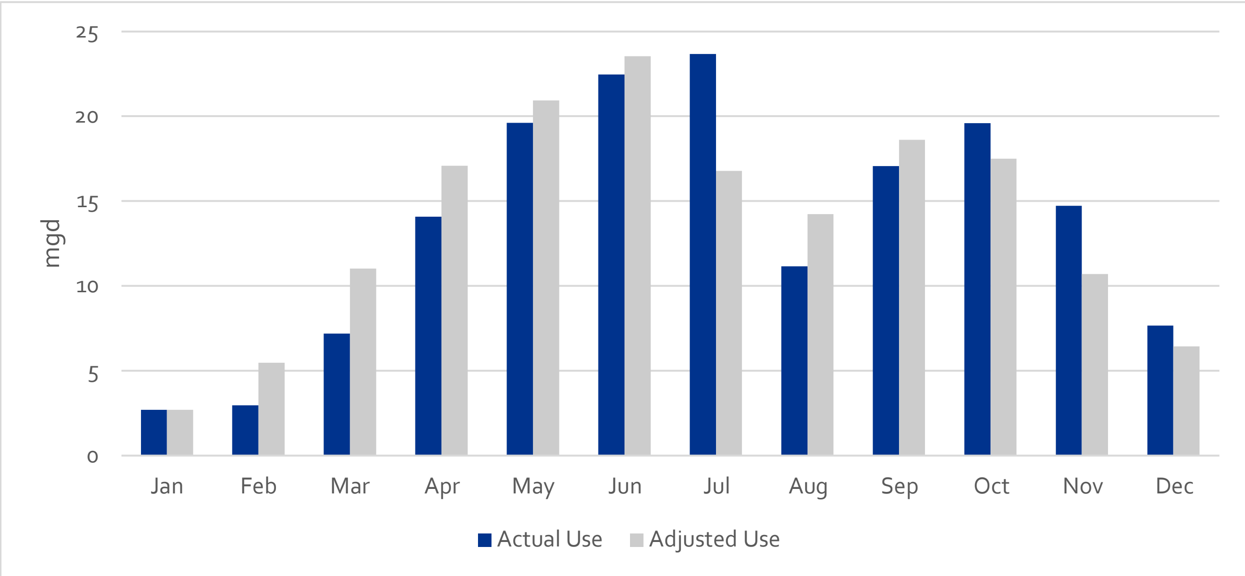


Figure A-2 2017 Reclaimed Water Consumption

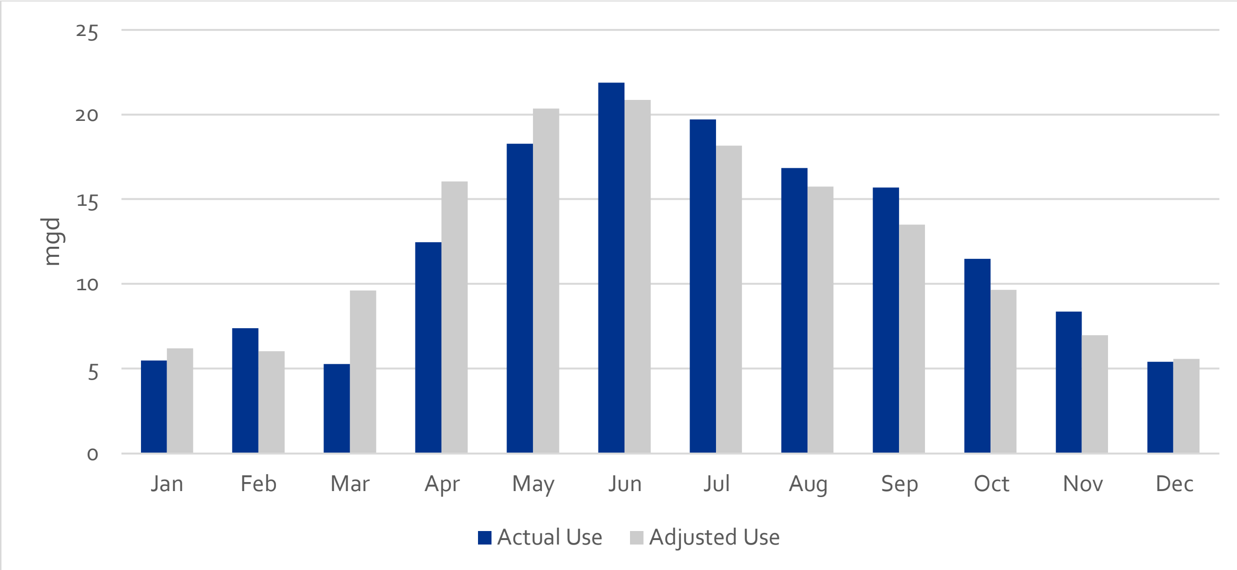


Figure A-3 2018 Reclaimed Water Consumption

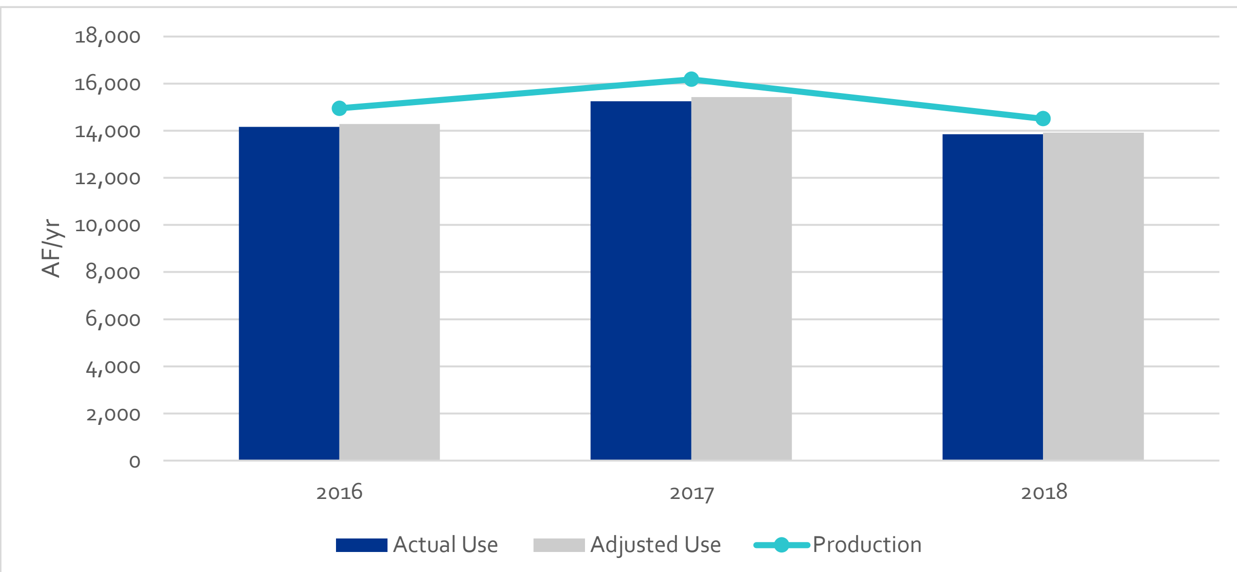


Figure A-4 Annual Reclaimed Water Production and Consumption Comparison

Appendix B

DEMAND PROJECTIONS BY WATER SERVICE AREA

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
14		0	24,553		0	3,985	2,483	31,020		25,385		5,755	30,808	31,270	2,721	33,991			25,385		5,755	30,835	31,298	2,723	34,021	9.6%	Not in obligated WSA
A1		12,271	7,628,015		343	3,575,581	974,713	12,178,309		9,824,287		4,562,297	14,233,387	14,446,888	1,256,879	15,703,767		897,574	10,721,861		4,562,297	15,134,832	15,361,854	1,336,481	16,698,336	28.9%	Infill/ Redevelopment
A3		0	37,371		0	1,118	3,348	41,837		38,827		1,354	39,752	40,349	3,510	43,859			38,827		1,354	39,788	40,384	3,513	43,898	4.8%	
A4		0	6,370		0	0	554	6,924		6,578			6,508	6,606	575	7,181			6,578			6,514	6,612	575	7,187	3.7%	
A5		0	39,687		10	174	3,468	43,329		39,687		174	39,437	40,028	3,482	43,511			39,687		174	39,472	40,064	3,486	43,550	0.4%	
AC		0	39,011		0	168	3,409	42,587		44,003		522	44,051	44,711	3,890	48,601			44,003		522	44,090	44,751	3,893	48,645	14.1%	
AL		0	2,576		0	0	224	2,801		3,616			3,578	3,632	316	3,948			3,616			3,581	3,635	316	3,951	41.0%	
B1		67	4,567,211		2,720	2,083,913	578,648	7,229,772		5,706,219		2,904,249	8,518,778	8,646,560	752,251	9,398,811		537,415	6,243,218		2,904,249	9,058,096	9,193,968	799,875	9,993,843	30.0%	Infill/ Redevelopment
B1		67	5,335,257		2,720	1,953,649	634,135	7,923,040		6,024,153		2,359,569	8,294,446	8,418,863	732,441	9,151,304		627,789	6,651,942		2,359,569	8,923,468	9,057,320	787,987	9,845,307	15.5%	Infill/ Redevelopment
B3		0	25,213		0	8,551	2,937	36,701		28,541		9,731	37,864	38,432	3,344	41,776			28,541		9,731	37,898	38,467	3,347	41,813	13.8%	
B4		0	317,491		0	56,721	32,556	406,768		343,907		65,807	405,351	411,431	35,795	447,226			343,907		65,807	405,711	411,797	35,826	447,623	9.9%	
B6		0	48,042		0	1,828	4,339	54,208		54,074		2,359	55,832	56,669	4,930	61,599			54,074		2,359	55,881	56,719	4,935	61,654	13.6%	
BC		0	432,461		9,534	13,000	38,755	484,216		465,117		18,133	478,104	485,276	42,219	527,495			465,117		18,133	478,529	485,707	42,256	527,963	8.9%	
BG		0	11,665		0	0	1,015	12,680		12,497		59	12,423	12,609	1,097	13,706			12,497		59	12,434	12,620	1,098	13,718	8.1%	
BM		0	2,581		0	476	266	3,323		2,581		476	3,025	3,070	267	3,337			2,581		476	3,027	3,073	267	3,340	0.4%	
BZ		440	309,724		0	8,816	27,713	346,253		312,012		8,934	317,528	322,291	28,039	350,330			312,012		8,934	317,810	322,577	28,064	350,642	1.2%	
C1		0	3,233,626		8	1,316,345	395,847	4,945,818		3,613,850		1,952,896	5,507,467	5,590,079	486,337	6,076,416		380,494	3,994,344		1,952,896	5,889,136	5,977,473	520,040	6,497,513	22.9%	Infill/ Redevelopment
C1		0	7,454,654		8	3,212,227	928,019	11,594,900		8,123,166		3,847,303	11,843,000	12,020,645	1,045,796	13,066,441		877,175	9,000,341		3,847,303	12,722,123	12,912,954	1,123,427	14,036,381	12.7%	Infill/ Redevelopment

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
C2		0	0		0	697	61	757				756	747	759	66	825					756	748	759	66	825	8.9%	
C3		0	32,277		0	120	2,819	35,216		35,397		356	35,372	35,903	3,124	39,027			35,397		356	35,404	35,935	3,126	39,061	10.8%	
C4		0	119,337		0	3,572	10,693	133,602		120,585		3,749	123,010	124,855	10,862	135,717			120,585		3,749	123,119	124,966	10,872	135,838	1.6%	
C5		0	2,030,453		81	536,371	223,314	2,790,137		2,270,485		552,596	2,793,019	2,834,914	246,638	3,081,552			2,270,901		552,596	2,795,911	2,837,850	246,893	3,084,743	10.4%	
C6		0	454,856		0	83,562	46,842	585,261		551,368		94,005	638,501	648,078	56,383	704,461			551,368		94,005	639,068	648,654	56,433	705,087	20.4%	
CD		0	226,664		0	1,262	19,830	247,756		231,448		1,852	230,816	234,278	20,382	254,660			231,448		1,852	231,021	234,486	20,400	254,887	2.8%	
CK		0	280,249		0	118,066	34,653	432,968		286,697		125,972	408,275	414,399	36,053	450,451			286,697		125,972	408,637	414,767	36,085	450,851	4.0%	
CL		0	62,804		0	13,358	6,626	82,788		110,852		13,358	122,887	124,730	10,852	135,582			110,852		13,358	122,996	124,841	10,861	135,702	63.8%	
CM		0	146,256		0	1,068	12,817	160,141		148,544		1,186	148,135	150,357	13,081	163,438			148,544		1,186	148,267	150,491	13,093	163,583	2.1%	
CN		0	74,537		0	40,815	10,036	125,388		96,585		44,296	139,381	141,472	12,308	153,780			96,585		44,296	139,505	141,597	12,319	153,916	22.6%	
CU		0	140,855		0	0	12,254	153,109		152,087		1,239	151,693	153,969	13,395	167,364			152,087		1,239	151,828	154,105	13,407	167,512	9.3%	
CW		0	16,467		0	0	1,433	17,899		18,131		472	18,405	18,681	1,625	20,306			18,131		472	18,421	18,697	1,627	20,324	13.4%	
CZ		1,245	369,151		0	16,955	33,591	419,697		420,319		20,023	435,653	442,188	38,470	480,658			420,319		20,023	436,040	442,580	38,504	481,085	14.5%	
D#		0	374		0	0	33	406		58,406		59	57,842	58,710	5,108	63,817			58,406		59	57,893	58,762	5,112	63,874	15611.9%	
D1		0	6,809,670		0	1,138,399	691,482	8,639,551		7,006,230		1,342,539	8,259,866	8,383,764	729,388	9,113,152		801,281	7,807,511		1,342,539	9,060,654	9,196,564	800,101	9,996,665	5.5%	Infill/ Redevelo-pment
D2		1,276	1,858		0	53,269	4,796	59,923		1,858		78,108	79,115	80,302	6,986	87,288			1,858		78,108	79,185	80,373	6,992	87,365	45.7%	
D4		0	1,276,123		0	61,543	116,377	1,454,043		1,343,307		65,319	1,393,626	1,414,531	123,064	1,537,595			1,343,307		65,319	1,394,864	1,415,787	123,173	1,538,961	5.7%	
D5		30	796,146		0	138,403	81,306	1,015,855		981,474		160,882	1,130,192	1,147,145	99,802	1,246,946			981,474		160,882	1,131,196	1,148,163	99,890	1,248,054	22.7%	
D6		0	89,487		0	11,231	8,762	109,481		98,015		11,821	108,666	110,296	9,596	119,892			98,015		11,821	108,763	110,394	9,604	119,999	9.5%	
D7		0	91,569		0	0	7,966	99,535		91,569			90,594	91,953	8,000	99,952			91,569			90,674	92,034	8,007	100,041	0.4%	
DH		2,310	744,009		2,273	1,075,861	158,329	1,978,198		1,046,649		1,506,974	2,526,430	2,564,326	223,096	2,787,423			1,727,641		1,555,413	3,250,978	3,299,743	287,078	3,586,820	40.9%	
DL		0	101,171		0	7,071	9,417	117,660		110,323		8,310	117,371	119,131	10,364	129,496			110,323		8,310	117,475	119,237	10,374	129,611	10.1%	
DN		0	12,372		0	0	1,076	13,448		12,996			12,857	13,050	1,135	14,186			12,996			12,869	13,062	1,136	14,198	5.5%	
DP		0	294,124		142	128,807	36,795	459,725		310,972		139,250	445,427	452,109	39,333	491,442			310,556		139,250	445,411	452,092	39,332	491,424	6.9%	
DQ		0	143,347		0	187	12,487	156,022		145,635		246	144,328	146,493	12,745	159,237			145,635		246	144,456	146,623	12,756	159,379	2.1%	
DU		88	242,545		0	42,948	24,838	310,331		270,833		50,264	317,678	322,443	28,053	350,496			270,833		50,264	317,960	322,730	28,077	350,807	12.9%	
DV		0	6,714		0	0	584	7,299		11,082		885	11,840	12,018	1,046	13,063			11,082		885	11,850	12,028	1,046	13,075	79.0%	

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
DZ		0	356		0	0	31	387		564		59	616	626	54	680			564		59	617	626	54	681	75.7%	
E1		1,037	4,096,027		0	459,713	396,349	4,952,090		4,196,699		508,919	4,655,510	4,725,343	411,105	5,136,447	18,512		4,215,211	1,770	508,919	4,677,976	4,748,145	413,089	5,161,234	3.7%	
E2	832	487	617,745	17,405	243,934	443,480	92,327	1,153,551	624	964,689	28,438	742,846	1,689,352	1,714,692	149,178	1,863,870	624		1,616,145	28,438	760,782	2,353,704	2,389,010	207,844	2,596,853	61.6%	
E4		0	64,956		0	7,243	6,281	78,480		66,412		7,243	72,871	73,964	6,435	80,399			66,412		7,243	72,935	74,030	6,441	80,470	2.4%	
E5		0	3,834		0	0	334	4,168		4,042			3,999	4,059	353	4,413			4,042			4,003	4,063	353	4,416	5.9%	
E6		5,150	446,931		0	46,147	42,898	535,976		520,563		52,224	566,687	575,188	50,041	625,229			520,563		52,224	567,191	575,699	50,086	625,784	16.7%	
E6		5,150	138,332		0	41,168	15,617	195,117		194,492		42,171	234,143	237,655	20,676	258,331			194,492		42,171	234,351	237,866	20,694	258,561	32.4%	
EC		0	10,834		0	0	943	11,776		11,874		177	11,922	12,101	1,053	13,154			11,874		177	11,933	12,112	1,054	13,166	11.7%	
EE		0	126,790		0	19,455	12,723	158,969		133,030		20,576	151,971	154,250	13,420	167,670			133,030		20,576	152,106	154,387	13,432	167,819	5.5%	
EK		0	7,293		0	0	634	7,927		7,293			7,215	7,323	637	7,960			7,293			7,221	7,330	638	7,967	0.4%	
EL		0	706		0	142,543	12,463	155,711		29,618		147,971	175,697	178,333	15,515	193,848			29,618		147,971	175,853	178,491	15,529	194,020	24.5%	
EN		0	22,394		0	1,147	2,048	25,590		24,266		1,737	25,727	26,112	2,272	28,384			24,266		1,737	25,749	26,136	2,274	28,409	10.9%	
EO		0	47,145		0	0	4,102	51,247		48,809		59	48,348	49,073	4,269	53,342			48,809		59	48,390	49,116	4,273	53,389	4.1%	
EQ		0	136,805		0	25,014	14,078	175,898		138,261		25,073	161,595	164,019	14,270	178,289			138,261		25,073	161,739	164,165	14,282	178,447	1.4%	
ES		0	98,438		0	0	8,564	107,002		106,758		354	105,971	107,561	9,358	116,918			106,758		354	106,065	107,656	9,366	117,022	9.3%	
ET		0	64,207		0	0	5,586	69,793		67,535		59	66,874	67,877	5,905	73,782			67,535		59	66,933	67,937	5,911	73,848	5.7%	
EU		0	865		0	0	75	941		1,073			1,062	1,078	94	1,172			1,073			1,063	1,079	94	1,173	24.6%	
EV		0	0		0	0	0	0																		N/A	
EW		0	6,972		0	194	623	7,789		8,636		489	9,028	9,163	797	9,960			8,636		489	9,036	9,171	798	9,969	27.9%	
EX		0	11,428		0	1,347	1,111	13,886		13,300		1,996	15,133	15,360	1,336	16,696			13,300		1,996	15,146	15,374	1,338	16,711	20.2%	
F1		0	1,277,586		0	99,211	119,781	1,496,578		1,849,794		143,520	1,972,088	2,001,669	174,145	2,175,814			1,849,794		143,520	1,973,839	2,003,446	174,300	2,177,746	45.4%	
F2		0	0	17,405	0	62,884	5,471	68,354		96,304	28,438	311,038	403,004	409,049	35,587	444,636			1,090,128	28,438	353,164	1,429,191	1,450,628	126,205	1,576,833	550.5%	
F3		0	27,756		0	0	2,415	30,171		28,172			27,872	28,290	2,461	30,751			28,172			27,897	28,315	2,463	30,778	1.9%	
F3		0	10,879		0	15,991	2,338	29,208		11,087		15,991	26,790	27,192	2,366	29,558			11,087		15,991	26,814	27,216	2,368	29,584	1.2%	
F4		0	2,506,999		0	387,783	251,846	3,146,628		2,558,167		391,028	2,917,790	2,961,557	257,655	3,219,212			2,558,167		391,028	2,920,381	2,964,187	257,884	3,222,071	2.3%	
F6		0	0		0	0	0	0		10,608			10,495	10,652	927	11,579			10,608			10,504	10,662	928	11,590	No existing develop-ment; growth planned	

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
FC		0	26,924		0	0	2,342	29,267		26,924			26,638	27,037	2,352	29,390	18,304		45,228	1,711		44,787	45,458	3,955	49,413	0.4%	
FM		0	3		717	79,574	6,923	86,501		2,291		79,692	81,111	82,327	7,162	89,490			2,291		79,692	81,183	82,400	7,169	89,569	3.5%	
FR		0	32,791		0	1,680	2,999	37,470		37,783		2,152	39,509	40,102	3,489	43,591			37,783		2,152	39,545	40,138	3,492	43,630	16.3%	
G#		0	0		0	0	0	0																		N/A	Not in obligated WSA
G1		0	134,021		0	10,779	12,598	157,398		137,349		12,431	148,185	150,408	13,085	163,494			137,349		12,431	148,317	150,542	13,097	163,639	3.9%	
G2		0	1,204,035		0	509,000	149,034	1,862,070		3,157,779		726,946	3,843,359	3,901,009	339,388	4,240,397			4,139,955		794,855	4,886,597	4,959,896	431,511	5,391,407	127.7%	
G4		0	360,105		0	30,099	33,948	424,152		364,681		30,217	390,693	396,554	34,500	431,054			364,681		30,217	391,040	396,906	34,531	431,437	1.6%	
G5		476,800	476,800		1,215,592	1,215,592	147,238	1,839,630		476,800		1,215,592	1,674,371	1,699,486	147,855	1,847,341			476,800		1,215,592	1,675,858	1,700,995	147,987	1,848,982	0.4%	
G6		0	145,531		0	29,379	15,217	190,127		175,275		30,264	203,350	206,400	17,957	224,357			175,275		30,264	203,531	206,584	17,973	224,557	18.0%	
G7		0	6,594		0	0	574	7,168		7,218		118	7,258	7,367	641	8,008			7,218		118	7,264	7,373	641	8,015	11.7%	
G8		0	48,174		0	0	4,191	52,365		48,174			47,661	48,376	4,209	52,585	18,304		66,478	1,711		65,829	66,816	5,813	72,629	0.4%	
GA		193	41,925		0	951	3,730	46,607		42,965		1,777	44,266	44,930	3,909	48,839			42,965		1,777	44,305	44,970	3,912	48,882	4.8%	
GB		0	3,745		0	114	336	4,195		3,953		114	4,024	4,085	355	4,440			3,953		114	4,028	4,088	356	4,444	5.8%	
GC		0	47,832		0	238	4,182	52,252		49,704		238	49,410	50,151	4,363	54,515	18,304		68,008	1,711	238	67,579	68,593	5,968	74,561	4.3%	
GE		0	24,183		0	0	2,104	26,287		24,183			23,926	24,285	2,113	26,398	18,304		42,487	1,711		42,072	42,703	3,715	46,419	0.4%	
GF		0	16,131		0	0	1,403	17,535		16,131			15,960	16,199	1,409	17,608			16,131			15,974	16,213	1,411	17,624	0.4%	
GL		0	4,912		0	92	435	5,440		6,784		92	6,803	6,905	601	7,506			6,784		92	6,809	6,911	601	7,512	38.0%	
GQ		0	22,502		0	2,134	2,143	26,779		25,206		2,606	27,516	27,928	2,430	30,358			25,206		2,606	27,540	27,953	2,432	30,385	13.4%	
GR		0	14,384		0	0	1,251	15,635		16,672		236	16,728	16,979	1,477	18,456			16,672		236	16,743	16,994	1,478	18,472	18.0%	
GS		0	9,317		0	127	822	10,266		10,565		186	10,637	10,797	939	11,736			10,565		186	10,646	10,806	940	11,746	14.3%	
GT		0	0		0	2,691	234	2,926		208		2,691	2,869	2,912	253	3,165			208		2,691	2,871	2,914	254	3,168	8.2%	
GV		0	2,609		0	0	227	2,836		2,609			2,581	2,620	228	2,848			2,609			2,583	2,622	228	2,850	0.4%	
GW		350	34,063		624	706	3,025	37,793		34,063		706	34,398	34,914	3,038	37,952			34,063		706	34,429	34,945	3,040	37,985	0.4%	
H#		0	0		0	0	0	0				1,534	1,518	1,540	134	1,674			341,952		24,662	363,032	368,478	32,058	400,535	No existing develop- ment; growth planned	
H#		0	0		0	12,405	1,079	13,485				12,405	12,273	12,457	1,084	13,541			284,752		32,642	314,293	319,008	27,754	346,762	0.4%	

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
H2		0	73,503		0	10,666	7,323	91,492		266,111		21,758	284,804	289,076	25,150	314,226			266,527		21,817	285,527	289,810	25,213	315,024	243.4%	
H3		0	6,315		0	147	562	7,024		6,315		147	6,393	6,488	564	7,053			6,315		147	6,398	6,494	565	7,059	0.4%	
H4		0	28,360		0	0	2,467	30,828		28,568			28,264	28,688	2,496	31,184			28,568			28,289	28,714	2,498	31,212	1.2%	
H5		0	4,339		0	0	377	4,716		4,339			4,292	4,357	379	4,736			4,339			4,296	4,361	379	4,740	0.4%	
HA		0	12,631		43	1,535	1,232	15,398		13,463		1,771	15,072	15,298	1,331	16,629			13,463		1,771	15,085	15,311	1,332	16,644	8.0%	
HF		0	0		0	76,400	6,647	83,047		416		79,999	79,558	80,752	7,025	87,777			416		79,999	79,629	80,824	7,032	87,855	5.7%	
HP		0	247,639		0	2,003	21,719	271,361		261,783		2,180	261,152	265,069	23,061	288,130			261,783		2,180	261,384	265,305	23,081	288,386	6.2%	
HQ		0	81,539		0	1,239	7,202	89,979		82,995		1,298	83,395	84,645	7,364	92,010			82,995		1,298	83,469	84,721	7,371	92,091	2.3%	
HR		0	30,521		0	3,598	2,968	37,087		34,057		3,893	37,546	38,109	3,315	41,425			34,057		3,893	37,579	38,143	3,318	41,461	11.7%	
HV		0	3,921		0	26	343	4,290		3,921		26	3,905	3,964	345	4,308			3,921		26	3,909	3,967	345	4,312	0.4%	
I2		0	0		0	0	0	0		4,160		118	4,232	4,296	374	4,670			274,144		19,529	290,804	295,166	25,679	320,845	No existing develop-ment; growth planned	
I2		0	14,606		0	0	1,271	15,876		14,606			14,450	14,667	1,276	15,943			14,606			14,463	14,680	1,277	15,957	0.4%	
I2		0	0		0	0	0	0		28,912		295	28,896	29,329	2,552	31,881			28,912		295	28,922	29,355	2,554	31,909	No existing develop-ment; growth planned	
I2		0	1,986		0	0	173	2,159		1,986			1,965	1,994	174	2,168			87,058		6,018	92,167	93,549	8,139	101,688	0.4%	
I4		0	178,483		0	20,571	17,318	216,372		180,563		20,689	199,109	202,096	17,582	219,678			180,563		20,689	199,286	202,275	17,598	219,873	1.5%	
I5		0	36,116		0	2,030	3,319	41,465		36,116		2,030	37,740	38,306	3,333	41,639			36,116		2,030	37,774	38,340	3,336	41,676	0.4%	
I6		363	59,288		0	11,406	6,150	76,844		59,288		11,524	70,058	71,109	6,186	77,295			59,288		11,524	70,120	71,172	6,192	77,364	0.6%	
IA		0	270,808		0	132,325	35,073	438,206		275,176		132,620	403,454	409,506	35,627	445,133			275,176		132,620	403,812	409,869	35,659	445,528	1.6%	
IB		0	1,693		0	0	147	1,840		2,317			2,292	2,326	202	2,529			2,317			2,294	2,328	203	2,531	37.4%	
IF		0	25,909		0	229	2,274	28,412		25,909		229	25,860	26,248	2,284	28,531			25,909		229	25,883	26,271	2,286	28,557	0.4%	

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
IL		0	0		0	0	0	0		832			823	835	73	908			832			824	836	73	909	No existing develop-ment; growth planned	
IM		0	21,934		0	0	1,908	23,842		31,710		177	31,547	32,020	2,786	34,806			31,710		177	31,575	32,049	2,788	34,837	46.0%	
IP		0	52,448		0	3,034	4,827	60,309		57,232		3,093	59,682	60,578	5,270	65,848			57,232		3,093	59,735	60,631	5,275	65,906	9.2%	
IP		0	5,405		0	0	470	5,875		5,613			5,553	5,636	490	6,127			5,613			5,558	5,641	491	6,132	4.3%	
IR		0	6,261		0	0	545	6,806		6,261			6,194	6,287	547	6,834	18,304		24,565	1,711		24,325	24,690	2,148	26,838	0.4%	
J3		0	17,222		0	0	1,498	18,720		17,638			17,450	17,712	1,541	19,253			17,638			17,466	17,728	1,542	19,270	2.8%	
J4		0	39,321		0	93	3,429	42,843		39,737		93	39,405	39,997	3,480	43,476			39,737		93	39,440	40,032	3,483	43,515	1.5%	
J7		0	3,747		0	0	326	4,073		3,747			3,707	3,762	327	4,090			3,747			3,710	3,766	328	4,093	0.4%	
JL		0	2,365		0	288	231	2,884		12,141		288	12,297	12,481	1,086	13,567			12,141		288	12,308	12,492	1,087	13,579	370.4%	
JM		0	2,150		0	0	187	2,337		4,230			4,185	4,247	370	4,617			4,230			4,188	4,251	370	4,621	97.6%	
K2		163	379,367		0	32,054	35,794	447,215		416,807		32,526	444,549	451,217	39,256	490,473			439,063		34,178	468,618	475,647	41,381	517,028	9.7%	
K5		0	5,102		0	0	444	5,546		5,102			5,048	5,124	446	5,569			5,102			5,052	5,128	446	5,574	0.4%	
KA		0	4,680		0	0	407	5,087		5,512			5,453	5,535	482	6,017			5,512			5,458	5,540	482	6,022	18.3%	
KL		0	0		0	0	0	0		624			617	627	55	681			624			618	627	55	682	No existing develop-ment; growth planned	
KM		0	13,673		0	0	1,190	14,862		35,513			35,135	35,662	3,103	38,764			35,513			35,166	35,693	3,105	38,799	160.8%	
LL		0	0		0	0	0	0		416			412	418	36	454			416			412	418	36	454	No existing develop-ment; growth planned	
M2		0	216,678		0	5,630	19,341	241,649		268,886		5,630	271,593	275,667	23,983	299,650			268,886		5,630	271,834	275,912	24,004	299,916	24.0%	
NL		0	0		0	0	0	0		18,096			17,903	18,172	1,581	19,753			18,096			17,919	18,188	1,582	19,770	No existing develop-ment; growth planned	

Pressure Zone	2018 Consumption (GPD)								2045 Consumption (GPD)								2100 Consumption (GPD)									Percent Change 2018 to 2045	Notes
	Residential Annexations	Points that fell outside	Residential	Non-Residential Annexations	Points that fell outside	Non-Residential	Non-Revenue	Total Potable Use	Residential Annexations	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Residential Annexations	Infill/ Redevelopment	Residential	Non-Residential Annexations	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use		
NM		0	0		0	0	0	0		4,368			4,321	4,386	382	4,768			4,368			4,325	4,390	382	4,772	No existing develop-ment; growth planned	
O2		0	914		0	0	80	994		43,762			43,296	43,945	3,823	47,769			43,762			43,334	43,984	3,827	47,811	4708.1%	
PP		0	0		0	956	83	1,039		26,416		5,263	31,342	31,812	2,768	34,579			26,416		5,263	31,369	31,840	2,770	34,610	3228.0%	Not in obligated WSA
PZ		0	279		0	65	30	374		487		773	1,247	1,266	110	1,376			487		773	1,248	1,267	110	1,377	267.6%	
Q2		0	0		0	0	0	0		4,992			4,939	5,013	436	5,449			4,992			4,943	5,017	437	5,454	No existing develop-ment; growth planned	Not in obligated WSA
QH		0	0		0	0	0	0		208			206	209	18	227			208			206	209	18	227	No existing develop-ment; growth planned	
UA		0	0		0	347,085	30,196	377,281		7,072		442,075	444,364	451,029	39,240	490,269			7,072		442,075	444,759	451,430	39,274	490,704	29.9%	Not in obligated WSA
W1		0	212,405		0	13,557	19,659	245,621		212,405		13,557	223,556	226,909	19,741	246,650			212,405		13,557	223,754	227,111	19,759	246,869	0.4%	
WC		0	16,429		0	0	1,429	17,859		16,429			16,255	16,498	1,435	17,934			16,429			16,269	16,513	1,437	17,950	0.4%	
X1		114	148,251		0	5,167	13,347	166,766		159,691		5,993	163,921	166,379	14,475	180,854			159,691		5,993	164,066	166,527	14,488	181,015	8.4%	
Y1		419	887,230		81	338,142	106,607	1,331,979		976,462		357,789	1,320,043	1,339,843	116,566	1,456,410			976,462		357,789	1,321,215	1,341,033	116,670	1,457,703	9.3%	
Z#		0	470		0	0	41	511		886			876	889	77	967			886			877	890	77	968	89.3%	
Z5		0	0		0	0	0	0																		N/A	SAVSARP
ZA		7,088	1,245,972		7,581	414,356	144,449	1,804,776		1,403,220		539,377	1,921,911	1,950,740	169,714	2,120,454			1,403,220		539,377	1,923,618	1,952,472	169,865	2,122,337	17.5%	
ZK		0	16,590		0	2	1,444	18,036		18,878		179	18,854	19,137	1,665	20,802			18,878		179	18,871	19,154	1,666	20,821	15.3%	
ZM		0	59,554		0	0	5,181	64,735		66,210		4,779	70,233	71,287	6,202	77,489			66,210		4,779	70,296	71,350	6,207	77,558	19.7%	
ZW		0	0		3,210	3,210	279	3,489				3,210	3,176	3,223	280	3,504					3,210	3,178	3,226	281	3,507	0.4%	SAVSARP
Sum	**832**	**515,109**	**60,896,887**	**34,810**	**1,489,620**	**20,784,810**	**7,106,308**	**88,788,005**	**624**	**71,562,295**	**56,876**	**26,191,039**	**96,712,395**	**98,163,081**	**8,540,188**	**106,703,269**	**110,656**	**4,121,728**	**80,106,519**	**67,201**	**26,437,954**	**105,503,534**	**107,086,087**	**9,316,490**	**116,402,576**		

Appendix C

DEMAND PROJECTIONS BY TRAFFIC ANALYSIS ZONE

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
1	0	21,939	1,909	23,848	1,664	22,529	23,934	24,293	2,114	26,407	0	0	1,664	22,529	23,955	24,315	2,115	26,430
2	0	41,768	3,634	45,402	4,784	59,173	63,273	64,222	5,587	69,809	0	0	4,784	59,173	63,329	64,279	5,592	69,872
3	21,639	5,294	2,343	29,277	79,463	31,726	110,000	111,650	9,714	121,363	21,639	11	81,650	31,726	112,263	113,947	9,913	123,860
4	0	13,883	1,208	15,091	0	13,883	13,734	13,940	1,213	15,153	0	0	0	13,883	13,747	13,953	1,214	15,167
5	2,581	41,995	3,878	48,454	5,077	52,320	56,783	57,635	5,014	62,649	2,581	1	5,338	52,320	57,092	57,948	5,041	62,990
6	0	23,516	2,046	25,561	2,496	31,068	33,204	33,702	2,932	36,634	0	0	2,496	31,068	33,234	33,732	2,935	36,667
7	805	11,216	1,046	13,067	6,005	49,330	54,743	55,564	4,834	60,398	805	0	6,086	49,330	54,872	55,695	4,845	60,541
8	0	16,278	1,416	17,694	20,800	19,346	39,716	40,312	3,507	43,819	0	0	20,800	19,346	39,752	40,348	3,510	43,858
9	0	22,621	1,968	24,589	13,520	29,052	42,116	42,748	3,719	46,467	0	0	13,520	29,052	42,154	42,786	3,722	46,509
10	0	25,586	2,226	27,812	416	26,884	27,008	27,413	2,385	29,798	0	0	416	26,884	27,032	27,437	2,387	29,824
11	0	12,131	1,055	13,187	0	12,249	12,118	12,300	1,070	13,370	0	0	0	12,249	12,129	12,311	1,071	13,382
12	0	17,957	1,562	19,519	38,896	26,453	64,649	65,619	5,709	71,328	0	0	38,896	26,453	64,707	65,678	5,714	71,392
13	0	897	78	975	78,832	33,701	111,328	112,998	9,831	122,829	0	0	78,832	33,701	111,428	113,099	9,840	122,939
14	778	18,154	1,647	20,579	117,466	30,603	146,484	148,681	12,935	161,617	778	0	117,544	30,603	146,693	148,893	12,954	161,847
15	20,830	31,809	4,580	57,218	64,302	52,990	116,036	117,777	10,247	128,023	20,830	10	66,407	52,990	118,224	119,997	10,440	130,437
16	0	47,358	4,120	51,478	0	53,376	52,805	53,597	4,663	58,260	0	0	0	53,376	52,852	53,645	4,667	58,312
17	49,064	66,314	10,038	125,416	69,240	74,515	142,217	144,350	12,558	156,908	49,064	24	74,198	74,515	147,253	149,462	13,003	162,465
18	0	28,692	2,496	31,188	4,160	47,513	51,120	51,887	4,514	56,401	0	0	4,160	47,513	51,166	51,933	4,518	56,451
19	0	74,281	6,462	80,743	50,752	96,465	145,641	147,826	12,861	160,687	0	0	50,752	96,465	145,771	147,958	12,872	160,830
20	395	7,655	700	8,750	22,651	32,494	54,554	55,373	4,817	60,190	395	0	22,691	32,494	54,643	55,462	4,825	60,287
21	14,355	39,876	4,718	58,950	29,747	53,741	82,595	83,834	7,294	91,128	14,355	7	31,198	53,741	84,105	85,367	7,427	92,794
22	60,954	22,184	7,233	90,370	115,034	44,840	158,162	160,535	13,967	174,501	60,954	30	121,194	44,840	164,403	166,869	14,518	181,386
23	58,043	7,007	5,659	70,709	66,363	22,406	87,819	89,136	7,755	96,891	58,043	28	72,228	22,406	93,705	95,111	8,275	103,385
24	0	26,416	2,298	28,714	0	32,375	32,029	32,509	2,828	35,337	0	0	0	32,375	32,057	32,538	2,831	35,369

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
25	32,071	13,252	3,943	49,266	42,679	15,022	57,083	57,939	5,041	62,980	32,071	16	45,920	15,022	60,343	61,248	5,329	66,577
26	19,994	8,091	2,443	30,528	26,026	9,566	35,211	35,739	3,109	38,848	19,994	10	28,046	9,566	37,243	37,802	3,289	41,090
27	36,058	3,251	3,420	42,729	40,634	8,148	48,260	48,984	4,262	53,246	36,058	18	44,278	8,148	51,912	52,690	4,584	57,274
28	30,168	11,055	3,586	44,810	62,616	18,135	79,887	81,085	7,054	88,140	30,168	15	65,665	18,135	82,977	84,222	7,327	91,549
29	28,001	3,675	2,756	34,432	46,721	9,398	55,519	56,352	4,903	61,254	28,001	14	49,551	9,398	58,370	59,246	5,154	64,400
30	21,023	1,628	1,971	24,621	24,975	2,631	27,310	27,720	2,412	30,131	21,023	10	27,099	2,631	29,438	29,880	2,600	32,479
31	1,738	14,457	1,409	17,605	2,570	16,935	19,297	19,586	1,704	21,290	1,738	1	2,746	16,935	19,488	19,780	1,721	21,501
32	18,380	32,953	4,466	55,799	49,788	45,992	94,755	96,176	8,367	104,544	18,380	9	51,645	45,992	96,679	98,129	8,537	106,666
33	0	3,192	278	3,469	1,040	27,500	28,234	28,658	2,493	31,151	0	0	1,040	27,500	28,260	28,683	2,495	31,179
34	12,807	42,749	4,833	60,390	13,847	47,115	60,310	61,214	5,326	66,540	12,807	6	15,141	47,115	61,645	62,570	5,444	68,013
35	23,418	90,707	9,929	124,054	41,098	106,519	146,037	148,228	12,896	161,123	23,418	11	43,465	106,519	148,511	150,738	13,114	163,853
36	36,000	34,635	6,145	76,781	55,344	41,833	96,137	97,579	8,489	106,069	36,000	17	58,983	41,833	99,825	101,323	8,815	110,138
37	130,028	60,583	16,583	207,194	227,580	74,389	298,737	303,218	26,380	329,598	130,028	63	240,720	74,389	312,015	316,695	27,552	344,248
38	116,046	54,279	14,818	185,143	223,166	74,280	294,262	298,676	25,985	324,661	116,046	56	234,893	74,280	306,137	310,729	27,033	337,763
39	66,821	66,285	11,580	144,686	136,917	90,475	224,958	228,333	19,865	248,198	66,821	32	143,670	90,475	231,846	235,323	20,473	255,796
40	20,818	9,662	2,652	33,132	37,042	12,022	48,539	49,267	4,286	53,553	20,818	10	39,146	12,022	50,665	51,425	4,474	55,899
41	200	38,394	3,358	41,951	200	47,303	46,994	47,699	4,150	51,848	200	0	220	47,303	47,056	47,762	4,155	51,917
42	0	470	41	511	0	765	757	768	67	835	0	0	0	765	757	769	67	836
43	0	34,554	3,006	37,561	0	34,908	34,535	35,053	3,050	38,102	0	0	0	34,908	34,566	35,084	3,052	38,136
44	1,602	30,570	2,799	34,971	3,145	31,455	34,230	34,743	3,023	37,766	1,602	1	3,307	31,455	34,420	34,937	3,039	37,976
45	8,754	47,642	4,906	61,302	8,961	50,651	58,973	59,858	5,208	65,066	8,754	4	9,847	50,651	59,903	60,802	5,290	66,092
46	18,291	135,917	13,416	167,624	114,179	146,655	258,042	261,912	22,786	284,699	18,291	9	116,027	146,655	260,102	264,004	22,968	286,972
47	118,908	10,185	11,231	140,323	186,092	22,929	206,783	209,885	18,260	228,145	118,908	58	198,108	22,929	218,867	222,150	19,327	241,477
48	20,697	594,762	53,545	669,004	31,158	737,719	760,649	772,058	67,169	839,227	20,697	10	33,250	737,719	763,398	774,849	67,412	842,261
49	113,567	10,830	10,823	135,220	114,190	10,830	123,682	125,537	10,922	136,459	113,567	55	125,668	10,830	135,158	137,185	11,935	149,120
50	106,355	11,859	10,285	128,499	108,435	11,918	119,065	120,851	10,514	131,365	106,355	52	119,183	11,918	129,814	131,761	11,463	143,224
51	58,217	28,512	7,545	94,274	102,313	41,787	142,558	144,696	12,589	157,285	58,217	28	108,196	41,787	148,511	150,738	13,114	163,852
52	6,188	23,483	2,581	32,252	13,676	30,032	43,240	43,888	3,818	47,707	6,188	3	14,301	30,032	43,898	44,556	3,876	48,432

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
53	61,928	51,847	9,898	123,674	111,224	66,538	175,860	178,497	15,529	194,027	61,928	30	117,482	66,538	182,213	184,947	16,090	201,037
54	15,161	23,512	3,365	42,037	52,601	31,713	83,411	84,663	7,366	92,028	15,161	7	54,133	31,713	85,003	86,278	7,506	93,784
55	175,681	64,654	20,909	261,244	178,177	64,890	240,466	244,073	21,234	265,307	175,681	85	195,931	64,890	258,260	262,134	22,806	284,940
56	54,991	16,341	6,206	77,537	58,943	17,993	76,112	77,254	6,721	83,975	54,991	27	64,500	17,993	81,683	82,908	7,213	90,121
57	17,858	58,598	6,652	83,107	26,386	61,902	87,342	88,653	7,713	96,365	17,858	9	28,190	61,902	89,207	90,545	7,877	98,423
58	68,924	7,069	6,611	82,604	72,668	8,367	80,167	81,370	7,079	88,449	68,924	33	79,633	8,367	87,136	88,443	7,695	96,137
59	116,418	25,629	12,358	154,405	157,602	28,756	184,364	187,129	16,280	203,409	116,418	57	169,367	28,756	196,178	199,120	17,323	216,444
60	0	0	0	0	0	0	0	0	0	0	0	0	59,072	4,248	62,698	63,639	5,537	69,175
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	1,200	0	104	1,304	1,404	0	1,389	1,410	123	1,532	0	0	101,664	7,139	107,734	109,350	9,513	118,864
63	0	0	0	0	0	0	0	0	0	0	0	0	83,200	5,900	88,225	89,548	7,791	97,339
64	13,789	377	1,232	15,399	15,022	377	15,233	15,462	1,345	16,807	0	0	27,517	1,321	28,555	28,983	2,522	31,505
65	0	0	0	0	0	0	0	0	0	0	0	0	27,248	1,947	28,908	29,342	2,553	31,895
66	0	0	0	0	0	57,053	56,442	57,289	4,984	62,273	0	0	0	57,053	56,493	57,340	4,989	62,329
67	0	0	0	0	2,211	21,712	23,667	24,022	2,090	26,112	0	0	2,288	21,712	23,764	24,121	2,099	26,219
68	131,207	17,733	12,958	161,898	131,207	17,733	147,346	149,556	13,011	162,567	131,207	64	144,467	17,733	160,607	163,016	14,182	177,198
69	130,901	92,739	19,457	243,097	131,109	92,739	221,453	224,774	19,555	244,330	130,901	64	144,338	92,739	234,749	238,270	20,730	259,000
70	235,115	49,932	24,799	309,846	235,323	49,932	282,202	286,435	24,920	311,355	235,115	114	259,084	49,932	305,981	310,571	27,020	337,590
71	0	0	0	0	4,655	472	5,072	5,148	448	5,596	0	0	4,655	472	5,076	5,152	448	5,601
72	0	0	0	0	1	0	1	1	0	1	0	0	1	0	1	1	0	1
73	0	0	0	0	60	0	59	60	5	65	0	0	60	0	59	60	5	65
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	20,020	59	19,864	20,162	1,754	21,916	0	0	20,020	59	19,881	20,180	1,756	21,935
78	0	0	0	0	58	0	57	58	5	63	0	0	58	0	58	58	5	63
79	0	0	0	0	4,807	59	4,814	4,886	425	5,311	0	0	84,656	6,018	89,784	91,130	7,928	99,059
80	0	0	0	0	5,308	118	5,368	5,448	474	5,922	0	0	5,408	118	5,472	5,554	483	6,037

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
81	0	0	0	0	0	59	58	59	5	64	0	0	0	59	58	59	5	64
82	0	0	0	0	114	0	113	114	10	124	0	0	208	0	206	209	18	227
83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	54	0	53	54	5	58	0	0	54	0	53	54	5	59
85	0	0	0	0	83,200	0	82,310	83,544	7,268	90,813	0	0	83,200	0	82,383	83,619	7,275	90,894
86	10,247	0	891	11,139	10,247	59	10,196	10,349	900	11,249	0	0	10,247	59	10,205	10,358	901	11,259
87	0	0	0	0	736	0	728	739	64	803	0	0	113,984	8,083	120,868	122,681	10,673	133,355
88	0	0	0	0	49,921	177	49,562	50,305	4,377	54,682	0	0	49,921	177	49,606	50,350	4,380	54,731
89	0	0	0	0	156,000	2,124	156,432	158,778	13,814	172,592	0	0	156,000	2,124	156,571	158,920	13,826	172,746
90	0	0	0	0	72,800	944	72,955	74,049	6,442	80,491	0	0	72,800	944	73,020	74,115	6,448	80,563
91	0	0	0	0	67,314	177	66,768	67,770	5,896	73,666	0	0	67,392	177	66,905	67,909	5,908	73,817
92	0	0	0	0	166,400	7,788	172,324	174,909	15,217	190,126	0	0	166,400	7,788	172,477	175,065	15,231	190,295
93	0	0	0	0	0	236	233	237	21	258	0	0	0	236	234	237	21	258
94	84,615	11,018	8,320	103,953	87,069	11,077	97,095	98,552	8,574	107,126	0	0	87,111	11,077	97,224	98,682	8,585	107,267
95	59,419	1,143	5,269	65,832	60,447	1,261	61,048	61,964	5,391	67,355	59,419	29	66,452	1,261	67,048	68,054	5,921	73,975
96	18,217	0	1,585	19,802	18,217	472	18,489	18,767	1,633	20,399	0	0	18,217	472	18,506	18,783	1,634	20,417
97	23,658	98	2,067	25,822	45,128	629	45,267	45,946	3,997	49,943	0	0	45,128	629	45,308	45,987	4,001	49,988
98	73,766	0	6,418	80,183	73,766	0	72,976	74,071	6,444	80,515	0	0	73,766	0	73,041	74,137	6,450	80,587
99	0	2,774	241	3,015	0	3,010	2,978	3,022	263	3,285	0	0	0	3,010	2,980	3,025	263	3,288
100	0	0	0	0	104,000	6,844	109,658	111,303	9,683	120,986	0	0	104,000	6,844	109,756	111,402	9,692	121,094
101	0	0	0	0	104,000	8,673	111,467	113,139	9,843	122,982	0	0	104,000	8,673	111,567	113,240	9,852	123,092
102	0	0	0	0	197,600	3,835	199,279	202,268	17,597	219,866	0	0	197,600	3,835	199,457	202,449	17,613	220,062
103	56,194	0	4,889	61,082	56,194	708	56,293	57,137	4,971	62,108	0	0	56,194	708	56,343	57,188	4,975	62,163
104	15,288	0	1,330	16,618	15,636	59	15,527	15,759	1,371	17,131	0	0	15,704	59	15,608	15,842	1,378	17,220
105	43,925	0	3,821	47,746	45,589	177	45,276	45,955	3,998	49,953	43,925	21	50,028	177	49,712	50,458	4,390	54,847
106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
107	75,682	4,110	6,942	86,734	75,890	4,110	79,143	80,331	6,989	87,319	0	0	75,890	4,110	79,214	80,402	6,995	87,397
108	19,511	29,686	4,280	53,477	22,442	29,981	51,862	52,640	4,580	57,220	19,511	9	24,414	29,981	53,861	54,669	4,756	59,425

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
109	134,054	1,081	11,757	146,892	134,054	1,081	133,689	135,695	11,805	147,500	0	0	134,054	1,081	133,809	135,816	11,816	147,632
110	0	0	0	0	124,800	1,593	125,040	126,916	11,042	137,958	0	0	124,800	1,593	125,152	127,029	11,052	138,081
111	72,560	5,092	6,756	84,407	72,768	5,505	77,435	78,596	6,838	85,434	0	0	72,768	5,505	77,504	78,667	6,844	85,511
112	0	76,400	6,647	83,047	624	83,303	83,028	84,274	7,332	91,606	0	0	624	83,303	83,103	84,349	7,338	91,688
113	20,912	10,569	2,739	34,219	25,703	13,460	38,744	39,325	3,421	42,746	0	0	25,703	13,460	38,778	39,360	3,424	42,784
114	0	0	0	0	135,200	8,437	142,100	144,231	12,548	156,779	0	0	135,200	8,437	142,226	144,360	12,559	156,919
115	18,986	0	1,652	20,638	278,986	2,832	278,802	282,984	24,620	307,604	0	0	278,986	2,832	279,051	283,237	24,642	307,878
116	101,500	6,114	9,362	116,976	101,708	8,887	109,411	111,052	9,662	120,713	0	0	101,708	8,887	109,508	111,151	9,670	120,821
117	80,909	574	7,089	88,572	81,949	2,167	83,215	84,464	7,348	91,812	0	0	81,949	2,167	83,290	84,539	7,355	91,894
118	199,809	19,721	19,099	238,629	200,017	41,374	238,807	242,389	21,088	263,477	0	0	200,017	41,374	239,020	242,606	21,107	263,712
119	82,713	15,193	8,518	106,424	94,942	16,314	110,065	111,716	9,719	121,436	0	0	94,985	16,314	110,206	111,859	9,732	121,591
120	155,463	2,322	13,727	171,512	155,671	5,390	159,337	161,727	14,070	175,797	155,463	76	171,381	5,390	175,036	177,661	15,457	193,118
121	77,226	19,567	8,421	105,213	77,434	21,160	97,538	99,001	8,613	107,614	0	0	77,434	21,160	97,625	99,089	8,621	107,710
122	120,406	2,664	10,707	133,777	122,072	4,375	125,094	126,970	11,046	138,017	0	0	122,072	4,375	125,206	127,084	11,056	138,140
123	14,735	0	1,282	16,017	14,735	413	14,986	15,211	1,323	16,534	0	0	14,735	413	14,999	15,224	1,324	16,549
124	0	0	0	0	0	1,003	992	1,007	88	1,095	0	0	154,960	11,033	164,363	166,828	14,514	181,342
125	0	0	0	0	0	0	0	0	0	0	0	0	108,368	7,670	114,899	116,622	10,146	126,768
126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	118	117	118	10	129	0	0	106,288	7,552	112,722	114,413	9,954	124,367
130	136,568	3,781	12,210	152,560	136,568	3,958	139,022	141,108	12,276	153,384	136,568	66	150,370	3,958	152,812	155,105	13,494	168,599
131	83,074	7,320	7,864	98,259	83,074	7,733	89,836	91,183	7,933	99,116	0	0	83,074	7,733	89,916	91,265	7,940	99,205
132	83,190	3,501	7,542	94,233	83,606	4,209	86,875	88,179	7,672	95,850	0	0	83,606	4,209	86,953	88,257	7,678	95,936
133	102,793	10,882	9,890	123,565	102,793	12,357	113,918	115,627	10,060	125,686	0	0	102,793	12,357	114,019	115,730	10,068	125,798
134	0	0	0	0	187,200	16,284	201,306	204,326	17,776	222,102	0	0	187,200	16,284	201,486	204,508	17,792	222,300
135	64,592	54,898	10,396	129,886	210,192	69,884	277,079	281,235	24,467	305,702	0	0	210,192	69,884	277,326	281,486	24,489	305,975
136	753	4,348	444	5,545	961	5,941	6,828	6,931	603	7,534	753	0	1,037	5,941	6,910	7,013	610	7,624

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
137	58,423	2,013	5,258	65,695	58,839	4,373	62,536	63,474	5,522	68,997	0	0	58,839	4,373	62,592	63,531	5,527	69,058
138	36	2	3	41	187,236	3,247	188,444	191,271	16,641	207,912	0	0	187,236	3,247	188,613	191,442	16,655	208,097
139	82,152	7,844	7,830	97,826	82,568	10,145	91,721	93,097	8,099	101,196	0	0	82,568	10,145	91,803	93,180	8,107	101,286
140	158,963	25,998	16,092	201,053	159,350	28,476	185,816	188,603	16,408	205,011	0	0	159,379	28,476	186,011	188,801	16,426	205,227
141	110,922	3,830	9,983	124,735	110,922	4,597	114,282	115,996	10,092	126,088	0	0	110,922	4,597	114,384	116,100	10,101	126,201
142	215,665	30,688	21,433	267,785	216,289	38,771	252,330	256,115	22,282	278,397	0	0	216,289	38,771	252,555	256,343	22,302	278,645
143	96,240	847	8,447	105,534	97,280	3,325	99,529	101,022	8,789	109,811	96,240	47	107,006	3,325	109,248	110,887	9,647	120,534
144	179,616	14,856	16,919	211,390	179,616	14,856	192,390	195,276	16,989	212,265	179,616	87	197,767	14,856	210,535	213,693	18,591	232,284
145	95,485	15,319	9,640	120,444	95,693	16,853	111,342	113,012	9,832	122,844	0	0	95,693	16,853	111,441	113,113	9,841	122,953
146	119,179	0	10,369	129,548	119,179	0	117,904	119,672	10,412	130,084	119,179	58	131,224	0	129,935	131,884	11,474	143,358
147	80,212	10,494	7,891	98,597	81,252	10,966	91,231	92,599	8,056	100,655	0	0	81,252	10,966	91,312	92,682	8,063	100,745
148	0	0	0	0	31,188	649	31,497	31,969	2,781	34,750	0	0	31,200	649	31,536	32,009	2,785	34,794
149	65	636	61	762	72,863	2,642	74,697	75,817	6,596	82,413	0	0	72,865	2,642	74,765	75,887	6,602	82,489
150	0	0	0	0	197,600	1,357	196,828	199,780	17,381	217,161	0	0	197,600	1,357	197,003	199,958	17,396	217,355
151	0	0	0	0	0	236	233	237	21	258	0	0	64,480	4,602	68,404	69,430	6,040	75,470
152	0	0	0	0	0	295	292	296	26	322	0	0	68,848	4,897	73,021	74,116	6,448	80,564
153	0	0	0	0	0	118	117	118	10	129	0	0	67,392	4,779	71,462	72,534	6,310	78,845
154	288,906	52,725	29,722	371,353	290,570	53,079	339,971	345,071	30,021	375,092	0	0	290,570	53,079	340,274	345,379	30,048	375,426
155	0	1,218	106	1,324	249,196	2,634	249,135	252,872	22,000	274,872	0	0	249,196	2,634	249,358	253,098	22,020	275,117
156	16,592	0	1,443	18,035	16,592	0	16,414	16,660	1,449	18,110	0	0	16,592	0	16,429	16,675	1,451	18,126
157	101,843	9,641	9,699	121,184	195,443	13,181	206,392	209,488	18,225	227,713	0	0	195,443	13,181	206,576	209,675	18,242	227,916
158	0	0	0	0	0	0	0	0	0	0	0	0	128,544	9,145	136,337	138,382	12,039	150,421
159	157,861	11,249	14,713	183,823	158,693	11,367	168,240	170,764	14,856	185,620	157,861	77	174,647	11,367	184,187	186,950	16,265	203,215
160	63,454	45,431	9,473	118,358	63,981	46,493	109,291	110,931	9,651	120,582	63,454	31	70,490	46,493	115,835	117,572	10,229	127,801
161	212,020	23,152	20,460	255,632	219,831	23,978	241,199	244,817	21,299	266,116	212,020	103	241,350	23,978	262,723	266,664	23,200	289,863
162	135,529	23,598	13,844	172,972	137,153	23,775	159,206	161,594	14,059	175,652	135,529	66	150,890	23,775	172,950	175,544	15,272	190,816
163	310,990	8,565	27,801	347,357	311,614	8,683	316,870	321,623	27,981	349,604	0	0	311,614	8,683	317,152	321,910	28,006	349,916
164	94	70,412	6,134	76,641	1,549	108,172	108,546	110,175	9,585	119,760	0	0	1,550	108,172	108,645	110,275	9,594	119,869

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
165	0	176,839	15,385	192,225	1,248	179,258	178,575	181,253	15,769	197,022	0	0	1,248	179,258	178,734	181,415	15,783	197,198
166	0	4,051	352	4,403	208	5,231	5,381	5,462	475	5,937	0	0	48,048	7,473	54,976	55,800	4,855	60,655
167	106,582	8,035	9,972	124,588	106,998	8,035	113,802	115,509	10,049	125,558	106,582	52	117,769	8,035	124,568	126,437	11,000	137,437
168	84,222	11,693	8,345	104,260	84,430	12,519	95,912	97,351	8,470	105,820	84,222	41	92,942	12,519	104,426	105,992	9,221	115,213
169	54,364	16,366	6,153	76,883	54,492	16,484	70,216	71,269	6,200	77,470	54,364	26	60,065	16,484	75,798	76,935	6,693	83,628
170	158,825	3,387	14,112	176,324	159,449	7,399	165,062	167,538	14,576	182,114	158,825	77	175,499	7,399	181,102	183,819	15,992	199,811
171	223,965	12,275	20,553	256,793	225,421	14,930	237,779	241,345	20,997	262,343	223,965	109	248,055	14,930	260,402	264,308	22,995	287,303
172	154,440	0	13,436	167,877	189,592	4,071	191,591	194,464	16,918	211,383	0	0	189,592	4,071	191,762	194,638	16,934	211,572
173	165,420	10,650	15,318	191,388	165,420	10,650	174,186	176,798	15,381	192,180	0	0	165,420	10,650	174,341	176,956	15,395	192,351
174	0	0	0	0	0	118	117	118	10	129	0	0	157,872	11,210	167,422	169,933	14,784	184,717
175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	0	12,405	1,079	13,485	0	12,405	12,273	12,457	1,084	13,540	0	0	199,056	26,506	223,347	226,698	19,723	246,420
177	199,016	10,819	18,256	228,091	199,640	12,648	210,016	213,166	18,545	231,712	199,016	97	219,752	12,648	230,118	233,570	20,321	253,890
178	168,578	33,588	17,588	219,754	170,658	39,606	208,013	211,134	18,369	229,502	0	0	170,658	39,606	208,199	211,322	18,385	229,707
179	79,651	116	6,940	86,706	80,769	3,833	83,697	84,952	7,391	92,343	0	0	80,769	3,833	83,771	85,028	7,397	92,425
180	18,794	24,196	3,740	46,729	19,210	28,621	47,318	48,028	4,178	52,207	18,794	9	21,109	28,621	49,241	49,980	4,348	54,328
181	70,083	309	6,124	76,517	70,083	309	69,639	70,684	6,149	76,833	0	0	70,083	309	69,701	70,747	6,155	76,902
182	104,297	5,910	9,588	119,796	118,233	9,804	126,667	128,567	11,185	139,753	104,297	51	128,774	9,804	137,217	139,275	12,117	151,392
183	156,477	11,238	14,591	182,306	167,917	11,946	177,938	180,607	15,713	196,320	156,477	76	183,730	11,946	193,755	196,661	17,110	213,770
184	96,803	0	8,422	105,225	97,219	472	96,646	98,096	8,534	106,630	0	0	97,219	472	96,732	98,183	8,542	106,725
185	112,745	0	9,809	122,554	113,284	2,065	114,115	115,826	10,077	125,903	112,745	55	124,763	2,065	125,583	127,466	11,090	138,556
186	129,092	48,328	15,436	192,856	129,300	48,328	175,727	178,363	15,518	193,881	129,092	63	142,346	48,328	188,802	191,634	16,672	208,306
187	96,951	40,156	11,928	149,035	97,367	40,687	136,576	138,625	12,060	150,685	96,951	47	107,164	40,687	146,399	148,595	12,928	161,523
188	172,831	108,061	24,438	305,330	174,070	122,575	293,470	297,872	25,915	323,787	0	0	174,079	122,575	293,741	298,147	25,939	324,086
189	0	0	0	0	0	0	0	0	0	0	0	0	90,688	6,431	96,165	97,608	8,492	106,100
190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
191	177,327	22,560	17,390	217,278	177,535	24,684	200,055	203,056	17,666	220,722	177,327	86	195,456	24,684	217,978	221,248	19,249	240,497
192	39,821	5,929	3,980	49,730	40,237	6,932	46,664	47,364	4,121	51,485	39,821	19	44,262	6,932	50,691	51,451	4,476	55,927

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
193	69,333	15,819	7,408	92,560	71,413	17,412	87,874	89,192	7,760	96,952	69,333	34	78,420	17,412	94,890	96,314	8,379	104,693
194	241,561	17,343	22,525	281,429	241,561	17,343	256,133	259,975	22,618	282,593	241,561	117	265,973	17,343	280,534	284,742	24,773	309,515
195	186,740	1,026	16,336	204,102	189,028	1,321	188,312	191,137	16,629	207,766	186,740	91	207,900	1,321	207,167	210,274	18,294	228,568
196	116,886	40,166	13,664	170,716	119,798	42,939	160,996	163,411	14,217	177,627	0	0	119,798	42,939	161,139	163,556	14,229	177,786
197	100,210	25,189	10,910	136,309	102,914	26,369	127,899	129,818	11,294	141,112	100,210	49	113,041	26,369	138,041	140,112	12,190	152,302
198	218,349	42,106	22,660	283,115	218,765	46,531	262,457	266,394	23,176	289,570	218,349	106	240,831	46,531	284,540	288,808	25,126	313,935
199	143,930	21,385	14,382	179,697	145,802	22,329	166,331	168,826	14,688	183,514	0	0	145,802	22,329	166,480	168,977	14,701	183,678
200	67,358	25,716	8,097	101,171	67,358	28,135	94,471	95,888	8,342	104,230	0	0	67,358	28,135	94,555	95,974	8,350	104,323
201	83,305	124,264	18,059	225,628	83,927	126,034	207,714	210,830	18,342	229,172	83,305	40	92,348	126,034	216,238	219,481	19,095	238,576
202	45,350	7,037	4,558	56,945	48,933	7,863	56,188	57,031	4,962	61,992	45,350	22	53,516	7,863	60,776	61,688	5,367	67,055
203	175,537	17,788	16,819	210,144	185,729	25,930	209,394	212,535	18,491	231,025	175,537	85	203,469	25,930	227,146	230,553	20,058	250,611
204	0	0	0	0	0	0	0	0	0	0	0	0	125,840	8,909	133,426	135,427	11,782	147,209
205	0	0	0	0	0	0	0	0	0	0	0	0	80,704	5,723	85,578	86,862	7,557	94,419
206	102,860	3,066	9,216	115,141	106,210	8,730	113,710	115,416	10,041	125,457	102,860	50	116,605	8,730	124,104	125,966	10,959	136,925
207	0	0	0	0	0	59,000	58,369	59,244	5,154	64,398	0	0	0	59,000	58,421	59,297	5,159	64,456
208	0	33,062	2,876	35,938	0	33,475	33,116	33,613	2,924	36,537	0	0	0	33,475	33,146	33,643	2,927	36,570
209	35,944	6,284	3,674	45,902	35,944	6,284	41,776	42,403	3,689	46,092	35,944	17	39,577	6,284	45,410	46,092	4,010	50,101
210	0	39,109	3,403	42,512	0	39,935	39,508	40,101	3,489	43,589	0	0	0	39,935	39,543	40,136	3,492	43,628
211	32,029	6,542	3,356	41,926	32,445	6,778	38,803	39,385	3,426	42,811	32,029	16	35,681	6,778	42,042	42,673	3,713	46,386
212	131,532	13,597	12,626	157,756	134,236	14,954	147,594	149,808	13,033	162,841	131,532	64	147,529	14,954	160,887	163,301	14,207	177,508
213	72,996	44,250	10,200	127,447	73,819	51,389	123,868	125,726	10,938	136,664	72,996	35	81,205	51,389	131,292	133,262	11,594	144,855
214	225,848	15,672	21,012	262,532	228,677	17,501	243,544	247,197	21,506	268,703	225,848	110	251,584	17,501	266,443	270,439	23,528	293,967
215	149,242	807	13,054	163,104	149,866	866	149,119	151,356	13,168	164,524	0	0	149,866	866	149,252	151,491	13,180	164,671
216	148,443	60,207	18,153	226,803	157,387	62,508	217,542	220,805	19,210	240,015	148,443	72	172,388	62,508	232,590	236,079	20,539	256,618
217	87,773	619	7,690	96,082	87,773	619	87,445	88,757	7,722	96,479	0	0	87,773	619	87,524	88,836	7,729	96,565
218	61,277	17,606	6,863	85,745	65,437	17,783	82,329	83,564	7,270	90,834	61,277	30	71,629	17,783	88,534	89,862	7,818	97,680
219	105,757	6,595	9,775	122,127	105,965	6,595	111,355	113,026	9,833	122,859	105,757	51	116,653	6,595	122,038	123,868	10,777	134,645
220	0	0	0	0	14,836	0	14,677	14,898	1,296	16,194	0	0	14,836	0	14,690	14,911	1,297	16,208

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
221	221,112	12,927	20,361	254,400	222,984	13,694	234,145	237,657	20,676	258,333	221,112	107	245,329	13,694	256,479	260,327	22,648	282,975
222	0	0	0	0	0	0	0	0	0	0	0	0	109,616	7,788	116,251	117,995	10,266	128,260
223	0	0	0	0	0	0	0	0	0	0	0	0	107,328	7,611	113,810	115,517	10,050	125,567
224	0	0	0	0	0	0	0	0	0	0	0	0	139,776	9,912	148,218	150,441	13,088	163,530
225	78,797	27,198	9,222	115,216	78,937	28,319	106,108	107,700	9,370	117,070	78,797	38	86,968	28,319	114,155	115,867	10,080	125,948
226	214,190	4,589	19,034	237,813	214,814	5,533	217,989	221,258	19,249	240,508	0	0	214,814	5,533	218,183	221,456	19,267	240,723
227	0	696	61	756	322	11,611	11,805	11,982	1,042	13,024	0	0	322	11,611	11,815	11,992	1,043	13,036
228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
229	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
230	79,852	184	6,963	86,998	85,260	5,435	89,724	91,070	7,923	98,993	0	0	85,260	5,435	89,804	91,151	7,930	99,081
231	89,359	2,190	7,965	99,514	89,775	2,308	91,097	92,464	8,044	100,508	0	0	89,775	2,308	91,179	92,546	8,052	100,598
232	87,305	38,915	10,981	137,201	88,345	44,343	131,268	133,237	11,592	144,828	87,305	42	97,168	44,343	140,121	142,223	12,373	154,596
233	140,702	285	12,266	153,252	140,702	285	139,478	141,570	12,317	153,886	140,702	68	154,921	285	153,682	155,987	13,571	169,558
234	277,828	35,745	27,281	340,854	284,484	36,925	317,970	322,739	28,078	350,817	277,828	135	312,561	36,925	346,055	351,245	30,558	381,804
235	88,785	19,332	9,406	117,523	88,993	19,568	107,399	109,010	9,484	118,494	88,785	43	97,965	19,568	116,379	118,125	10,277	128,402
236	47,474	14,817	5,419	67,709	56,210	36,293	91,512	92,885	8,081	100,966	47,474	23	61,007	36,293	96,344	97,789	8,508	106,297
237	5,007	59,046	5,573	69,626	8,127	70,138	77,427	78,589	6,837	85,426	5,007	2	8,633	70,138	77,998	79,168	6,888	86,055
238	0	0	0	0	0	59,000	58,369	59,244	5,154	64,398	0	0	0	59,000	58,421	59,297	5,159	64,456
239	0	1,560	136	1,696	1,559	105,046	105,464	107,046	9,313	116,359	0	0	1,559	105,046	105,558	107,142	9,321	116,463
240	0	5,843	508	6,352	49,201	6,374	54,981	55,806	4,855	60,661	0	0	49,296	6,374	55,124	55,950	4,868	60,818
241	79,941	34,421	9,950	124,312	81,605	41,855	122,139	123,971	10,786	134,757	79,941	39	89,684	41,855	130,248	132,201	11,502	143,703
242	0	2,539	221	2,760	10,096	2,834	12,792	12,984	1,130	14,113	0	0	10,192	2,834	12,898	13,092	1,139	14,231
243	8,474	0	737	9,211	8,743	0	8,649	8,779	764	9,543	8,474	4	9,599	0	9,505	9,647	839	10,487
244	0	1,206	105	1,310	0	1,206	1,193	1,211	105	1,316	0	0	0	1,206	1,194	1,212	105	1,317
245	200,706	71,557	23,687	295,951	201,096	71,675	269,852	273,900	23,829	297,729	200,706	98	221,405	71,675	290,203	294,556	25,626	320,182
246	0	0	0	0	0	0	0	0	0	0	0	0	62,816	4,484	66,639	67,639	5,885	73,523
247	164,802	29,664	16,919	211,384	165,426	29,723	193,060	195,956	17,048	213,004	164,802	80	182,081	29,723	209,724	212,869	18,520	231,389
248	190,778	25,143	18,785	234,706	192,442	30,335	220,392	223,698	19,462	243,160	190,778	93	211,722	30,335	239,679	243,275	21,165	264,439

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
249	36,743	59,575	8,380	104,698	41,527	65,003	105,390	106,971	9,306	116,277	36,743	18	45,240	65,003	109,161	110,798	9,639	120,438
250	105,825	13,802	10,407	130,034	106,033	28,080	132,677	134,667	11,716	146,383	105,825	51	116,727	28,080	143,385	145,536	12,662	158,197
251	87,290	19,049	9,252	115,591	91,658	29,079	119,445	121,237	10,548	131,784	87,290	42	100,480	29,079	128,286	130,211	11,328	141,539
252	219,808	7,607	19,785	247,200	229,792	10,380	237,601	241,165	20,981	262,147	219,808	107	252,005	10,380	259,809	263,706	22,942	286,648
253	160,345	22,746	15,929	199,020	167,209	23,454	188,622	191,452	16,656	208,108	160,345	78	183,413	23,454	204,836	207,908	18,088	225,996
254	88,132	112,953	17,494	218,580	91,876	118,322	207,949	211,068	18,363	229,431	88,132	43	100,783	118,322	216,953	220,208	19,158	239,366
255	0	79,036	6,876	85,912	5,200	100,866	104,931	106,505	9,266	115,771	0	0	5,200	100,866	105,024	106,600	9,274	115,874
256	158,159	232,500	33,987	424,646	162,527	244,536	402,706	408,747	35,561	444,307	158,159	77	178,510	244,536	418,892	425,175	36,990	462,165
257	0	6,574	572	7,146	55,003	62,329	116,075	117,817	10,250	128,067	0	0	55,003	62,329	116,179	117,922	10,259	128,181
258	0	20,668	1,798	22,466	0	58,664	58,036	58,907	5,125	64,032	0	0	0	58,664	58,088	58,959	5,129	64,089
259	852	55,645	4,915	61,412	1,054	68,920	69,225	70,263	6,113	76,376	0	0	1,054	68,920	69,287	70,326	6,118	76,444
260	37,300	17,407	4,759	59,466	274,004	58,412	328,858	333,790	29,040	362,830	0	0	274,004	58,412	329,151	334,088	29,066	363,154
261	130,441	722	11,411	142,574	148,651	958	148,008	150,228	13,070	163,298	0	0	148,745	958	148,233	150,456	13,090	163,546
262	0	0	0	0	208	118	322	327	28	356	0	0	91,104	6,490	96,636	98,085	8,533	106,619
263	156,475	87,923	21,263	265,660	156,683	87,923	241,988	245,618	21,369	266,986	156,475	76	172,496	87,923	257,862	261,730	22,770	284,500
264	0	23,163	2,015	25,179	624	26,231	26,568	26,966	2,346	29,313	0	0	624	26,231	26,592	26,991	2,348	29,339
265	0	0	0	0	0	0	0	0	0	0	0	0	88,816	6,313	94,195	95,608	8,318	103,926
266	0	0	0	0	0	0	0	0	0	0	0	0	100,256	7,139	106,340	107,935	9,390	117,326
267	0	0	0	0	0	0	0	0	0	0	0	0	65,312	4,602	69,227	70,266	6,113	76,379
268	0	0	0	0	0	0	0	0	0	0	0	0	132,704	9,440	140,748	142,859	12,429	155,288
269	0	0	0	0	0	0	0	0	0	0	0	0	137,072	9,735	145,365	147,546	12,836	160,382
270	0	0	0	0	603	0	597	606	53	658	0	0	92,144	6,549	97,724	99,190	8,630	107,819
271	0	0	0	0	0	0	0	0	0	0	0	0	129,584	9,204	137,425	139,486	12,135	151,622
272	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
273	0	27,728	2,412	30,140	2,268	31,209	33,119	33,616	2,925	36,540	0	0	2,288	31,209	33,168	33,665	2,929	36,594
274	97,984	7,773	9,201	114,958	109,424	17,095	125,165	127,043	11,053	138,095	97,984	48	119,326	17,095	135,082	137,108	11,928	149,036
275	110,621	13,291	10,780	134,692	111,453	13,350	123,467	125,319	10,903	136,222	110,621	54	122,633	13,350	134,647	136,666	11,890	148,556
276	105,052	14,778	10,425	130,255	106,978	15,014	120,686	122,496	10,657	133,154	105,052	51	117,594	15,014	131,306	133,276	11,595	144,870

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
277	258,821	62,448	27,950	349,219	260,069	63,923	320,524	325,332	28,304	353,636	258,821	126	286,225	63,923	346,710	351,910	30,616	382,527
278	80,365	49,262	11,278	140,905	87,021	63,009	148,424	150,651	13,107	163,757	80,365	39	95,143	63,009	156,599	158,948	13,828	172,776
279	102,548	38,327	12,256	153,131	107,956	45,053	151,371	153,642	13,367	167,009	102,548	50	118,320	45,053	161,768	164,195	14,285	178,479
280	142,516	9,488	13,224	165,228	142,932	21,878	163,046	165,492	14,398	179,889	0	0	142,932	21,878	163,191	165,639	14,411	180,050
281	0	127,236	11,070	138,305	33,488	190,012	221,108	224,424	19,525	243,949	0	0	33,488	190,012	221,305	224,625	19,542	244,167
282	198,248	79,122	24,131	301,501	203,448	81,482	281,881	286,109	24,891	311,000	198,248	96	223,483	81,482	301,970	306,500	26,665	333,165
283	0	243,135	21,153	264,287	0	243,135	240,532	244,140	21,240	265,381	0	0	0	243,135	240,747	244,358	21,259	265,618
284	240,778	38,332	24,283	303,392	241,836	38,391	277,228	281,387	24,481	305,868	240,778	117	266,169	38,391	301,570	306,093	26,630	332,723
285	139,127	19,682	13,816	172,625	184,887	41,984	224,442	227,809	19,819	247,628	139,127	68	198,947	41,984	238,564	242,143	21,066	263,209
286	90,108	11,430	8,834	110,372	94,268	13,672	106,785	108,387	9,430	117,816	90,108	44	103,374	13,672	115,897	117,635	10,234	127,870
287	276,086	97,247	32,480	405,813	314,150	120,021	429,525	435,967	37,929	473,897	276,086	134	342,051	120,021	457,535	464,398	40,403	504,800
288	43,493	37,343	7,033	87,869	44,109	37,343	80,580	81,789	7,116	88,905	43,493	21	48,513	37,343	85,013	86,288	7,507	93,795
289	67,766	5,310	6,358	79,434	67,974	7,139	74,310	75,424	6,562	81,986	67,766	33	74,823	7,139	81,157	82,375	7,167	89,541
290	83,560	46,568	11,321	141,449	83,560	46,568	128,735	130,666	11,368	142,034	83,560	41	92,005	46,568	137,212	139,270	12,116	151,386
291	102,845	26,537	11,256	140,638	112,413	29,841	140,731	142,842	12,427	155,269	102,845	50	122,806	29,841	151,148	153,415	13,347	166,762
292	99,507	39,661	12,108	151,276	99,507	40,015	138,029	140,099	12,189	152,288	99,507	48	109,563	40,015	148,109	150,331	13,079	163,410
293	107,892	28,692	11,883	148,467	110,804	44,799	153,938	156,247	13,593	169,840	107,892	52	121,708	44,799	164,871	167,344	14,559	181,903
294	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
295	0	0	0	0	3	0	3	3	0	4	0	0	3	0	3	3	0	4
296	0	0	0	0	4	0	4	4	0	4	0	0	4	0	4	4	0	4
297	0	0	0	0	0	0	0	0	0	0	0	0	49,296	3,481	52,259	53,043	4,615	57,657
298	0	0	0	0	0	0	0	0	0	0	0	0	45,968	3,245	48,730	49,461	4,303	53,764
299	0	0	0	0	0	0	0	0	0	0	0	0	103,168	7,316	109,399	111,040	9,660	120,701
300	0	0	0	0	0	0	0	0	0	0	0	0	52,832	3,776	56,052	56,893	4,950	61,843
301	0	7,266	632	7,898	0	82,786	81,900	83,128	7,232	90,361	0	0	0	82,786	81,973	83,203	7,239	90,441
302	40,999	16,424	4,996	62,420	53,687	55,128	107,651	109,266	9,506	118,772	40,999	20	57,831	55,128	111,850	113,528	9,877	123,405
303	67,613	208,691	24,038	300,342	67,613	312,118	375,667	381,302	33,173	414,475	67,613	33	74,446	312,118	382,768	388,509	33,800	422,309
304	181,324	22,032	17,692	221,048	205,660	30,469	233,602	237,106	20,628	257,734	181,324	88	223,984	30,469	251,955	255,734	22,249	277,983

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
305	75,141	62,109	11,941	149,190	88,661	70,369	157,328	159,687	13,893	173,580	75,141	37	96,254	70,369	164,987	167,462	14,569	182,031
306	86,643	37,464	10,797	134,904	101,426	38,526	138,454	140,531	12,226	152,757	86,643	42	110,182	38,526	147,247	149,456	13,003	162,459
307	111,422	22,048	11,612	145,082	120,990	23,051	142,499	144,637	12,583	157,220	111,422	54	132,250	23,051	153,776	156,083	13,579	169,662
308	14,236	20,477	3,020	37,733	14,652	20,595	34,870	35,393	3,079	38,472	14,236	7	16,090	20,595	36,325	36,870	3,208	40,078
309	59,879	5,529	5,690	71,098	60,919	5,588	65,795	66,782	5,810	72,592	59,879	29	66,970	5,588	71,846	72,923	6,344	79,268
310	0	155,249	13,507	168,756	14,144	174,365	186,491	189,289	16,468	205,757	0	0	14,144	174,365	186,658	189,458	16,483	205,941
311	148,578	98,368	21,484	268,430	175,894	122,735	295,433	299,864	26,088	325,952	0	0	175,894	122,735	295,696	300,132	26,111	326,243
312	154,433	29,383	15,992	199,809	159,425	31,153	188,539	191,367	16,649	208,016	154,433	75	175,032	31,153	204,161	207,223	18,028	225,251
313	43,266	7,654	4,430	55,350	45,762	8,480	53,661	54,466	4,739	59,204	43,266	21	50,134	8,480	58,038	58,909	5,125	64,034
314	80,479	26,602	9,316	116,396	90,347	27,605	116,689	118,439	10,304	128,743	80,479	39	98,480	27,605	124,846	126,719	11,025	137,743
315	198,432	8,734	18,023	225,189	199,472	19,885	217,009	220,264	19,163	239,427	0	0	199,472	19,885	217,203	220,461	19,180	239,641
316	64,596	1,637	5,762	71,996	89,325	3,407	91,739	93,116	8,101	101,217	0	0	89,348	3,407	91,845	93,222	8,110	101,333
317	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
318	84,023	32,779	10,162	126,963	93,591	38,974	131,146	133,113	11,581	144,694	84,023	41	102,082	38,974	139,671	141,766	12,334	154,099
319	164,605	33,219	17,211	215,035	170,845	34,399	203,048	206,093	17,930	224,024	164,605	80	187,480	34,399	219,700	222,996	19,401	242,397
320	72,805	18,832	7,972	99,609	73,637	18,891	91,537	92,910	8,083	100,993	72,805	35	80,994	18,891	98,904	100,388	8,734	109,121
321	11,580	92,152	9,025	112,757	11,580	92,152	102,622	104,161	9,062	113,223	11,580	6	12,750	92,152	103,872	105,430	9,172	114,603
322	45,516	27,067	6,315	78,898	49,844	27,834	76,846	77,999	6,786	84,785	45,516	22	54,484	27,834	81,510	82,733	7,198	89,930
323	38,489	13,627	4,534	56,651	39,321	16,754	55,475	56,307	4,899	61,206	38,489	19	43,211	16,754	59,376	60,267	5,243	65,510
324	96,150	18,210	9,949	124,309	96,358	146,122	239,884	243,483	21,183	264,666	96,150	47	106,074	146,122	249,720	253,465	22,051	275,517
325	42,163	41,019	7,237	90,418	55,475	43,910	98,321	99,796	8,682	108,478	42,163	20	59,736	43,910	102,628	104,167	9,063	113,230
326	67,774	1,147	5,996	74,916	71,236	1,265	71,725	72,801	6,334	79,134	67,774	33	78,159	1,265	78,643	79,823	6,945	86,768
327	84,738	34,579	10,381	129,698	111,362	37,175	146,947	149,152	12,976	162,128	84,738	41	119,926	37,175	155,558	157,891	13,737	171,628
328	69,679	40,461	9,582	119,722	74,879	41,759	115,389	117,120	10,189	127,309	69,679	34	81,920	41,759	122,464	124,301	10,814	135,116
329	61,127	46,404	9,355	116,885	61,293	46,876	107,010	108,616	9,450	118,065	61,127	30	67,512	46,876	113,264	114,963	10,002	124,965
330	0	143	12	156	0	143	142	144	13	157	0	0	87,984	6,397	93,455	94,856	8,253	103,109
331	0	0	0	0	0	0	0	0	0	0	0	0	46,176	3,304	48,994	49,729	4,326	54,055
332	0	0	0	0	0	0	0	0	0	0	0	0	42,640	3,009	45,201	45,879	3,991	49,870

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
333	0	0	0	0	1	0	1	1	0	1	0	0	1	0	1	1	0	1
334	0	0	0	0	0	0	0	0	0	0	0	0	43,680	3,127	46,347	47,043	4,093	51,135
335	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
336	0	0	0	0	0	0	0	0	0	0	0	0	47,840	3,422	50,759	51,520	4,482	56,002
337	81,796	42,730	10,834	135,360	81,796	42,730	123,194	125,042	10,879	135,920	81,796	40	90,062	42,730	131,489	133,461	11,611	145,072
338	89,461	40,877	11,339	141,678	89,877	41,290	129,763	131,710	11,459	143,169	89,461	43	98,918	41,290	138,831	140,914	12,259	153,173
339	101,910	63,357	14,378	179,644	119,798	64,478	182,303	185,037	16,098	201,136	101,910	50	130,096	64,478	192,663	195,553	17,013	212,566
340	77,140	1,933	6,879	85,952	77,140	1,933	78,227	79,400	6,908	86,308	77,140	37	84,936	1,933	86,016	87,306	7,596	94,902
341	84,208	19,253	9,001	112,462	84,831	19,253	102,970	104,514	9,093	113,607	84,208	41	93,342	19,253	111,489	113,162	9,845	123,007
342	96,509	20,388	10,170	127,067	101,085	22,689	122,449	124,286	10,813	135,099	96,509	47	110,838	22,689	132,216	134,199	11,675	145,875
343	81,250	11,907	8,105	101,262	81,458	11,907	92,366	93,752	8,156	101,908	81,250	39	89,669	11,907	100,579	102,088	8,882	110,969
344	117,295	23,436	12,244	152,975	124,120	23,967	146,503	148,700	12,937	161,637	117,295	57	136,012	23,967	158,409	160,785	13,988	174,773
345	119,605	22,982	12,405	154,991	157,253	26,699	181,983	184,712	16,070	200,782	119,605	58	169,340	26,699	194,113	197,025	17,141	214,166
346	151,932	33,683	16,149	201,764	157,964	36,220	192,106	194,988	16,964	211,952	151,932	74	173,319	36,220	207,481	210,593	18,322	228,915
347	63,641	7,128	6,157	76,927	68,841	8,780	76,791	77,943	6,781	84,724	63,641	31	75,273	8,780	83,228	84,476	7,349	91,825
348	578	25,140	2,238	27,956	578	42,604	42,721	43,361	3,772	47,134	578	0	637	42,604	42,817	43,459	3,781	47,240
350	0	0	0	0	7	0	7	7	1	8	0	0	7	0	7	7	1	8
351	8,289	1,006	809	10,103	8,289	1,773	9,954	10,103	879	10,982	0	0	8,289	1,773	9,962	10,112	880	10,992
352	98,023	39,248	11,943	149,213	99,447	41,372	139,312	141,401	12,302	153,703	98,023	48	109,385	41,372	149,276	151,515	13,182	164,697
353	0	49,254	4,285	53,539	7,075	53,915	60,337	61,242	5,328	66,570	0	0	7,075	53,915	60,391	61,297	5,333	66,630
354	71,378	5,314	6,672	83,364	71,378	5,314	75,871	77,009	6,700	83,709	71,378	35	78,592	5,314	83,081	84,328	7,337	91,664
355	58,977	42,357	8,816	110,150	123,873	59,703	181,611	184,335	16,037	200,373	58,977	29	129,833	59,703	187,675	190,490	16,573	207,063
356	87,941	48,778	11,895	148,613	88,149	48,778	135,461	137,493	11,962	149,455	87,941	43	97,036	48,778	144,382	146,548	12,750	159,297
357	191,364	66,262	22,414	280,040	195,316	68,917	261,405	265,326	23,083	288,410	191,364	93	214,655	68,917	280,788	285,000	24,795	309,795
358	94,465	25,706	10,455	130,626	95,505	28,007	122,190	124,023	10,790	134,813	94,465	46	105,051	28,007	131,752	133,728	11,634	145,362
359	85,066	26,879	9,739	121,685	85,066	38,207	121,954	123,783	10,769	134,552	85,066	41	93,663	38,207	130,575	132,534	11,530	144,064
360	453	276	63	793	453	25,174	25,353	25,733	2,239	27,972	0	0	453	25,174	25,375	25,756	2,241	27,997
361	114,092	11,062	10,888	136,042	155,900	13,894	167,977	170,496	14,833	185,330	114,092	55	167,430	13,894	179,543	182,237	15,855	198,091

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
362	167,184	27,577	16,944	211,705	170,096	29,583	197,542	200,505	17,444	217,949	167,184	81	186,991	29,583	214,448	217,665	18,937	236,601
363	170,642	4,617	15,248	190,507	199,970	27,863	225,395	228,776	19,904	248,679	170,642	83	217,215	27,863	242,672	246,312	21,429	267,741
364	0	0	0	0	0	0	0	0	0	0	0	0	47,840	3,422	50,759	51,520	4,482	56,002
365	0	0	0	0	0	0	0	0	0	0	0	0	44,304	3,127	46,965	47,670	4,147	51,817
366	0	0	0	0	0	0	0	0	0	0	0	0	45,968	3,245	48,730	49,461	4,303	53,764
367	0	0	0	0	0	0	0	0	0	0	0	0	48,672	3,481	51,641	52,415	4,560	56,976
368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
369	127,505	19,691	12,806	160,001	127,708	19,868	145,996	148,186	12,892	161,078	127,505	62	140,598	19,868	158,890	161,273	14,031	175,304
370	4	42,073	3,661	45,738	4	43,607	43,145	43,792	3,810	47,602	4	0	5	43,607	43,183	43,831	3,813	47,645
371	97,256	17,482	9,982	124,721	151,960	21,140	171,248	173,817	15,122	188,939	97,256	47	161,789	21,140	181,133	183,850	15,995	199,845
372	43,528	6,639	4,365	54,532	44,360	6,934	50,745	51,506	4,481	55,987	43,528	21	48,759	6,934	55,146	55,973	4,870	60,843
373	136,907	15,521	13,261	165,689	138,571	16,052	152,968	155,262	13,508	168,770	136,907	67	152,407	16,052	166,804	169,306	14,730	184,036
374	85,231	9,069	8,204	102,503	97,711	14,202	110,715	112,375	9,777	122,152	85,231	41	106,324	14,202	119,342	121,132	10,539	131,671
375	14,908	39,336	4,719	58,964	16,060	46,121	61,515	62,438	5,432	67,870	14,908	7	17,663	46,121	63,158	64,105	5,577	69,682
376	15,333	6,528	1,902	23,763	16,581	7,413	23,737	24,094	2,096	26,190	15,333	7	18,131	7,413	25,293	25,672	2,233	27,906
377	171,087	29,151	17,421	217,659	186,687	31,747	216,096	219,338	19,082	238,420	171,087	83	203,977	31,747	233,409	236,910	20,611	257,522
378	0	20,077	1,747	21,824	0	41,022	40,583	41,192	3,584	44,776	0	0	0	41,022	40,619	41,229	3,587	44,816
379	80,781	22,168	8,957	111,906	80,781	29,720	109,319	110,959	9,653	120,612	0	0	80,781	29,720	109,416	111,058	9,662	120,720
380	0	161,010	14,008	175,018	0	170,922	169,093	171,629	14,932	186,561	0	0	0	170,922	169,244	171,783	14,945	186,728
381	9,178	11,184	1,772	22,134	10,584	13,249	23,578	23,932	2,082	26,014	9,178	4	11,562	13,249	24,568	24,936	2,169	27,106
382	0	47,168	4,104	51,272	0	50,590	50,049	50,800	4,420	55,219	0	0	0	50,590	50,094	50,845	4,424	55,268
383	119,378	23,797	12,456	155,631	122,858	24,859	146,136	148,329	12,905	161,233	0	0	122,914	24,859	146,322	148,517	12,921	161,438
384	100,005	7,107	9,319	116,430	101,669	7,579	108,078	109,700	9,544	119,243	100,005	49	111,775	7,579	118,182	119,955	10,436	130,391
385	0	4,911	427	5,338	0	4,911	4,858	4,931	429	5,360	0	0	0	4,911	4,862	4,935	429	5,365
386	641	31,548	2,800	34,990	641	35,501	35,756	36,292	3,157	39,449	641	0	706	35,501	35,852	36,390	3,166	39,555
387	0	82,897	7,212	90,109	158,912	204,496	359,518	364,911	31,747	396,658	0	0	158,912	204,496	359,839	365,237	31,776	397,012
388	22,736	10,892	2,926	36,554	32,814	14,786	47,090	47,797	4,158	51,955	22,736	11	35,111	14,786	49,408	50,149	4,363	54,512
389	0	62,122	5,405	67,526	0	88,259	87,314	88,624	7,710	96,334	0	0	0	88,259	87,392	88,703	7,717	96,420

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
390	0	59,485	5,175	64,660	0	62,494	61,825	62,752	5,459	68,212	0	0	0	62,494	61,880	62,808	5,464	68,273
391	146,880	9,645	13,618	170,143	146,880	10,471	155,667	158,002	13,746	171,748	146,880	71	161,723	10,471	170,503	173,061	15,056	188,117
392	87,806	17,626	9,173	114,605	87,806	18,039	104,712	106,283	9,247	115,529	87,806	43	96,680	18,039	113,592	115,296	10,031	125,327
393	1,309	72,831	6,450	80,590	1,309	144,516	144,264	146,428	12,739	159,167	1,309	1	1,441	144,516	144,524	146,691	12,762	159,454
394	0	56,349	4,902	61,252	0	61,423	60,766	61,677	5,366	67,043	0	0	0	61,423	60,820	61,733	5,371	67,103
395	51,623	4,993	4,926	61,542	52,663	5,111	57,156	58,013	5,047	63,060	51,623	25	57,880	5,111	62,373	63,308	5,508	68,816
396	0	110,679	9,629	120,308	0	110,679	109,494	111,137	9,669	120,805	0	0	0	110,679	109,592	111,236	9,678	120,913
397	150,356	11,678	14,097	176,131	150,772	11,678	160,711	163,122	14,192	177,314	150,356	73	165,967	11,678	175,900	178,539	15,533	194,072
398	153,300	28,752	15,839	197,891	154,340	28,870	181,249	183,968	16,005	199,973	153,300	74	169,833	28,870	196,751	199,702	17,374	217,076
399	124,935	5,561	11,353	141,850	128,678	10,340	137,530	139,593	12,145	151,738	124,935	61	141,305	10,340	150,156	152,408	13,260	165,668
400	173,193	31,834	17,837	222,865	221,865	44,873	263,884	267,842	23,302	291,144	173,193	84	239,368	44,873	281,450	285,672	24,853	310,525
401	161,176	29,975	16,630	207,781	186,136	31,981	215,782	219,019	19,055	238,074	161,176	78	202,424	31,981	232,103	235,585	20,496	256,080
402	0	0	0	0	0	0	0	0	0	0	0	0	99,424	7,080	105,458	107,040	9,312	116,352
403	200,784	19,172	19,136	239,092	217,008	28,081	242,466	246,103	21,411	267,514	200,784	98	237,299	28,081	262,774	266,716	23,204	289,920
404	148,960	59,511	18,137	226,607	159,776	62,874	220,267	223,571	19,451	243,021	148,960	72	174,829	62,874	235,369	238,899	20,784	259,684
405	209,798	28,948	20,771	259,517	221,739	32,311	251,331	255,101	22,194	277,294	209,798	102	242,940	32,311	272,549	276,637	24,067	300,704
406	0	0	0	0	0	0	0	0	0	0	0	0	105,664	7,493	112,046	113,726	9,894	123,621
407	0	0	0	0	0	0	0	0	0	0	0	0	82,368	5,841	87,343	88,653	7,713	96,366
408	75,429	12,202	7,624	95,255	75,845	12,497	87,396	88,707	7,718	96,425	75,429	37	83,468	12,497	95,022	96,447	8,391	104,838
409	0	0	0	0	0	0	0	0	0	0	0	0	47,632	3,363	50,494	51,252	4,459	55,711
410	0	0	0	0	0	0	0	0	0	0	0	0	44,512	3,186	47,230	47,938	4,171	52,109
411	0	0	0	0	0	0	0	0	0	0	0	0	46,384	3,245	49,142	49,879	4,339	54,218
412	0	0	0	0	0	0	0	0	0	0	0	0	48,464	3,481	51,435	52,206	4,542	56,748
413	385	2,273	231	2,890	385	2,273	2,630	2,669	232	2,901	0	0	385	2,273	2,632	2,672	232	2,904
414	34,182	4,981	3,407	42,570	39,798	9,465	48,735	49,466	4,304	53,770	34,182	17	43,252	9,465	52,199	52,982	4,609	57,592
415	0	230,953	20,093	251,046	0	240,275	237,704	241,269	20,990	262,260	0	0	0	240,275	237,916	241,485	21,009	262,494
416	4,003	31,613	3,099	38,715	4,835	39,873	44,230	44,893	3,906	48,799	4,003	2	5,240	39,873	44,670	45,340	3,945	49,285
417	0	39,683	3,452	43,136	21,424	53,607	74,228	75,342	6,555	81,896	0	0	21,424	53,607	74,294	75,409	6,561	81,969

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
418	193,037	754	16,860	210,651	195,117	6,654	199,612	202,606	17,627	220,233	193,037	94	214,625	6,654	219,107	222,393	19,348	241,741
419	101,843	10,169	9,745	121,757	102,051	10,169	111,019	112,684	9,804	122,487	101,843	49	112,343	10,169	121,309	123,128	10,712	133,841
420	88,241	29,195	10,217	127,653	111,329	36,393	146,141	148,333	12,905	161,238	88,241	43	120,247	36,393	155,101	157,428	13,696	171,124
421	73,489	5,583	6,879	85,951	73,689	6,291	79,124	80,311	6,987	87,298	73,489	36	81,123	6,291	86,556	87,854	7,643	95,498
422	104,256	11,777	10,095	126,127	104,672	14,491	117,887	119,655	10,410	130,066	104,256	51	115,208	14,491	128,425	130,351	11,341	141,692
423	90,786	14,987	9,202	114,975	105,138	19,884	123,684	125,539	10,922	136,461	90,786	44	114,313	19,884	132,879	134,872	11,734	146,606
424	158,620	6,096	14,330	179,046	159,451	6,214	163,892	166,351	14,473	180,823	158,620	77	175,481	6,214	179,911	182,610	15,887	198,497
425	121,466	17,300	12,073	150,839	134,778	21,607	154,711	157,032	13,662	170,694	121,466	59	147,053	21,607	167,004	169,509	14,747	184,256
426	92,955	14,580	9,356	116,890	93,579	14,580	107,001	108,606	9,449	118,055	92,955	45	102,973	14,580	116,398	118,144	10,279	128,423
427	112,584	13,046	10,930	136,560	113,416	13,223	125,284	127,163	11,063	138,227	112,584	55	124,794	13,223	136,662	138,712	12,068	150,780
428	117,064	32,878	13,045	162,987	118,936	33,232	150,539	152,797	13,293	166,091	117,064	57	130,766	33,232	162,388	164,824	14,340	179,163
429	42,362	6,555	4,256	53,173	47,354	13,163	59,869	60,768	5,287	66,054	42,362	21	51,635	13,163	64,162	65,124	5,666	70,790
430	0	30,763	2,676	33,439	0	31,058	30,725	31,186	2,713	33,899	0	0	0	31,058	30,753	31,214	2,716	33,930
431	55,344	1,255	4,924	61,522	55,552	1,255	56,198	57,041	4,963	62,004	55,344	27	61,145	1,255	61,787	62,713	5,456	68,169
432	132,934	2,386	11,773	147,094	134,390	3,271	136,188	138,231	12,026	150,257	132,934	65	147,824	3,271	149,612	151,856	13,211	165,068
433	90,515	17,167	9,368	117,051	93,219	20,471	112,473	114,160	9,932	124,092	90,515	44	102,366	20,471	121,631	123,456	10,741	134,196
434	107,971	56,235	14,286	178,491	107,971	56,235	162,448	164,885	14,345	179,230	107,971	52	118,882	56,235	173,397	175,998	15,312	191,310
435	116	27,727	2,422	30,265	42,964	32,742	74,896	76,019	6,614	82,633	116	0	42,975	32,742	74,974	76,099	6,621	82,719
436	578	49,196	4,330	54,104	10,770	52,087	62,184	63,116	5,491	68,607	578	0	10,828	52,087	62,297	63,231	5,501	68,732
437	116,871	0	10,168	127,039	116,871	0	115,620	117,354	10,210	127,564	116,871	57	128,682	0	127,418	129,329	11,252	140,581
438	111,564	4,681	10,113	126,358	113,228	4,740	116,705	118,456	10,306	128,761	111,564	54	124,503	4,740	127,973	129,893	11,301	141,193
439	0	2,487	216	2,704	0	2,487	2,461	2,498	217	2,715	0	0	0	2,487	2,463	2,500	217	2,717
440	62,912	21,717	7,363	91,992	66,240	23,900	89,175	90,513	7,875	98,388	62,912	31	72,598	23,900	95,550	96,983	8,438	105,421
441	66,995	31,112	8,535	106,642	89,291	49,697	137,500	139,563	12,142	151,705	66,995	33	96,061	49,697	144,327	146,492	12,745	159,237
442	100,933	54,739	13,543	169,216	112,165	58,810	169,145	171,682	14,936	186,619	100,933	49	122,365	58,810	179,396	182,087	15,842	197,929
443	162,248	38,618	17,475	218,341	162,828	40,447	201,099	204,116	17,758	221,874	162,248	79	179,268	40,447	217,557	220,820	19,211	240,032
444	231,334	9,062	20,914	261,311	250,768	10,124	258,100	261,972	22,792	284,763	231,334	112	274,146	10,124	281,479	285,701	24,856	310,557
445	105,717	19,348	10,881	135,946	116,741	24,068	139,302	141,392	12,301	153,693	105,717	51	127,425	24,068	150,005	152,255	13,246	165,501

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
446	110,959	17,365	11,164	139,488	123,647	22,734	144,814	146,986	12,788	159,774	110,959	54	134,860	22,734	156,046	158,387	13,780	172,166
447	120,460	26,980	12,827	160,267	124,620	39,901	162,760	165,202	14,373	179,574	120,460	59	136,794	39,901	174,959	177,584	15,450	193,034
448	145,600	25,645	14,898	186,144	152,880	26,058	177,023	179,679	15,632	195,311	145,600	71	167,595	26,058	191,751	194,627	16,933	211,560
449	88,079	63,781	13,212	165,071	96,815	66,849	161,912	164,341	14,298	178,638	88,079	43	105,716	66,849	170,870	173,433	15,089	188,522
450	115,162	17,461	11,538	144,161	122,026	21,768	142,255	144,389	12,562	156,951	115,162	56	133,664	21,768	153,906	156,215	13,591	169,805
451	18,045	10,890	2,517	31,453	84,119	85,289	167,595	170,109	14,799	184,908	18,045	9	86,013	85,289	169,620	172,164	14,978	187,142
452	0	49,742	4,328	54,070	4,160	50,273	53,851	54,658	4,755	59,414	0	0	4,160	50,273	53,899	54,707	4,760	59,467
453	554	175,260	15,296	191,110	1,594	471,558	468,088	475,109	41,335	516,444	554	0	1,650	471,558	468,561	475,590	41,376	516,966
454	108,069	15,929	10,788	134,786	115,349	21,357	135,243	137,272	11,943	149,215	108,069	53	126,270	21,357	146,178	148,371	12,908	161,279
455	0	27,576	2,399	29,976	0	27,576	27,281	27,690	2,409	30,100	0	0	0	27,576	27,306	27,715	2,411	30,126
456	82,836	1,742	7,358	91,937	84,500	12,126	95,592	97,026	8,441	105,468	82,836	40	92,872	12,126	103,967	105,526	9,181	114,707
457	45,159	1,526	4,062	50,747	54,935	1,998	56,324	57,169	4,974	62,143	45,159	22	59,499	1,998	60,893	61,807	5,377	67,184
458	7,857	5,168	1,133	14,159	39,265	16,142	54,814	55,637	4,840	60,477	7,857	4	40,059	16,142	55,649	56,484	4,914	61,398
459	49,672	17,532	5,847	73,051	52,584	20,836	72,635	73,724	6,414	80,138	49,672	24	57,604	20,836	77,670	78,835	6,859	85,694
460	194,704	30,959	19,633	245,296	196,142	31,077	224,787	228,159	19,850	248,009	194,704	95	215,837	31,077	244,489	248,157	21,590	269,746
461	15,685	3,978	1,711	21,373	117,605	10,704	126,935	128,839	11,209	140,048	15,685	8	119,190	10,704	128,618	130,547	11,358	141,905
462	156,410	50,359	17,989	224,758	184,906	59,740	242,028	245,658	21,372	267,031	156,410	76	200,713	59,740	257,895	261,764	22,773	284,537
463	30,639	7,781	3,342	41,762	31,048	7,781	38,414	38,990	3,392	42,382	30,639	15	34,151	7,781	41,520	42,143	3,666	45,809
464	69,925	40,264	9,586	119,775	79,701	43,273	121,658	123,483	10,743	134,226	69,925	34	86,767	43,273	128,764	130,695	11,370	142,065
465	129,393	19,362	12,942	161,697	132,929	19,598	150,895	153,158	13,325	166,483	129,393	63	146,005	19,598	163,977	166,437	14,480	180,917
466	94,677	6,133	8,770	109,580	103,413	16,753	118,879	120,662	10,498	131,160	94,677	46	112,981	16,753	128,459	130,386	11,344	141,730
467	114,409	11,854	10,985	137,248	114,617	11,854	125,118	126,994	11,049	138,043	114,409	56	126,180	11,854	136,678	138,728	12,069	150,797
468	146,228	512	12,766	159,506	156,628	7,828	162,696	165,136	14,367	179,503	146,228	71	171,405	7,828	177,473	180,135	15,672	195,807
469	47,002	10,966	5,043	63,011	52,618	11,261	63,195	64,143	5,580	69,723	47,002	23	57,368	11,261	67,954	68,974	6,001	74,975
470	75,533	8,531	7,314	91,378	102,781	11,658	113,215	114,913	9,997	124,910	75,533	37	110,415	11,658	120,874	122,687	10,674	133,361
471	222,211	20,033	21,075	263,320	234,691	22,688	254,625	258,444	22,485	280,929	222,211	108	257,147	22,688	277,088	281,244	24,468	305,712
472	121,378	9,398	11,378	142,154	121,586	11,994	132,151	134,133	11,670	145,803	121,378	59	133,852	11,994	144,415	146,581	12,753	159,333
473	0	84,211	7,326	91,538	16,432	98,076	113,283	114,982	10,003	124,986	0	0	16,432	98,076	113,384	115,085	10,012	125,097

TAZ	2018 Consumption (GPD) Residential	2018 Non-Residential	2018 Non-Revenue	2018 Total Potable Use	2045 Consumption (GPD) Residential	2045 Non-Residential	2045 Subtotal after Conservation	2045 Subtotal after Climate Change	2045 Non-Revenue	2045 Total Potable Use	2100 Consumption (GPD) Infill/ Redevelopment TAZ Use	2100 Infill/ Redevelopment HU	2100 Residential	2100 Non-Residential	2100 Subtotal after Conservation	2100 Subtotal after Climate Change	2100 Non-Revenue	2100 Total Potable Use
474	0	29,997	2,610	32,606	24,336	32,711	56,436	57,283	4,984	62,266	0	0	24,336	32,711	56,487	57,334	4,988	62,322
475	0	86,948	7,565	94,513	15,184	96,388	110,378	112,034	9,747	121,781	0	0	15,184	96,388	110,477	112,134	9,756	121,890
476	0	10,776	937	11,713	113,568	227,070	336,992	342,047	29,758	371,805	0	0	113,568	227,070	337,293	342,352	29,785	372,137
477	13,395	24,883	3,330	41,607	15,249	24,942	39,760	40,357	3,511	43,868	0	0	15,267	24,942	39,813	40,411	3,516	43,926
478	369	3,811	364	4,543	369	152,609	151,340	153,610	13,364	166,974	0	0	369	152,609	151,475	153,747	13,376	167,124
479	0	262,680	22,853	285,533	0	324,335	320,864	325,676	28,334	354,010	0	0	0	324,335	321,150	325,967	28,359	354,326
480	5,234	23,096	2,465	30,795	7,106	35,781	42,428	43,065	3,747	46,811	5,234	3	7,635	35,781	42,990	43,635	3,796	47,431
481	100,439	21,302	10,591	132,333	112,711	23,013	134,272	136,286	11,857	148,142	100,439	49	122,861	23,013	144,442	146,608	12,755	159,363
482	102,999	20,812	10,772	134,583	113,607	26,653	138,759	140,841	12,253	153,094	102,999	50	124,016	26,653	149,190	151,428	13,174	164,602
483	108,339	33,165	12,311	153,815	140,163	43,136	181,337	184,057	16,013	200,070	108,339	53	151,112	43,136	192,340	195,225	16,985	212,210
484	171,844	13,678	16,140	201,662	172,260	23,236	193,403	196,304	17,078	213,383	171,844	83	189,626	23,236	210,772	213,933	18,612	232,545
485	114,563	41,860	13,609	170,032	118,723	42,863	159,856	162,254	14,116	176,370	114,563	56	130,300	42,863	171,463	174,035	15,141	189,176
486	165,880	45,663	18,404	229,947	171,556	49,439	218,630	221,909	19,306	241,215	165,880	81	188,320	49,439	235,424	238,955	20,789	259,744
487	270,396	59,031	28,660	358,087	286,505	60,270	343,063	348,209	30,294	378,504	270,396	131	313,830	60,270	370,427	375,984	32,711	408,694
488	75,401	1,285	6,672	83,357	87,257	12,082	98,275	99,749	8,678	108,428	75,401	37	94,877	12,082	105,908	107,497	9,352	116,849
489	70,311	4,225	6,485	81,021	76,551	5,051	80,729	81,940	7,129	89,068	70,311	34	83,656	5,051	87,836	89,154	7,756	96,910
490	0	41,573	3,617	45,190	0	53,491	52,919	53,713	4,673	58,386	0	0	0	53,491	52,966	53,761	4,677	58,438
491	48,846	2,546	4,471	55,864	61,534	4,021	64,854	65,827	5,727	71,554	48,846	24	66,471	4,021	69,800	70,847	6,164	77,010
492	72,245	1,811	6,443	80,498	79,941	3,522	82,569	83,808	7,291	91,099	72,245	35	87,242	3,522	89,872	91,220	7,936	99,157
493	0	37,833	3,291	41,124	56,576	48,394	103,846	105,404	9,170	114,574	0	0	56,576	48,394	103,939	105,498	9,178	114,677
494	28,797	1,025	2,594	32,416	31,293	11,999	42,828	43,470	3,782	47,252	28,797	14	34,203	11,999	45,748	46,434	4,040	50,474
495	0	250,841	21,823	272,665	0	254,204	251,484	255,256	22,207	277,463	0	0	0	254,204	251,708	255,484	22,227	277,711
496	0	41,830	3,639	45,469	3,952	44,662	48,094	48,815	4,247	53,062	0	0	3,952	44,662	48,137	48,859	4,251	53,109
497	20,308	6,574	2,339	29,221	80,212	50,824	129,634	131,578	11,447	143,025	20,308	10	82,264	50,824	131,781	133,758	11,637	145,395
498	0	74,946	6,520	81,466	0	74,946	74,144	75,256	6,547	81,803	0	0	0	74,946	74,210	75,323	6,553	81,876
499	42,514	19,854	5,426	67,794	44,802	21,093	65,190	66,168	5,757	71,924	42,514	21	49,098	21,093	69,502	70,545	6,137	76,682
500	124,690	24,818	13,007	162,516	132,594	25,349	156,253	158,597	13,798	172,395	124,690	61	145,195	25,349	168,870	171,403	14,912	186,315
501	85,446	11,220	8,410	105,075	88,982	24,377	112,145	113,827	9,903	123,730	85,446	42	97,617	24,377	120,795	122,607	10,667	133,274

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
502	201,138	13,330	18,659	233,127	215,490	17,932	230,924	234,388	20,392	254,780	201,138	98	235,817	17,932	251,257	255,026	22,187	277,213
503	59,673	17,916	6,750	84,339	70,281	29,539	98,752	100,233	8,720	108,953	59,673	29	76,311	29,539	104,811	106,383	9,255	115,639
504	47,480	5,994	4,652	58,126	55,176	13,015	67,461	68,473	5,957	74,430	47,480	23	59,974	13,015	72,273	73,357	6,382	79,739
505	63,071	12,775	6,599	82,444	69,265	21,330	89,625	90,969	7,914	98,884	63,071	31	75,685	21,330	96,061	97,502	8,483	105,985
506	70,689	1,350	6,267	78,306	90,657	4,241	93,882	95,291	8,290	103,581	70,689	34	97,800	4,241	101,040	102,555	8,922	111,478
507	14,862	7,073	1,908	23,843	40,238	13,917	53,575	54,378	4,731	59,109	14,862	7	41,739	13,917	55,110	55,936	4,866	60,803
508	28,655	5,719	2,990	37,364	57,359	16,634	73,200	74,298	6,464	80,762	28,655	14	60,254	16,634	76,133	77,275	6,723	83,998
509	31,229	10,382	3,620	45,232	40,797	26,902	66,975	67,980	5,914	73,894	31,229	15	43,953	26,902	70,160	71,212	6,195	77,408
510	91,919	11,050	8,958	111,927	103,359	11,935	114,060	115,771	10,072	125,843	91,919	45	112,648	11,935	123,360	125,210	10,893	136,103
511	70	113,684	9,897	123,651	4,496	113,920	117,148	118,905	10,345	129,250	70	0	4,503	113,920	117,260	119,018	10,355	129,373
512	4,572	16,187	1,806	22,565	4,780	21,910	26,404	26,800	2,332	29,132	4,572	2	5,242	21,910	26,885	27,289	2,374	29,663
513	99,965	16,151	10,102	126,218	99,965	17,036	115,749	117,485	10,221	127,706	99,965	49	110,067	17,036	125,855	127,743	11,114	138,857
514	21,910	16,605	3,351	41,866	32,942	20,971	53,336	54,136	4,710	58,846	21,910	11	35,156	20,971	55,576	56,409	4,908	61,317
515	0	72,906	6,343	79,249	6,240	76,918	82,268	83,502	7,265	90,766	0	0	6,240	76,918	82,341	83,576	7,271	90,847
516	101,988	10,653	9,800	122,440	106,356	12,482	117,566	119,329	10,382	129,711	101,988	50	116,663	12,482	127,876	129,794	11,292	141,086
517	75,157	3,682	6,859	85,699	85,973	6,101	91,089	92,456	8,044	100,499	75,157	37	93,569	6,101	98,691	100,172	8,715	108,887
518	63,700	5,504	6,021	75,224	70,564	7,687	77,413	78,574	6,836	85,410	63,700	31	77,001	7,687	83,856	85,114	7,405	92,519
519	79,329	14,957	8,203	102,489	98,049	18,969	115,765	117,502	10,223	127,724	79,329	39	106,066	18,969	123,807	125,664	10,933	136,597
520	156,591	27,906	16,051	200,548	166,367	32,272	196,513	199,460	17,353	216,813	156,591	76	182,192	32,272	212,358	215,543	18,752	234,295
521	181,316	41,795	19,411	242,522	193,796	43,093	234,354	237,869	20,695	258,563	181,316	88	212,120	43,093	252,706	256,497	22,315	278,812
522	28,523	41,349	6,079	75,951	28,523	44,948	72,685	73,775	6,418	80,194	28,523	14	31,405	44,948	75,604	76,738	6,676	83,414
523	46,472	13,464	5,214	65,150	70,392	18,184	87,628	88,942	7,738	96,680	46,472	23	75,088	18,184	92,356	93,742	8,156	101,897
524	77,783	46,822	10,841	135,446	100,247	57,560	156,118	158,460	13,786	172,246	77,783	38	108,107	57,560	164,041	166,501	14,486	180,987
525	125,204	17,138	12,384	154,726	152,452	19,262	169,877	172,425	15,001	187,426	125,204	61	165,105	19,262	182,557	185,295	16,121	201,416
526	142,431	19,463	14,085	175,979	162,191	21,174	181,402	184,123	16,019	200,142	142,431	69	176,585	21,174	195,817	198,754	17,292	216,046
527	125,728	7,376	11,580	144,684	150,480	9,559	158,326	160,701	13,981	174,682	125,728	61	163,186	9,559	171,049	173,614	15,104	188,719
528	131,318	157,764	25,150	314,232	152,326	159,475	308,464	313,091	27,239	340,330	131,318	64	165,597	159,475	321,880	326,708	28,424	355,132
529	160,058	21,642	15,808	197,507	164,010	24,120	186,116	188,908	16,435	205,343	160,058	78	180,185	24,120	202,298	205,333	17,864	223,197

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
530	121,097	2,146	10,722	133,965	126,089	2,618	127,330	129,240	11,244	140,484	121,097	59	138,327	2,618	139,561	141,655	12,324	153,979
531	135,228	37,162	14,998	187,388	142,716	39,876	180,638	183,348	15,951	199,299	135,228	66	156,382	39,876	194,331	197,246	17,160	214,406
532	161,119	17,802	15,566	194,487	164,447	24,056	186,485	189,282	16,468	205,750	161,119	78	180,729	24,056	202,774	205,816	17,906	223,722
533	122,288	32,178	13,439	167,905	146,000	39,612	183,626	186,380	16,215	202,595	122,288	59	158,358	39,612	196,027	198,967	17,310	216,277
534	112,430	28,737	12,282	153,449	137,598	38,767	174,478	177,095	15,407	192,503	112,430	55	148,960	38,767	185,884	188,673	16,415	205,087
535	25,958	29,035	4,784	59,777	34,902	33,460	67,630	68,644	5,972	74,616	25,958	13	37,525	33,460	70,288	71,342	6,207	77,549
536	109,125	15,032	10,802	134,959	126,597	21,168	146,183	148,376	12,909	161,285	109,125	53	137,625	21,168	157,234	159,592	13,885	173,477
537	97,224	57,162	13,432	167,817	117,192	60,702	175,989	178,629	15,541	194,170	97,224	47	127,017	60,702	185,875	188,663	16,414	205,077
538	0	127,297	11,075	138,372	5,616	132,253	136,393	138,439	12,044	150,484	0	0	5,616	132,253	136,515	138,563	12,055	150,618
539	46,429	23,301	6,066	75,796	46,429	23,301	68,983	70,018	6,092	76,110	46,429	23	51,121	23,301	73,691	74,796	6,507	81,303
540	213,441	65,772	24,292	303,504	236,850	75,625	309,131	313,768	27,298	341,066	213,441	104	258,515	75,625	330,858	335,821	29,216	365,038
541	101,248	9,957	9,675	120,880	101,456	12,376	112,613	114,303	9,944	124,247	101,248	49	111,688	12,376	122,845	124,688	10,848	135,536
542	20,943	14,250	3,062	38,255	28,431	17,141	45,084	45,760	3,981	49,741	20,943	10	30,547	17,141	47,220	47,928	4,170	52,098
543	57,366	4,340	5,368	67,074	57,366	4,340	61,046	61,961	5,391	67,352	57,366	28	63,164	4,340	66,840	67,843	5,902	73,745
544	88,014	85,214	15,071	188,299	95,918	85,981	179,952	182,652	15,891	198,542	88,014	43	104,813	85,981	188,920	191,754	16,683	208,437
545	159,376	34,568	16,873	210,817	184,544	39,111	221,261	224,580	19,538	244,118	159,376	77	200,650	39,111	237,406	240,968	20,964	261,932
546	0	16,481	1,434	17,914	0	16,481	16,304	16,549	1,440	17,988	0	0	0	16,481	16,319	16,563	1,441	18,004
547	79,608	22,843	8,913	111,364	112,888	25,439	136,846	138,899	12,084	150,983	79,608	39	120,933	25,439	144,935	147,109	12,798	159,907
548	130,651	12,259	12,433	155,343	134,395	13,380	146,193	148,386	12,910	161,296	130,651	63	147,598	13,380	159,397	161,788	14,076	175,864
549	63,108	12,326	6,563	81,997	63,108	12,326	74,627	75,746	6,590	82,336	63,108	31	69,486	12,326	81,009	82,224	7,153	89,377
550	133,900	9,880	12,509	156,288	161,980	12,063	172,180	174,763	15,204	189,967	133,900	65	175,511	12,063	185,732	188,518	16,401	204,919
551	144,913	27,403	14,992	187,308	160,097	30,176	188,237	191,061	16,622	207,683	144,913	70	174,742	30,176	202,906	205,949	17,918	223,867
552	66,699	26,374	8,097	101,171	73,147	27,318	99,390	100,881	8,777	109,658	66,699	32	79,888	27,318	106,153	107,746	9,374	117,119
553	0	5,772	502	6,274	0	5,772	5,710	5,795	504	6,300	0	0	0	5,772	5,715	5,801	505	6,305
554	0	75,472	6,566	82,038	4,784	80,723	84,592	85,861	7,470	93,330	0	0	4,784	80,723	84,667	85,937	7,477	93,414
555	19,375	11,302	2,669	33,345	19,999	13,839	33,475	33,978	2,956	36,934	19,375	9	21,957	13,839	35,444	35,976	3,130	39,106
556	20,961	85,561	9,267	115,789	39,473	98,187	136,187	138,229	12,026	150,255	20,961	10	41,591	98,187	138,406	140,482	12,222	152,704
557	96,897	20,626	10,225	127,748	137,420	31,836	167,445	169,956	14,786	184,743	96,897	47	147,249	31,836	177,327	179,987	15,659	195,646

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
558	83,870	44,875	11,201	139,946	99,054	50,067	147,525	149,738	13,027	162,765	83,870	41	107,530	50,067	156,049	158,390	13,780	172,170
559	54,227	869	4,793	59,890	55,059	928	55,388	56,219	4,891	61,110	54,227	26	60,539	928	60,864	61,777	5,375	67,151
560	0	41,577	3,617	45,194	21,761	51,784	72,758	73,849	6,425	80,274	0	0	21,840	51,784	72,901	73,994	6,438	80,432
561	23,405	113,381	11,900	148,687	46,701	116,803	161,754	164,180	14,284	178,464	23,405	11	49,066	116,803	164,241	166,704	14,503	181,207
562	28,760	11,768	3,526	44,053	75,976	15,839	90,832	92,194	8,021	100,215	28,760	14	78,882	15,839	93,791	95,198	8,282	103,480
563	83,413	10,419	8,163	101,995	91,109	12,248	102,251	103,784	9,029	112,814	83,413	41	99,539	12,248	110,689	112,349	9,774	122,123
564	49,517	34,592	7,317	91,426	57,629	37,129	93,744	95,150	8,278	103,428	49,517	24	62,633	37,129	98,782	100,264	8,723	108,987
565	4,183	8,322	1,088	13,593	57,015	22,482	78,646	79,826	6,945	86,771	4,183	2	57,438	22,482	79,135	80,322	6,988	87,310
566	0	24,786	2,156	26,942	0	28,857	28,548	28,976	2,521	31,497	0	0	0	28,857	28,573	29,002	2,523	31,525
567	156,492	15,863	14,995	187,349	157,254	15,863	171,264	173,833	15,123	188,956	156,492	76	173,139	15,863	187,145	189,953	16,526	206,478
568	62,033	41,271	8,987	112,291	82,625	65,992	147,026	149,232	12,983	162,215	62,033	30	88,894	65,992	153,365	155,665	13,543	169,208
569	26,468	17,813	3,852	48,134	30,628	167,909	196,412	199,359	17,344	216,703	26,468	13	33,303	167,909	199,236	202,225	17,594	219,818
570	34,716	17,590	4,551	56,857	251,036	125,737	372,741	378,332	32,915	411,247	34,716	17	254,545	125,737	376,547	382,195	33,251	415,446
571	32,416	6,904	3,421	42,740	32,505	6,963	39,045	39,631	3,448	43,079	32,416	16	35,780	6,963	42,324	42,958	3,737	46,696
572	0	80,457	7,000	87,457	4,160	114,264	117,157	118,914	10,346	129,260	0	0	4,160	114,264	117,261	119,020	10,355	129,375
573	0	0	0	0	165	0	163	166	14	180	0	0	208	0	206	209	18	227
574	0	8,214	715	8,928	3,589	8,627	12,085	12,267	1,067	13,334	0	0	3,589	8,627	12,096	12,278	1,068	13,346
575	0	0	0	0	18	0	18	18	2	19	0	0	18	0	18	18	2	19
576	0	0	0	0	13	0	12	13	1	14	0	0	13	0	12	13	1	14
577	64,948	21,827	7,549	94,324	67,329	23,420	89,777	91,124	7,928	99,052	64,948	32	73,893	23,420	96,357	97,802	8,509	106,311
578	81,337	24,489	9,207	115,033	86,362	25,846	111,007	112,672	9,803	122,475	0	0	86,362	25,846	111,106	112,773	9,811	122,584
579	0	179,907	15,652	195,559	1,248	179,966	179,274	181,963	15,831	197,794	0	0	1,248	179,966	179,434	182,126	15,845	197,971
580	99,669	37,749	11,955	149,374	107,781	38,162	144,382	146,548	12,750	159,297	99,669	48	117,854	38,162	154,484	156,801	13,642	170,443
581	0	50,170	4,365	54,535	1,456	51,999	52,883	53,677	4,670	58,346	0	0	1,456	51,999	52,931	53,724	4,674	58,399
582	67,714	42,865	9,620	120,199	76,658	97,912	172,701	175,291	15,250	190,542	67,714	33	83,501	97,912	179,631	182,325	15,862	198,188
583	148,554	74,571	19,412	242,537	185,786	85,781	268,661	272,691	23,724	296,415	148,554	72	200,799	85,781	283,766	288,022	25,058	313,080
584	130,611	13,212	12,513	156,336	141,011	20,292	159,577	161,971	14,091	176,062	130,611	63	154,211	20,292	172,789	175,381	15,258	190,639
585	132,596	2,987	11,796	147,379	146,324	3,754	148,472	150,699	13,111	163,810	132,596	64	159,724	3,754	161,873	164,301	14,294	178,595

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
586	2,866	43,184	4,006	50,057	11,444	56,990	67,702	68,717	5,978	74,696	2,866	1	11,733	56,990	68,049	69,070	6,009	75,079
587	137,834	51,133	16,440	205,408	156,970	56,266	210,954	214,119	18,628	232,747	137,834	67	170,899	56,266	224,935	228,309	19,863	248,172
588	143,661	54,531	17,243	215,435	165,709	56,242	219,575	222,869	19,390	242,259	143,661	70	180,227	56,242	234,147	237,659	20,676	258,335
589	44,239	15,313	5,181	64,733	56,719	15,785	71,728	72,804	6,334	79,138	44,239	21	61,190	15,785	76,219	77,362	6,731	84,093
592	139,184	25,492	14,327	179,002	156,656	31,569	186,210	189,003	16,443	205,446	139,184	68	170,721	31,569	200,304	203,308	17,688	220,996
593	64,606	121,636	16,203	202,445	95,806	133,023	226,380	229,776	19,991	249,766	64,606	31	102,335	133,023	233,047	236,543	20,579	257,122
594	121,152	14,594	11,810	147,556	124,896	14,889	138,289	140,363	12,212	152,575	121,152	59	137,139	14,889	150,535	152,793	13,293	166,086
595	179,896	43,682	19,451	243,029	183,640	45,570	226,756	230,158	20,024	250,182	179,896	87	201,820	45,570	244,960	248,635	21,631	270,266
596	245,529	36,536	24,540	306,604	286,713	78,249	361,055	366,471	31,883	398,354	245,529	119	311,526	78,249	385,947	391,736	34,081	425,817
597	86,537	388	7,562	94,487	89,449	1,391	89,868	91,216	7,936	99,151	86,537	42	98,194	1,391	98,607	100,086	8,708	108,794
598	0	2,995	261	3,255	800	4,706	5,446	5,528	481	6,009	0	0	832	4,706	5,483	5,565	484	6,050
599	0	0	0	0	2,282	1,947	4,184	4,247	369	4,616	0	0	2,288	1,947	4,193	4,256	370	4,627
600	187,399	7,254	16,935	211,587	198,007	9,850	205,632	208,716	18,158	226,874	187,399	91	216,945	9,850	224,567	227,936	19,830	247,766
601	145,149	9,784	13,479	168,413	165,741	10,905	174,756	177,377	15,432	192,809	145,149	71	180,410	10,905	189,437	192,278	16,728	209,006
602	82,000	12,085	8,185	102,271	86,784	12,793	98,511	99,989	8,699	108,688	82,000	40	95,071	12,793	106,805	108,407	9,431	117,838
603	231,203	128,184	31,267	390,654	247,427	129,659	373,050	378,646	32,942	411,588	231,203	112	270,792	129,659	396,519	402,467	35,015	437,481
604	55,658	4,467	5,231	65,356	60,234	4,703	64,242	65,205	5,673	70,878	55,658	27	65,859	4,703	69,868	70,917	6,170	77,086
606	122,463	24,047	12,746	159,256	126,623	25,699	150,691	152,952	13,307	166,258	122,463	59	138,999	25,699	163,080	165,526	14,401	179,927
607	100,721	55,017	13,549	169,287	134,417	87,880	219,918	223,216	19,420	242,636	100,721	49	144,596	87,880	230,193	233,645	20,327	253,973
608	1,082	972	179	2,233	2,285	1,444	3,689	3,745	326	4,070	1,082	1	2,439	1,444	3,846	3,903	340	4,243
609	0	0	0	0	5,650	590	6,174	6,266	545	6,811	0	0	5,650	590	6,179	6,272	546	6,817
610	68,453	67,477	11,826	147,756	75,909	80,457	154,693	157,013	13,660	170,673	68,453	33	82,859	80,457	161,712	164,138	14,280	178,418
611	114,375	82,640	17,140	214,155	141,831	93,909	233,217	236,715	20,594	257,309	114,375	56	153,389	93,909	244,870	248,543	21,623	270,166
612	0	0	0	0	1,664	177	1,821	1,849	161	2,009	0	0	1,664	177	1,823	1,850	161	2,011
613	258,952	16,359	23,952	299,263	265,400	40,726	302,850	307,393	26,743	334,136	258,952	126	291,570	40,726	329,032	333,968	29,055	363,023
614	0	57,006	4,960	61,966	1,248	62,375	62,942	63,886	5,558	69,444	0	0	1,248	62,375	62,998	63,943	5,563	69,506
615	0	532	46	578	43	591	627	636	55	692	0	0	43	591	627	637	55	692
616	0	21,785	1,895	23,680	32,656	34,470	66,407	67,403	5,864	73,267	0	0	32,656	34,470	66,466	67,463	5,869	73,333

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
617	250,109	34,869	24,793	309,771	250,109	34,869	281,928	286,157	24,896	311,053	250,109	122	275,385	34,869	307,207	311,815	27,128	338,943
618	1,316	22,805	2,099	26,220	13,588	26,286	39,448	40,039	3,483	43,523	1,316	1	13,721	26,286	39,614	40,209	3,498	43,707
619	182,820	1,945	16,075	200,839	194,468	2,594	194,952	197,877	17,215	215,092	182,820	89	212,943	2,594	213,420	216,622	18,846	235,468
620	0	0	0	0	117	118	233	236	21	257	0	0	208	118	323	328	29	356
621	28,465	336	2,506	31,307	28,885	395	28,967	29,402	2,558	31,960	0	0	28,885	395	28,993	29,428	2,560	31,988
622	0	0	0	0	7	177	182	185	16	201	0	0	7	177	182	185	16	201
623	80,857	11,610	8,045	100,511	85,579	12,141	96,674	98,124	8,537	106,661	80,857	39	93,812	12,141	104,912	106,486	9,264	115,750
624	33,512	1,073	3,009	37,594	44,298	11,988	55,683	56,519	4,917	61,436	33,512	16	47,715	11,988	59,116	60,003	5,220	65,223
625	44,587	10,094	4,757	59,439	49,557	11,392	60,296	61,201	5,324	66,525	0	0	49,579	11,392	60,373	61,278	5,331	66,609
626	36,892	41,116	6,787	84,794	42,047	42,001	83,148	84,395	7,342	91,738	0	0	42,092	42,001	83,267	84,516	7,353	91,869
627	73	22,341	1,950	24,364	1,937	139,397	139,821	141,919	12,347	154,266	73	0	1,952	139,397	139,961	142,060	12,359	154,420
628	66,086	47,712	9,900	123,699	66,478	49,364	114,603	116,322	10,120	126,442	0	0	66,502	49,364	114,728	116,449	10,131	126,580
629	71,974	0	6,262	78,236	79,254	767	79,165	80,352	6,991	87,343	0	0	79,254	767	79,235	80,424	6,997	87,421
630	33,117	40,596	6,413	80,126	43,578	42,779	85,433	86,715	7,544	94,259	33,117	16	46,925	42,779	88,823	90,156	7,844	97,999
631	79,093	1,742	7,033	87,868	90,625	3,630	93,247	94,645	8,234	102,880	79,093	38	98,618	3,630	101,244	102,763	8,940	111,704
632	157,457	6,664	14,278	178,399	157,457	7,077	162,773	165,214	14,374	179,588	0	0	157,457	7,077	162,918	165,362	14,386	179,748
633	100,098	4,904	9,135	114,137	109,177	7,382	115,311	117,041	10,183	127,224	100,098	49	119,366	7,382	125,503	127,386	11,083	138,468
634	236,434	12,200	21,631	270,266	259,881	17,569	274,480	278,598	24,238	302,836	236,434	115	283,832	17,569	298,442	302,918	26,354	329,272
635	148,094	17,325	14,391	179,811	155,790	24,346	178,208	180,882	15,737	196,618	148,094	72	170,756	24,346	193,187	196,085	17,059	213,144
636	0	33,224	2,890	36,115	208	33,283	33,133	33,630	2,926	36,555	0	0	208	33,283	33,162	33,660	2,928	36,588
637	272,103	1,087	23,768	296,958	284,791	2,916	284,628	288,897	25,134	314,031	272,103	132	312,290	2,916	312,110	316,792	27,561	344,353
638	0	6,690	582	7,272	3,536	10,289	13,677	13,883	1,208	15,090	0	0	3,536	10,289	13,690	13,895	1,209	15,104
639	0	3,697	322	4,018	58	3,697	3,714	3,770	328	4,098	0	0	58	3,697	3,717	3,773	328	4,101
640	7,437	2,367	853	10,657	39,469	3,842	42,847	43,490	3,784	47,274	7,437	4	40,221	3,842	43,630	44,284	3,853	48,137
650	40,470	3,455	3,821	47,746	40,470	3,455	43,455	44,107	3,837	47,944	0	0	40,470	3,455	43,494	44,146	3,841	47,987
680	0	2,519	219	2,738	11	2,637	2,619	2,658	231	2,889	0	0	11	2,637	2,621	2,660	231	2,892
687	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
693	129,486	16,444	12,696	158,625	140,790	19,866	158,937	161,321	14,035	175,356	0	0	140,790	19,866	159,079	161,465	14,047	175,512

TAZ	2018 Consumption (GPD) Residential	2018 Non-Residential	2018 Non-Revenue	2018 Total Potable Use	2045 Consumption (GPD) Residential	2045 Non-Residential	2045 Subtotal after Conservation	2045 Subtotal after Climate Change	2045 Non-Revenue	2045 Total Potable Use	2100 Consumption (GPD) Infill/ Redevelopment TAZ Use	2100 Infill/ Redevelopment HU	2100 Residential	2100 Non-Residential	2100 Subtotal after Conservation	2100 Subtotal after Climate Change	2100 Non-Revenue	2100 Total Potable Use
697	47,742	23,212	6,173	77,126	52,017	24,510	75,708	76,843	6,685	83,529	0	0	52,110	24,510	75,867	77,005	6,699	83,704
698	0	51,635	4,492	56,127	1,543	53,051	54,009	54,819	4,769	59,588	0	0	1,543	53,051	54,057	54,868	4,774	59,641
699	109,523	0	9,528	119,051	110,019	3,599	112,402	114,088	9,926	124,014	0	0	110,019	3,599	112,502	114,190	9,935	124,125
700	98,815	40,999	12,164	151,978	105,679	44,008	148,085	150,306	13,077	163,383	0	0	105,679	44,008	148,217	150,440	13,088	163,529
703	43,629	41	3,799	47,469	43,863	41	43,435	44,086	3,835	47,922	0	0	43,863	41	43,473	44,125	3,839	47,964
704	73,463	2,543	6,613	82,619	74,136	2,543	75,858	76,996	6,699	83,695	0	0	74,136	2,543	75,926	77,065	6,705	83,769
710	0	0	0	0	13	0	13	13	1	15	0	0	13	0	13	13	1	15
717	706	49,825	4,396	54,927	7,117	50,415	56,916	57,770	5,026	62,796	0	0	7,154	50,415	57,003	57,858	5,034	62,892
719	15,964	92,718	9,455	118,138	73,212	105,167	176,470	179,117	15,583	194,700	0	0	73,212	105,167	176,627	179,277	15,597	194,874
720	16,431	0	1,430	17,861	18,087	59	17,952	18,222	1,585	19,807	0	0	18,095	59	17,976	18,246	1,587	19,833
721	86,952	28,685	10,060	125,697	88,381	29,511	116,630	118,379	10,299	128,678	0	0	88,408	29,511	116,761	118,512	10,311	128,823
722	70,648	4,932	6,575	82,156	92,270	5,109	96,336	97,781	8,507	106,288	0	0	92,280	5,109	96,433	97,879	8,515	106,395
723	0	0	0	0	11	0	11	11	1	12	0	0	11	0	11	11	1	12
725	56,188	50,993	9,325	116,506	56,188	51,819	106,851	108,454	9,435	117,889	0	0	56,188	51,819	106,946	108,551	9,444	117,994
726	25,433	0	2,213	27,646	25,475	0	25,202	25,580	2,226	27,806	0	0	25,475	0	25,225	25,603	2,227	27,831
727	7,277	381	666	8,323	12,813	381	13,053	13,249	1,153	14,401	0	0	12,893	381	13,143	13,340	1,161	14,501
728	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
729	583	662	108	1,354	598	780	1,363	1,384	120	1,504	583	0	657	780	1,423	1,444	126	1,570
730	0	60,011	5,221	65,231	0	60,542	59,894	60,792	5,289	66,081	0	0	0	60,542	59,947	60,846	5,294	66,140
731	127,935	40,045	14,614	182,594	136,195	41,815	176,104	178,746	15,551	194,297	127,935	62	149,184	41,815	189,123	191,960	16,701	208,661
732	77,476	7,302	7,376	92,153	81,109	7,892	88,049	89,369	7,775	97,144	0	0	81,109	7,892	88,127	89,449	7,782	97,231
733	26,636	3,232	2,599	32,467	50,227	3,645	53,296	54,095	4,706	58,801	0	0	50,227	3,645	53,343	54,143	4,710	58,854
734	34,789	2,949	3,283	41,021	38,374	3,421	41,347	41,967	3,651	45,618	0	0	38,374	3,421	41,384	42,005	3,654	45,659
735	48,655	0	4,233	52,888	148,983	59	147,447	149,659	13,020	162,679	0	0	148,983	59	147,579	149,792	13,032	162,824
736	28,198	41,595	6,072	75,865	110,172	55,991	164,384	166,850	14,516	181,366	0	0	110,172	55,991	164,531	166,999	14,529	181,528
737	55,846	10,373	5,761	71,980	55,912	10,373	65,576	66,560	5,791	72,350	0	0	55,912	10,373	65,634	66,619	5,796	72,415
738	96,487	6,454	8,956	111,897	96,487	6,454	101,839	103,367	8,993	112,360	0	0	96,487	6,454	101,930	103,459	9,001	112,460
741	94,427	23,910	10,295	128,632	123,132	29,633	151,130	153,397	13,346	166,742	0	0	123,132	29,633	151,265	153,534	13,357	166,891

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
742	11,488	0	999	12,488	41,005	708	41,267	41,886	3,644	45,530	0	0	41,024	708	41,322	41,942	3,649	45,591
743	22,193	646	1,987	24,826	34,108	1,000	34,733	35,254	3,067	38,321	0	0	34,108	1,000	34,764	35,285	3,070	38,355
744	0	28,127	2,447	30,574	0	28,481	28,176	28,599	2,488	31,087	0	0	0	28,481	28,201	28,624	2,490	31,115
745	103,041	0	8,965	112,006	111,482	826	111,106	112,773	9,811	122,584	103,041	50	121,982	826	121,602	123,426	10,738	134,164
746	3,419	444	336	4,198	7,308	916	8,135	8,257	718	8,975	0	0	7,371	916	8,205	8,328	725	9,052
747	47,357	15,936	5,507	68,800	49,012	17,116	65,421	66,402	5,777	72,179	0	0	49,021	17,116	65,488	66,470	5,783	72,253
748	274	157,764	13,749	171,787	274	169,859	168,312	170,837	14,863	185,700	0	0	274	169,859	168,462	170,989	14,876	185,865
752	73,195	22,359	8,313	103,867	74,780	24,542	98,259	99,733	8,677	108,409	0	0	74,859	24,542	98,424	99,901	8,691	108,592
753	441,428	119,715	48,819	609,962	502,203	122,901	618,413	627,689	54,609	682,298	0	0	502,203	122,901	618,965	628,250	54,658	682,907
754	0	1,510	131	1,641	25,211	3,044	27,952	28,372	2,468	30,840	0	0	25,211	3,044	27,977	28,397	2,471	30,868
756	122,238	170	10,649	133,057	135,532	1,173	135,241	137,270	11,942	149,213	122,238	59	147,903	1,173	147,612	149,826	13,035	162,861
760	44,144	205	3,858	48,207	51,995	500	51,932	52,711	4,586	57,297	0	0	52,048	500	52,032	52,813	4,595	57,407
761	116,922	36,331	13,333	166,586	116,922	36,390	151,671	153,946	13,393	167,339	0	0	116,922	36,390	151,806	154,084	13,405	167,489
762	98,843	519	8,644	108,006	108,550	932	108,310	109,935	9,564	119,499	0	0	108,619	932	108,475	110,102	9,579	119,681
763	107,998	579	9,446	118,023	107,998	579	107,415	109,026	9,485	118,511	0	0	107,998	579	107,511	109,123	9,494	118,617
767	109,183	8,296	10,221	127,700	109,183	8,355	116,280	118,024	10,268	128,293	0	0	109,183	8,355	116,384	118,130	10,277	128,407
768	136,756	41,293	15,490	193,540	136,756	41,293	176,144	178,786	15,554	194,340	0	0	136,756	41,293	176,301	178,945	15,568	194,514
769	108,738	52,514	14,029	175,281	192,746	52,573	242,694	246,334	21,431	267,765	0	0	192,770	52,573	242,934	246,578	21,452	268,030
770	61,392	380	5,374	67,146	66,268	734	66,284	67,279	5,853	73,132	0	0	66,268	734	66,344	67,339	5,858	73,197
771	17,457	6,537	2,088	26,082	20,214	6,773	26,699	27,099	2,358	29,457	0	0	20,214	6,773	26,722	27,123	2,360	29,483
772	167,413	38,127	17,882	223,422	179,269	44,086	220,964	224,279	19,512	243,791	0	0	179,269	44,086	221,162	224,479	19,530	244,009
773	111,380	1,005	9,777	122,162	111,380	1,064	111,240	112,908	9,823	122,731	0	0	111,380	1,064	111,339	113,009	9,832	122,841
774	65,869	80,357	12,722	158,947	106,937	84,251	189,142	191,979	16,702	208,681	0	0	106,937	84,251	189,310	192,150	16,717	208,867
775	33,096	4,490	3,270	40,856	37,442	4,490	41,482	42,105	3,663	45,768	0	0	37,464	4,490	41,542	42,165	3,668	45,833
776	65,350	1,208	5,791	72,348	70,271	1,385	70,889	71,952	6,260	78,212	0	0	70,342	1,385	71,022	72,088	6,272	78,359
777	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
779	5,411	0	471	5,882	9,504	0	9,402	9,544	830	10,374	0	0	9,571	0	9,477	9,619	837	10,456
784	5,780	0	503	6,283	7,700	0	7,618	7,732	673	8,405	0	0	7,700	0	7,625	7,739	673	8,412

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
824	15,666	0	1,363	17,029	15,737	0	15,568	15,802	1,375	17,176	0	0	15,737	0	15,582	15,816	1,376	17,192
825	763	0	66	830	763	0	755	766	67	833	0	0	763	0	756	767	67	834
826	476,800	1,215,592	147,238	1,839,630	476,800	1,215,592	1,674,279	1,699,393	147,847	1,847,240	0	0	476,800	1,215,592	1,675,773	1,700,910	147,979	1,848,889
835	107,412	3,887	9,683	120,982	107,412	3,887	110,108	111,759	9,723	121,482	0	0	107,412	3,887	110,206	111,859	9,732	121,591
837	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
838	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
840	58,719	8,220	5,824	72,763	58,719	8,220	66,223	67,217	5,848	73,064	0	0	58,719	8,220	66,282	67,277	5,853	73,130
841	35,958	0	3,128	39,086	35,958	0	35,573	36,106	3,141	39,248	0	0	35,958	0	35,604	36,139	3,144	39,283
842	219,353	1,430	19,208	239,991	226,494	1,725	225,776	229,163	19,937	249,100	0	0	226,494	1,725	225,978	229,367	19,955	249,322
845	6,530	26	570	7,126	6,530	26	6,486	6,583	573	7,156	0	0	6,530	26	6,492	6,589	573	7,162
846	125,281	82	10,907	136,270	125,281	82	124,022	125,882	10,952	136,834	0	0	125,281	82	124,132	125,994	10,961	136,956
848	0	81	7	88	0	81	80	81	7	88	0	0	0	81	80	81	7	88
849	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
851	350	624	85	1,059	350	624	963	978	85	1,063	0	0	350	624	964	979	85	1,064
854	45,557	2,030	4,140	51,727	45,557	2,030	47,078	47,784	4,157	51,941	0	0	45,557	2,030	47,120	47,827	4,161	51,987
859	16,033	710	1,457	18,200	16,033	710	16,564	16,812	1,463	18,275	16,033	8	17,654	710	18,183	18,456	1,606	20,061
860	5,702	3,210	775	9,687	5,702	3,210	8,817	8,949	779	9,727	0	0	5,702	3,210	8,824	8,957	779	9,736
861	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
863	56,226	0	4,892	61,118	56,292	0	55,689	56,525	4,918	61,442	0	0	56,292	0	55,739	56,575	4,922	61,497
864	0	3,822	333	4,155	0	3,822	3,781	3,838	334	4,172	0	0	0	3,822	3,785	3,842	334	4,176
868	0	0	0	0	4	0	4	4	0	5	0	0	4	0	4	4	0	5
869	68,019	2,004	6,092	76,115	90,239	2,358	91,606	92,980	8,089	101,069	68,019	33	97,149	2,358	98,530	100,008	8,701	108,709
875	59,202	1,068	5,244	65,514	59,310	1,068	59,732	60,628	5,275	65,902	59,202	29	65,393	1,068	65,808	66,796	5,811	72,607
878	30,962	0	2,694	33,656	56,388	0	55,785	56,621	4,926	61,548	0	0	56,388	0	55,835	56,672	4,930	61,602
881	104,131	25,721	11,297	141,149	105,290	25,780	129,667	131,612	11,450	143,062	0	0	105,379	25,780	129,871	131,819	11,468	143,287
887	151,003	13,557	14,317	178,877	151,003	13,557	162,799	165,241	14,376	179,617	0	0	151,003	13,557	162,944	165,388	14,389	179,777
889	61,402	0	5,342	66,744	61,402	0	60,745	61,656	5,364	67,020	0	0	61,402	0	60,799	61,711	5,369	67,080
893	63,035	8,887	6,257	78,179	63,035	8,887	71,152	72,220	6,283	78,503	0	0	63,035	8,887	71,216	72,284	6,289	78,573

	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
TAZ	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
910	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
911	99,985	368	8,731	109,083	99,985	368	99,278	100,768	8,767	109,534	0	0	99,985	368	99,367	100,857	8,775	109,632
913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
922	0	1,417	123	1,540	0	1,417	1,402	1,423	124	1,547	0	0	0	1,417	1,403	1,424	124	1,548
929	16,131	0	1,403	17,535	16,178	0	16,005	16,245	1,413	17,659	0	0	16,178	0	16,020	16,260	1,415	17,674
930	914	0	80	994	914	0	904	918	80	998	0	0	914	0	905	919	80	999
932	31,218	8,216	3,431	42,865	32,281	8,216	40,064	40,665	3,538	44,203	0	0	32,281	8,216	40,100	40,701	3,541	44,242
948	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
949	260,187	23,309	24,664	308,160	270,859	23,309	291,020	295,386	25,699	321,084	0	0	270,859	23,309	291,280	295,649	25,721	321,371
950	5,851	4,940	939	11,730	53,256	4,940	57,573	58,437	5,084	63,521	0	0	53,275	4,940	57,643	58,508	5,090	63,598
951	0	435	38	472	0	435	430	436	38	474	0	0	0	435	430	437	38	475
953	152,900	645	13,358	166,904	165,942	645	164,804	167,276	14,553	181,829	0	0	166,004	645	165,013	167,488	14,571	182,060
954	71,814	0	6,248	78,062	105,939	0	104,805	106,377	9,255	115,632	0	0	105,939	0	104,898	106,472	9,263	115,735
955	258,509	58,550	27,584	344,643	269,534	58,786	324,807	329,679	28,682	358,361	0	0	269,534	58,786	325,096	329,973	28,708	358,681
956	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
957	102,634	1,479	9,058	113,171	117,026	1,951	117,704	119,470	10,394	129,864	0	0	117,026	1,951	117,809	119,576	10,403	129,979
958	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
959	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
960	0	0	0	0	0	52,982	52,415	53,201	4,629	57,830	0	0	0	52,982	52,462	53,249	4,633	57,881
961	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
962	241,414	1,541	21,137	264,091	246,549	1,718	245,610	249,294	21,689	270,983	0	0	246,614	1,718	245,893	249,581	21,714	271,295
963	177,515	22,937	17,439	217,891	178,950	22,996	199,784	202,781	17,642	220,423	0	0	178,971	22,996	199,984	202,983	17,660	220,643
964	130,973	3,322	11,684	145,979	133,053	3,381	134,974	136,998	11,919	148,917	0	0	133,053	3,381	135,094	137,121	11,930	149,050
965	147,925	8,893	13,643	170,461	150,817	9,129	158,234	160,608	13,973	174,580	0	0	150,837	9,129	158,395	160,771	13,987	174,758
966	180,189	11,945	16,716	208,849	181,021	12,004	190,958	193,823	16,863	210,685	0	0	181,021	12,004	191,129	193,996	16,878	210,873
967	165,168	23,664	16,428	205,260	168,496	24,136	190,570	193,429	16,828	210,257	0	0	168,496	24,136	190,740	193,601	16,843	210,445
968	396,007	5,798	34,957	436,762	420,790	6,093	422,314	428,649	37,292	465,941	0	0	420,790	6,093	422,691	429,031	37,326	466,357
969	362,041	13,513	32,673	408,227	387,553	14,280	397,532	403,495	35,104	438,599	362,041	176	424,212	14,280	434,186	440,699	38,341	479,040

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
970	197,544	27,516	19,580	244,640	208,124	27,811	233,409	236,911	20,611	257,522	197,544	96	228,116	27,811	253,413	257,215	22,378	279,592
971	183,228	6,996	16,549	206,774	187,370	8,412	193,686	196,592	17,103	213,695	183,228	89	205,905	8,412	212,212	215,395	18,739	234,135
972	141,522	17,911	13,871	173,303	154,834	18,383	171,363	173,933	15,132	189,065	0	0	154,834	18,383	171,516	174,088	15,146	189,234
973	418,005	38,777	39,740	496,523	421,957	38,954	455,979	462,818	40,265	503,084	418,005	203	464,200	38,954	498,214	505,687	43,995	549,682
974	217,116	21,449	20,755	259,320	217,324	21,449	236,217	239,761	20,859	260,620	0	0	217,324	21,449	236,428	239,975	20,878	260,853
975	123,738	13,012	11,897	148,647	163,136	17,083	178,290	180,964	15,744	196,708	123,738	60	175,641	17,083	190,831	193,694	16,851	210,545
976	447,832	18,088	40,535	506,455	451,368	18,206	464,548	471,517	41,022	512,538	0	0	451,368	18,206	464,963	471,937	41,059	512,996
977	202,237	20,199	19,352	241,788	203,069	20,199	220,878	224,192	19,505	243,696	0	0	203,069	20,199	221,076	224,392	19,522	243,914
978	316,427	157,083	41,195	514,705	319,947	157,142	471,983	479,062	41,678	520,741	0	0	319,963	157,142	472,419	479,506	41,717	521,223
979	272,350	11,890	24,729	308,969	281,270	12,126	290,256	294,610	25,631	320,241	272,350	132	308,818	12,126	317,792	322,559	28,063	350,622
980	183,965	114,471	25,964	324,400	199,000	117,126	312,743	317,434	27,617	345,051	183,965	89	217,592	117,126	331,431	336,402	29,267	365,669
981	0	0	0	0	215	7,080	7,217	7,325	637	7,963	0	0	215	7,080	7,223	7,332	638	7,970
982	229,639	15,071	21,290	266,000	234,459	15,189	246,976	250,681	21,809	272,490	229,639	112	257,666	15,189	270,176	274,228	23,858	298,086
983	138,562	22,592	14,020	175,174	140,434	22,946	161,631	164,056	14,273	178,329	138,562	67	154,437	22,946	175,641	178,275	15,510	193,785
984	50,283	0	4,375	54,658	53,264	118	52,810	53,603	4,663	58,266	0	0	53,264	118	52,858	53,650	4,668	58,318
985	2,373	55	211	2,640	3,154	173	3,291	3,341	291	3,631	2,373	1	3,394	173	3,532	3,585	312	3,897
986	44,454	0	3,868	48,322	44,454	0	43,979	44,638	3,884	48,522	44,454	22	48,947	0	48,466	49,193	4,280	53,473
987	113,378	20,389	11,638	145,406	132,306	20,448	151,120	153,386	13,345	166,731	113,378	55	143,764	20,448	162,600	165,039	14,358	179,397
988	136,224	4,477	12,241	152,942	136,420	4,536	139,448	141,540	12,314	153,854	0	0	136,432	4,536	139,584	141,678	12,326	154,004
989	120,781	4,298	10,882	135,961	120,781	4,298	123,740	125,596	10,927	136,523	0	0	120,781	4,298	123,851	125,708	10,937	136,645
990	40,144	461	3,533	44,137	40,961	461	40,978	41,593	3,619	45,212	0	0	40,976	461	41,030	41,645	3,623	45,268
991	85,380	7,381	8,070	100,831	85,380	7,381	91,768	93,145	8,104	101,248	0	0	85,380	7,381	91,850	93,228	8,111	101,339
992	76,321	203	6,658	83,181	76,321	203	75,705	76,840	6,685	83,525	0	0	76,321	203	75,772	76,909	6,691	83,600
993	117,865	0	10,254	128,119	223,764	118	221,486	224,808	19,558	244,367	0	0	223,764	118	221,684	225,009	19,576	244,585
994	224,982	74,065	26,017	325,064	228,044	74,065	298,876	303,359	26,392	329,751	0	0	228,102	74,065	299,200	303,688	26,421	330,109
995	61,031	211	5,328	66,570	64,496	270	64,072	65,033	5,658	70,691	0	0	64,567	270	64,200	65,163	5,669	70,832
996	40,718	0	3,542	44,260	53,357	118	52,903	53,696	4,672	58,368	0	0	53,406	118	52,998	53,793	4,680	58,473
997	41,927	147	3,660	45,734	49,119	442	49,030	49,766	4,330	54,095	0	0	49,207	442	49,161	49,899	4,341	54,240

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
998	7,345	8,188	1,351	16,885	13,680	9,014	22,451	22,788	1,983	24,770	0	0	13,680	9,014	22,471	22,808	1,984	24,792
999	95,131	1,145	8,376	104,651	111,393	6,219	116,353	118,098	10,275	128,372	0	0	111,393	6,219	116,456	118,203	10,284	128,487
1000	39,376	18,627	5,046	63,050	67,801	22,993	89,823	91,170	7,932	99,102	0	0	67,872	22,993	89,973	91,323	7,945	99,268
1001	192,730	1,460	16,895	211,086	199,042	1,519	198,415	201,391	17,521	218,913	0	0	199,042	1,519	198,592	201,571	17,537	219,108
1002	232,289	15,929	21,595	269,813	232,496	15,929	245,766	249,453	21,702	271,155	0	0	232,497	15,929	245,987	249,676	21,722	271,398
1003	174,533	30,642	17,850	223,025	180,367	32,235	210,326	213,481	18,573	232,054	0	0	180,367	32,235	210,514	213,672	18,589	232,261
1004	132,450	115,962	21,612	270,024	137,063	116,788	251,135	254,902	22,176	277,078	0	0	137,063	116,788	251,359	255,129	22,196	277,325
1006	78,469	36,449	9,998	124,916	96,943	38,455	133,949	135,958	11,828	147,786	0	0	96,981	38,455	134,106	136,118	11,842	147,960
1007	43,984	33	3,829	47,846	50,146	328	49,933	50,682	4,409	55,091	0	0	50,224	328	50,055	50,806	4,420	55,226
1008	140,612	72,985	18,583	232,179	150,479	75,758	223,815	227,172	19,764	246,936	140,612	68	164,689	75,758	238,085	241,657	21,024	262,681
1009	169,504	8,117	15,453	193,074	175,612	8,530	182,171	184,904	16,087	200,991	169,504	82	192,742	8,530	199,295	202,285	17,599	219,884
1010	220,422	8,934	19,954	249,310	233,352	9,878	240,626	244,236	21,249	265,484	0	0	233,352	9,878	240,841	244,454	21,267	265,721
1011	50,017	23,593	6,404	80,014	57,818	24,891	81,824	83,051	7,225	90,277	0	0	57,921	24,891	81,999	83,229	7,241	90,469
1012	49,179	17,630	5,812	72,622	70,189	19,223	88,455	89,782	7,811	97,593	0	0	70,189	19,223	88,534	89,862	7,818	97,680
1013	73,420	1,503	6,518	81,441	91,554	3,214	93,754	95,160	8,279	103,439	0	0	91,554	3,214	93,838	95,245	8,286	103,531
1014	2,133	993	272	3,399	5,599	1,406	6,931	7,035	612	7,647	0	0	5,669	1,406	7,006	7,111	619	7,730
1015	150,596	401	13,137	164,134	153,662	1,109	153,114	155,411	13,521	168,932	150,596	73	168,935	1,109	168,374	170,900	14,868	185,768
1016	75,856	8,933	7,377	92,165	113,633	9,228	121,545	123,369	10,733	134,102	75,856	37	121,377	9,228	129,323	131,262	11,420	142,682
1017	81,451	0	7,086	88,537	94,457	177	93,621	95,025	8,267	103,292	0	0	94,555	177	93,802	95,209	8,283	103,492
1018	76,015	15,020	7,920	98,955	94,112	15,492	108,432	110,058	9,575	119,633	0	0	94,112	15,492	108,528	110,156	9,584	119,740
1019	6,924	5,317	1,065	13,306	7,222	5,317	12,404	12,590	1,095	13,685	0	0	7,222	5,317	12,415	12,601	1,096	13,697
1020	5,974	7,181	1,144	14,299	6,782	7,240	13,872	14,080	1,225	15,305	0	0	6,806	7,240	13,908	14,116	1,228	15,344
1021	0	145,198	12,632	157,830	0	145,198	143,644	145,798	12,684	158,483	0	0	0	145,198	143,772	145,929	12,696	158,624
1022	43,208	0	3,759	46,967	47,593	118	47,200	47,908	4,168	52,076	0	0	47,593	118	47,243	47,951	4,172	52,123
1023	21,018	37,500	5,091	63,608	27,062	39,034	65,388	66,369	5,774	72,143	0	0	27,062	39,034	65,446	66,428	5,779	72,207
1024	3,339	0	290	3,629	10,593	1,062	11,530	11,703	1,018	12,721	0	0	10,619	1,062	11,566	11,739	1,021	12,761
1025	89,590	528	7,840	97,958	125,362	3,655	127,636	129,551	11,271	140,821	0	0	125,366	3,655	127,753	129,670	11,281	140,951
1026	127,838	4,073	11,476	143,387	140,125	5,843	144,406	146,572	12,752	159,324	0	0	140,125	5,843	144,535	146,703	12,763	159,466

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
1027	0	13,675	1,190	14,864	0	13,675	13,528	13,731	1,195	14,926	0	0	0	13,675	13,540	13,744	1,196	14,939
1029	0	23,615	2,054	25,669	0	23,615	23,362	23,713	2,063	25,775	0	0	0	23,615	23,383	23,734	2,065	25,799
1030	0	42,205	3,672	45,877	0	42,795	42,337	42,972	3,739	46,710	0	0	0	42,795	42,375	43,010	3,742	46,752
1031	130,831	0	11,382	142,214	141,652	16,048	156,012	158,353	13,777	172,129	0	0	141,652	16,048	156,152	158,494	13,789	172,283
1032	0	0	0	0	255,849	4,307	257,372	261,233	22,727	283,960	0	0	255,849	4,307	257,602	261,466	22,748	284,213
1034	2,730	1,741	389	4,860	3,571	1,859	5,372	5,453	474	5,927	0	0	3,571	1,859	5,377	5,458	475	5,933
1035	42,606	55,240	8,513	106,359	50,715	56,361	105,931	107,520	9,354	116,874	42,606	21	55,024	56,361	110,292	111,946	9,739	121,685
1036	200,709	3,140	17,735	221,584	224,264	4,143	225,963	229,352	19,954	249,306	200,709	98	244,547	4,143	246,248	249,942	21,745	271,687
1037	172,229	27,389	17,367	216,985	175,708	27,507	201,040	204,056	17,753	221,808	172,229	84	193,171	27,507	218,510	221,788	19,296	241,084
1038	46,904	36,513	7,257	90,674	49,423	36,749	85,249	86,528	7,528	94,056	46,904	23	54,163	36,749	90,019	91,369	7,949	99,318
1039	154,320	11,656	14,440	180,416	157,242	12,187	167,615	170,130	14,801	184,931	154,320	75	172,837	12,187	183,207	185,955	16,178	202,133
1040	161,635	1,850	14,223	177,708	167,254	2,322	167,761	170,277	14,814	185,091	0	0	167,254	2,322	167,910	170,429	14,827	185,256
1041	0	2,831	246	3,077	0	3,775	3,734	3,790	330	4,120	0	0	0	3,775	3,738	3,794	330	4,124
1042	14,036	22,037	3,138	39,212	14,036	22,214	35,863	36,401	3,167	39,567	0	0	14,036	22,214	35,895	36,433	3,170	39,603
1043	68,126	0	5,927	74,053	75,614	531	75,331	76,460	6,652	83,113	68,126	33	82,499	531	82,215	83,448	7,260	90,708
1044	196,497	11,138	18,064	225,700	198,690	11,256	207,699	210,815	18,341	229,155	196,497	95	218,643	11,256	227,642	231,056	20,102	251,158
1047	0	851	74	925	367	910	1,263	1,282	112	1,393	0	0	416	910	1,313	1,333	116	1,448
1048	0	0	0	0	132	0	131	133	12	144	0	0	208	0	206	209	18	227
1049	0	0	0	0	3	0	3	3	0	3	0	0	3	0	3	3	0	3
1051	76,490	220	6,674	83,384	76,490	220	75,889	77,027	6,701	83,728	0	0	76,490	220	75,957	77,096	6,707	83,803
1052	0	0	0	0	1	0	1	1	0	2	0	0	1	0	1	1	0	2
1060	43,029	4,177	4,107	51,312	43,150	4,177	46,820	47,523	4,134	51,657	43,029	21	47,585	4,177	51,253	52,022	4,526	56,548
1061	65,140	8,178	6,379	79,696	72,241	9,594	80,958	82,173	7,149	89,322	0	0	72,241	9,594	81,031	82,246	7,155	89,401
1062	29,218	8,893	3,316	41,427	30,055	9,660	39,290	39,879	3,469	43,349	29,218	14	33,008	9,660	42,249	42,882	3,731	46,613
1063	3,161	14,705	1,554	19,420	4,544	15,000	19,334	19,624	1,707	21,332	3,161	2	4,936	15,000	19,740	20,037	1,743	21,780
1064	501	10,981	999	12,481	1,146	11,158	12,173	12,356	1,075	13,431	501	0	1,197	11,158	12,234	12,418	1,080	13,498
1065	55,484	4,364	5,207	65,055	55,576	4,364	59,299	60,188	5,236	65,425	0	0	55,576	4,364	59,352	60,242	5,241	65,483
1066	155,383	1,067	13,611	170,061	157,187	1,185	156,677	159,027	13,835	172,863	155,383	75	172,957	1,185	172,432	175,019	15,227	190,245

TAZ	2018 Consumption (GPD)				2045 Consumption (GPD)						2100 Consumption (GPD)							
	Residential	Non-Residential	Non-Revenue	Total Potable Use	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use	Infill/ Redevelopment TAZ Use	Infill/ Redevelopment HU	Residential	Non-Residential	Subtotal after Conservation	Subtotal after Climate Change	Non-Revenue	Total Potable Use
1067	102,764	3,956	9,285	116,005	108,006	4,841	111,639	113,314	9,858	123,172	0	0	108,006	4,841	111,739	113,415	9,867	123,282
1069	0	295	26	321	80	354	429	436	38	474	0	0	80	354	430	436	38	474
1070	0	0	0	0	620	0	613	623	54	677	0	0	624	0	618	627	55	682
1072	15,337	49,390	5,631	70,358	15,882	49,390	64,573	65,542	5,702	71,244	0	0	15,961	49,390	64,709	65,679	5,714	71,393
1074	58,407	10,392	5,986	74,785	58,874	10,628	68,759	69,790	6,072	75,862	0	0	58,874	10,628	68,820	69,852	6,077	75,930
1076	71,307	5,051	6,643	83,002	73,122	6,231	78,504	79,681	6,932	86,614	0	0	73,179	6,231	78,631	79,810	6,943	86,754
1077	424,308	21,694	38,802	484,804	434,292	21,989	451,398	458,169	39,861	498,029	0	0	434,292	21,989	451,800	458,577	39,896	498,474
1078	0	0	0	0	1	0	1	1	0	1	0	0	1	0	1	1	0	1
1079	58,210	759	5,130	64,099	62,360	936	62,618	63,557	5,529	69,087	0	0	62,370	936	62,684	63,624	5,535	69,160
1080	204,379	16,133	19,185	239,697	211,659	16,369	225,588	228,972	19,921	248,892	0	0	211,659	16,369	225,789	229,176	19,938	249,115
1081	148,101	12,710	13,991	174,801	153,210	12,887	164,319	166,783	14,510	181,294	0	0	153,301	12,887	164,556	167,024	14,531	181,555
1082	118,834	10,220	11,228	140,282	127,082	10,456	136,066	138,107	12,015	150,122	0	0	127,154	10,456	136,259	138,303	12,032	150,335
1083	233,152	160,462	34,244	427,858	239,808	160,639	396,161	402,103	34,983	437,086	0	0	239,808	160,639	396,514	402,462	35,014	437,476
1084	199,700	7,201	18,000	224,902	201,364	7,260	206,391	209,487	18,225	227,713	0	0	201,364	7,260	206,576	209,674	18,242	227,916
1086	0	55,478	4,827	60,304	0	55,478	54,884	55,707	4,847	60,554	0	0	0	55,478	54,933	55,757	4,851	60,608
1095	176,199	61,233	20,657	258,088	183,642	61,292	242,312	245,947	21,397	267,344	176,199	86	201,493	61,292	260,204	264,107	22,977	287,085
1096	148,094	14,859	14,177	177,129	148,422	14,859	161,533	163,956	14,264	178,220	148,094	72	163,476	14,859	176,583	179,232	15,593	194,825
1097	112,441	51	9,787	122,279	113,897	110	112,787	114,479	9,960	124,438	0	0	113,897	110	112,888	114,581	9,969	124,550
1098	191,312	35,334	19,718	246,364	194,615	35,452	227,605	231,019	20,099	251,117	191,312	93	213,973	35,452	246,976	250,681	21,809	272,490
1099	101,388	38,496	12,170	152,053	102,220	38,555	139,268	141,357	12,298	153,655	101,388	49	112,466	38,555	149,538	151,781	13,205	164,986
1100	223,136	5,983	19,933	249,053	223,339	5,983	226,868	230,271	20,034	250,304	223,136	108	245,894	5,983	249,404	253,145	22,024	275,168
1101	137,953	1,399	12,124	151,476	138,161	1,399	138,066	140,137	12,192	152,329	137,953	67	152,102	1,399	151,994	154,274	13,422	167,696
1102	156,436	5,098	14,053	175,588	156,641	5,098	160,008	162,408	14,130	176,538	156,436	76	172,454	5,098	175,808	178,445	15,525	193,970
1103	195,272	13,757	18,186	227,215	195,667	14,052	207,475	210,587	18,321	228,908	195,272	95	215,422	14,052	227,221	230,630	20,065	250,694
1104	100,399	10,528	9,651	120,577	102,391	10,528	111,711	113,386	9,865	123,251	0	0	102,479	10,528	111,897	113,576	9,881	123,457
Sum	**60,890,838**	**20,747,272**	**7,102,516**	**88,740,626**	**71,348,914**	**25,909,477**	**96,217,452**	**97,660,714**	**8,496,482**	**106,157,196**	**40,785,596**	**19,816**	**79,789,907**	**26,213,150**	**104,962,118**	**106,536,550**	**9,268,680**	**115,805,229**

Appendix D

SUPPLY / DEMAND BALANCE WITH LTSCs

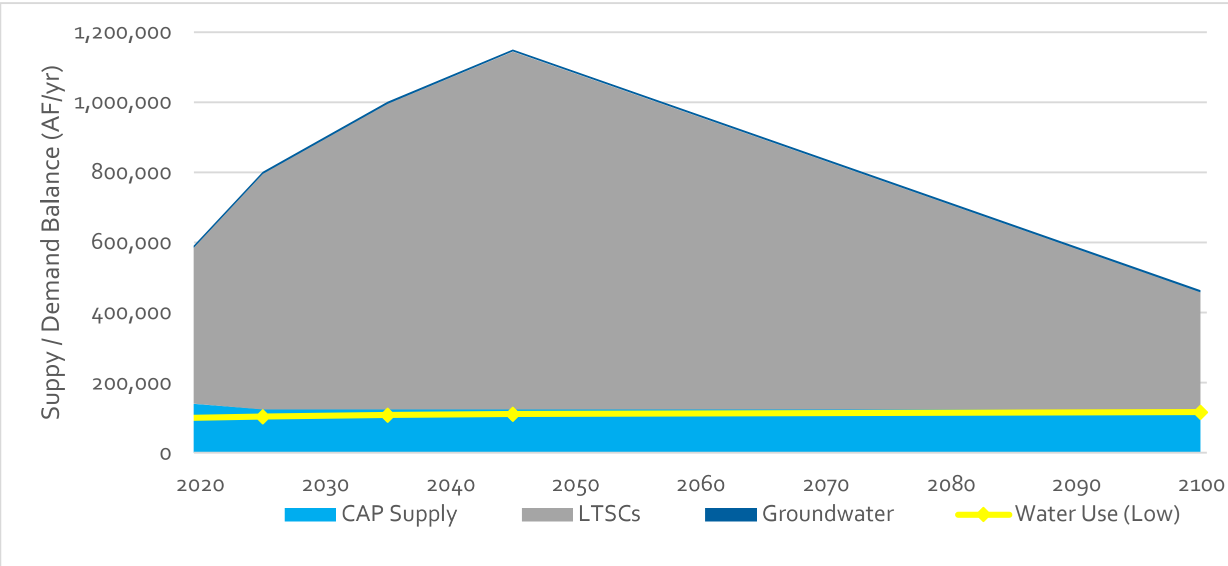


Figure D-1 Supply / Demand (Low) Balance with LTSCs (Drought Contingency Plan Tier 3)

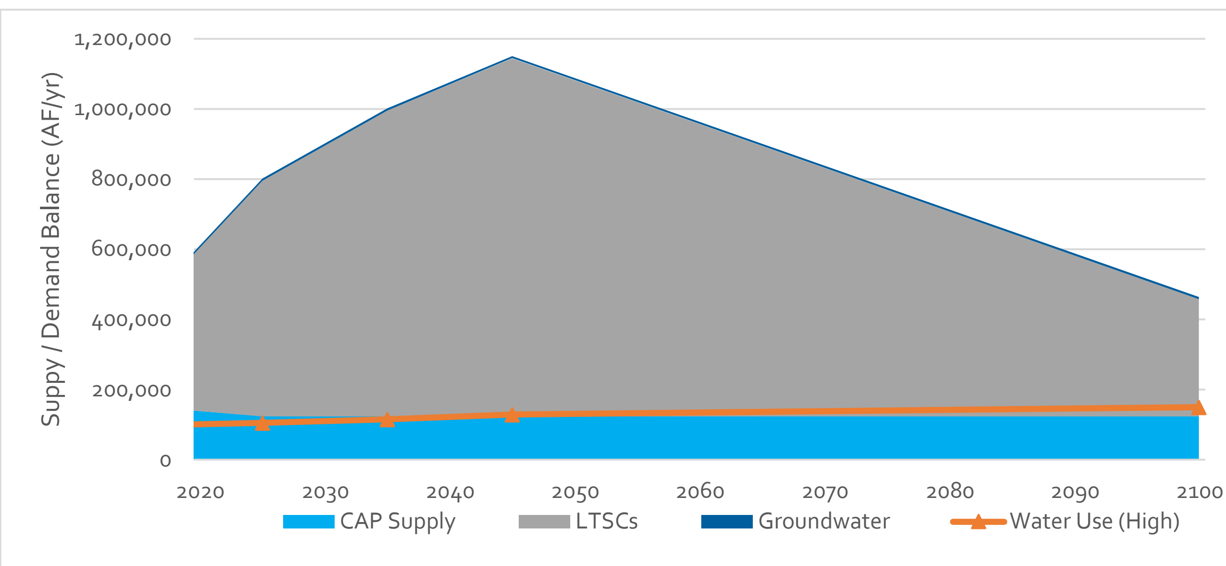


Figure D-2 Supply / Demand (High) Balance with LTSCs (Drought Contingency Plan Tier 3)

Appendix L

ONE WATER 2100 STATISTICALLY VALID SURVEY RESULTS

Tucson Water
One Water 2100 strategy survey
Results Presentation

December 2022

Opinion Research on Elections and Public Policy

PROBOLSKY RESEARCH
23 Corporate Plaza Suite 150 Newport Beach CA 92660
Newport Beach (949) 855-6400
San Francisco (415) 870-8150
Washington DC (202) 559-0270

Survey Methodology*

	Survey Details
Mode	Phone (landline and mobile) and Online (email and text to web)
Language	English and Spanish
Length	10 minutes (online) 12 minutes (phone)
Target Respondents	Tucson Water customers
Survey Fielding	December 9 – December 12, 2022
Margin of Error	+/-5%
Survey Participants	400

Sample

The sample was secured through consumer data. We called, emailed, and texted a demographically representative sample of Tucson Water service area residents.

Data Collection Explained

Interviews were conducted by phone (30%) and online (70%) modes. Phone interviews were conducted via landline (29%) or mobile (71%). Online participants were invited by email (36%) and text message (64%) for the online method.

Respondents in all modes chose their preferred language, English (97%) and Spanish (3%).

The online survey was accessible by computer, tablet, and smart phone.

Security measures precluded individuals from completing the survey more than once.

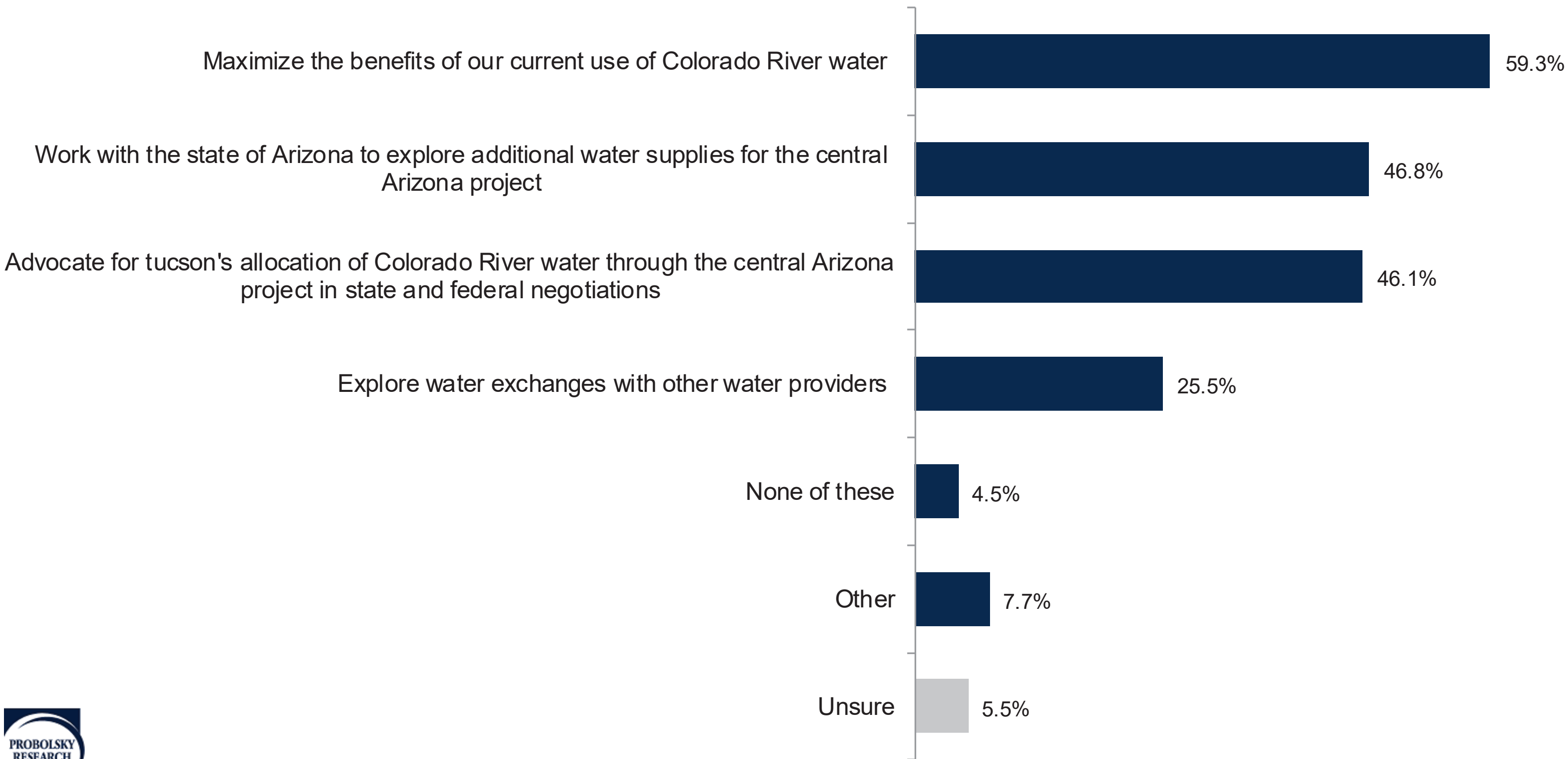
PROBOLSKY RESEARCH

Probolsky Research is a Latina- and woman-owned market and opinion research firm with corporate, election, government, and non-profit clients.

**Due to rounding, totals shown on charts may not add up to 100%*

Maximizing the benefits of the Colorado River is the most important surface water strategy

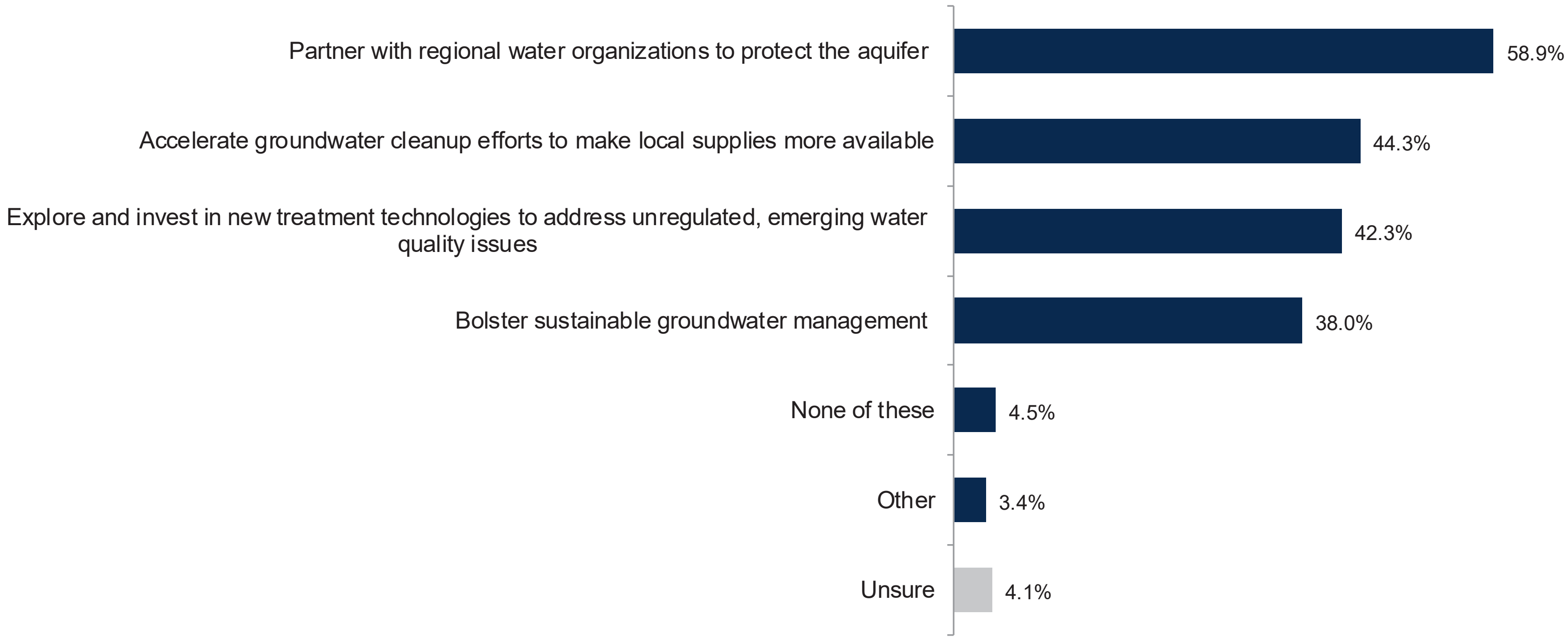
Question 1: First, let's talk about surface water. Our drinking water comes from recovered Colorado River water delivered through the Central Arizona Project canal. Below are possible opportunities for surface water sustainability. Which of the following strategies seem most important to you? Choose two.



PROBOLSKY RESEARCH

Partnering with regional water organizations is the most important ground water strategy

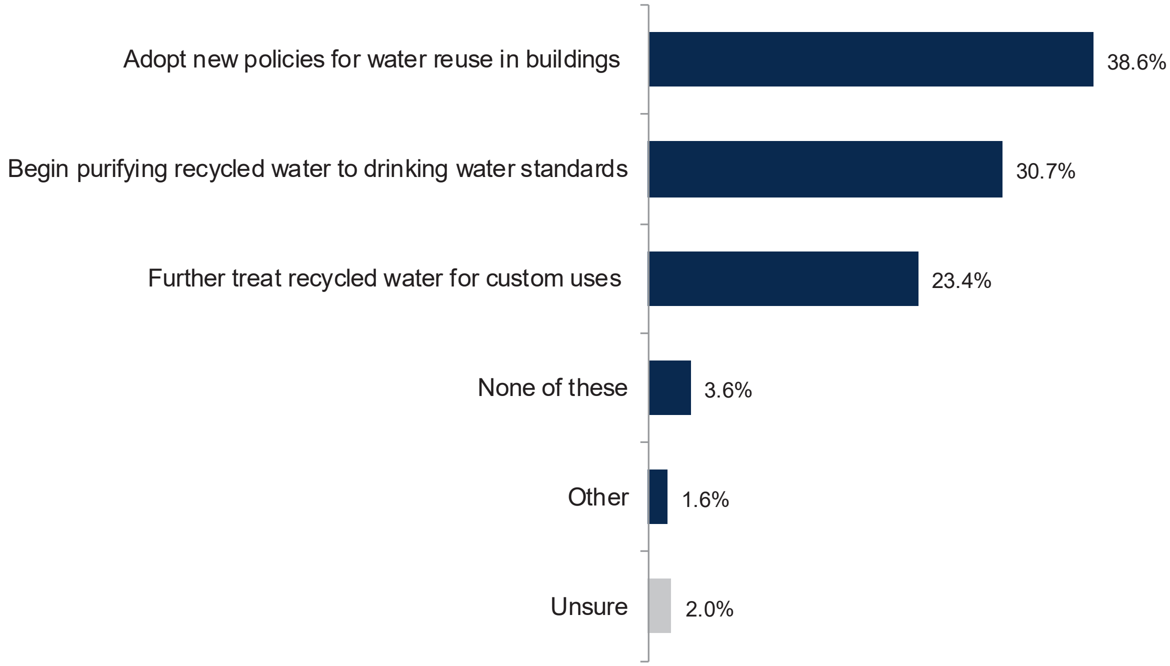
Question 2: Now let's talk about groundwater. Below are possible opportunities for groundwater sustainability. Which of the following strategies seem most important to you? Choose two.



PROBOLSKY RESEARCH

Adopting new policies for water reuse in buildings is the most important recycled water strategy

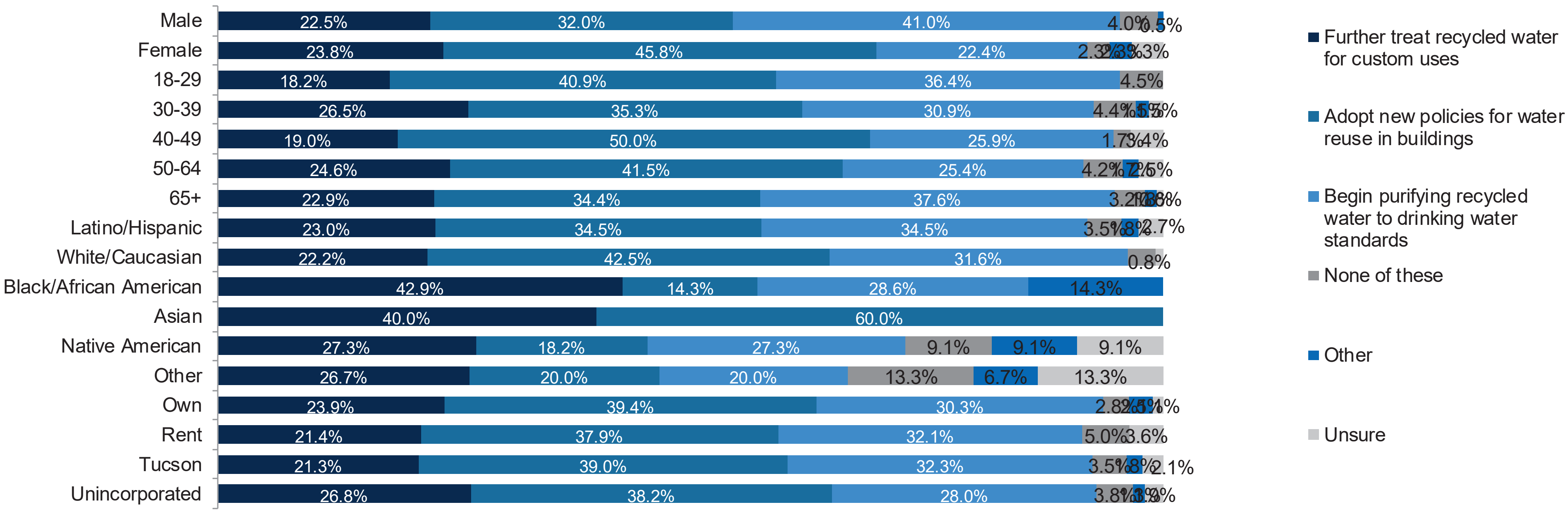
Question 3: Now let's talk about recycled water. Below are possible opportunities for recycled water use. Which of the following strategies seem most important to you? Choose one.



PROBOLSKY RESEARCH

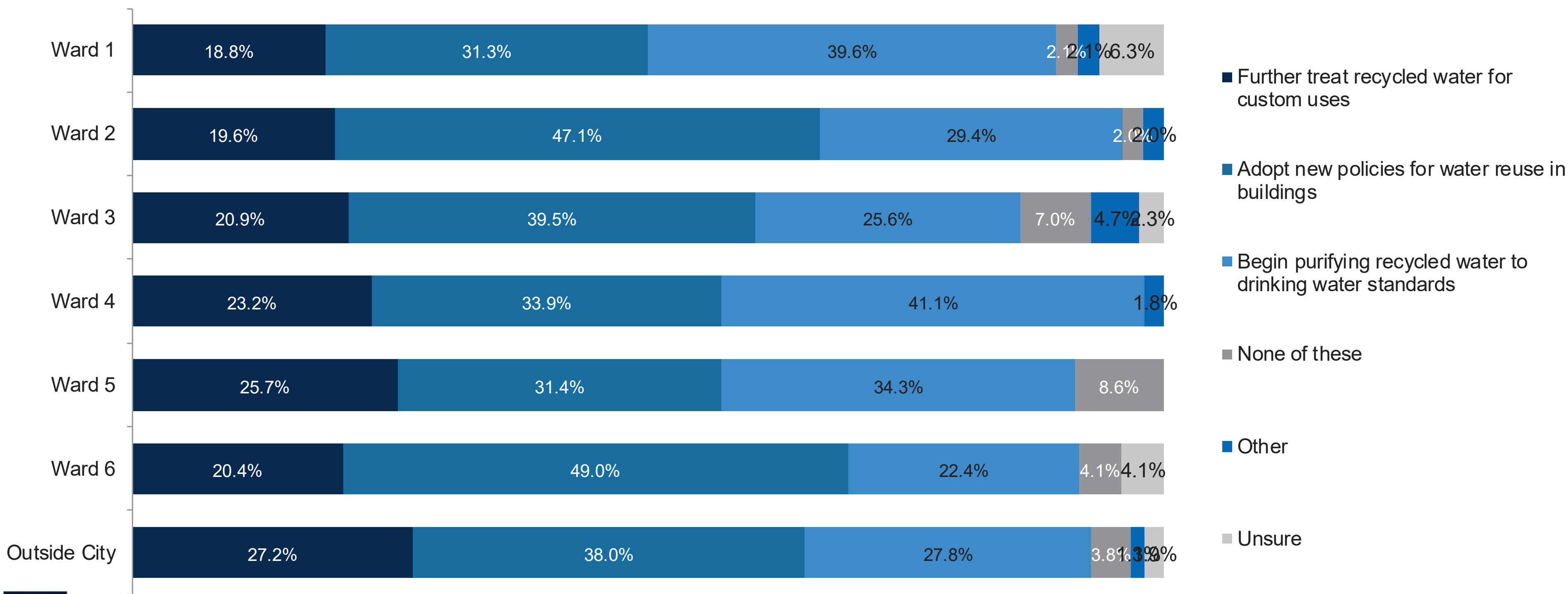
Results by gender, age, ethnicity, home type, and region

Question 3: Now let's talk about recycled water. Below are possible opportunities for recycled water use. Which of the following strategies seem most important to you? Choose one.



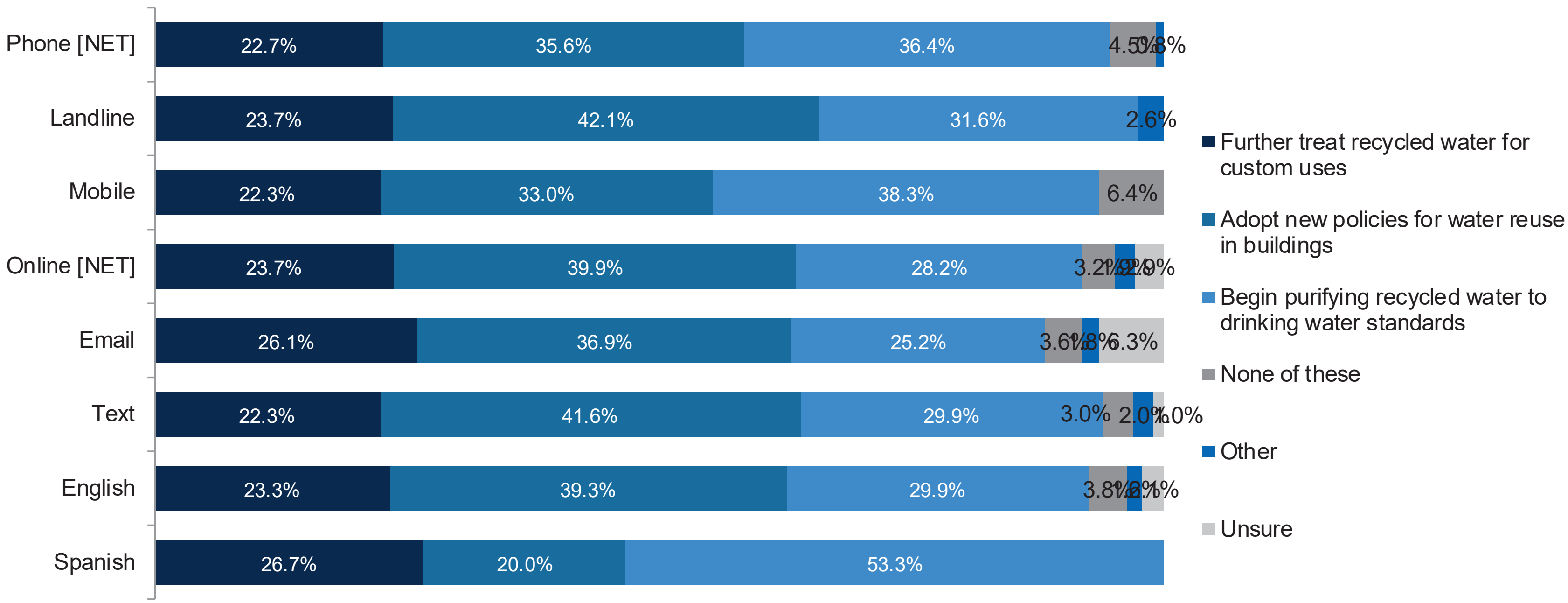
Results by Ward

Question 3: Now let's talk about recycled water. Below are possible opportunities for recycled water use. Which of the following strategies seem most important to you? Choose one.



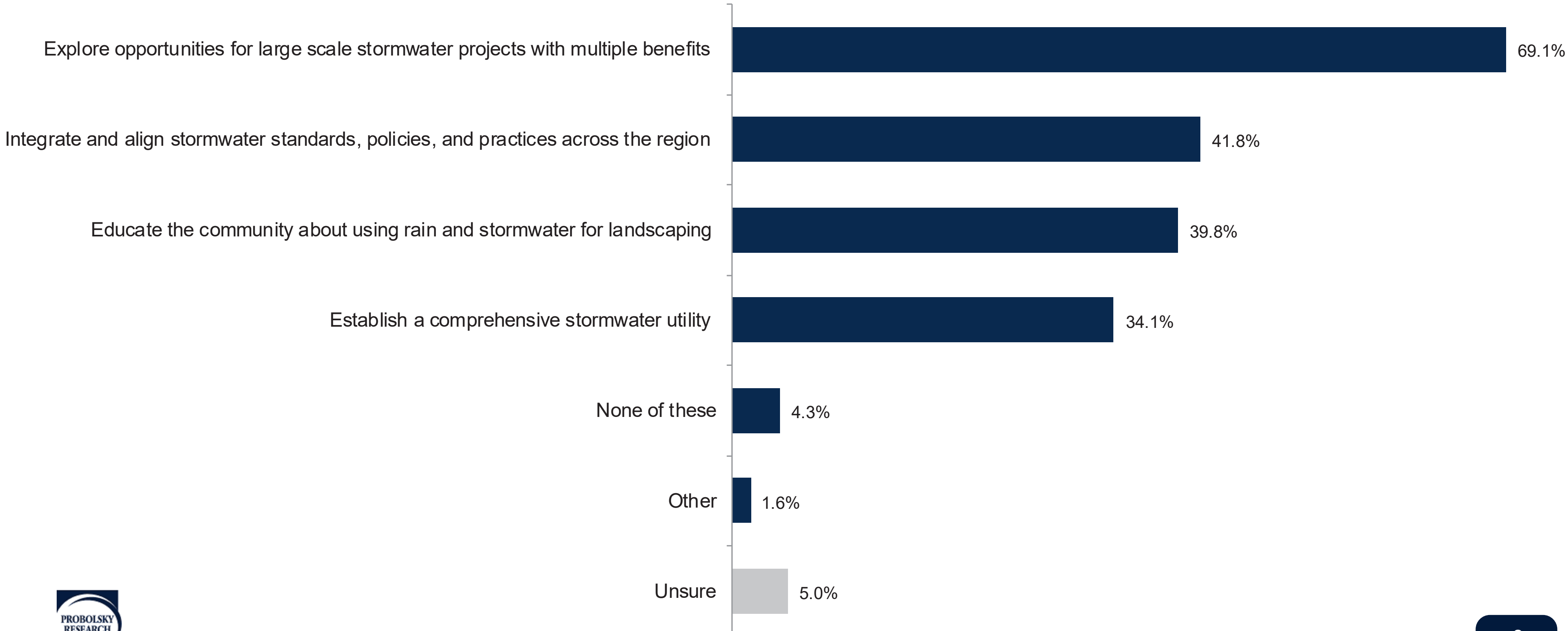
Results by survey mode and survey language

Question 3: Now let's talk about recycled water. Below are possible opportunities for recycled water use. Which of the following strategies seem most important to you? Choose one.



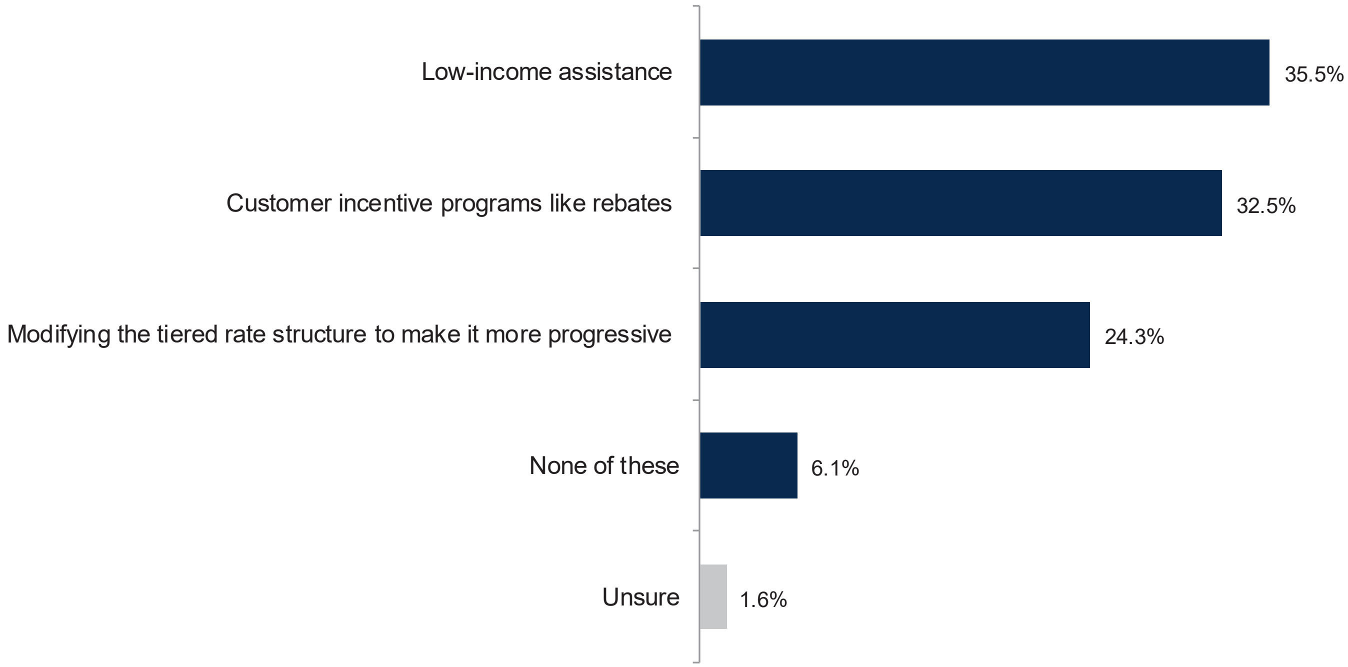
Exploring opportunities for large scale stormwater projects with multiple benefits is the most important storm water strategy

Question 4: Now let's talk about stormwater. Below are possible opportunities for stormwater use. Which of the following strategies seem most important to you? Choose two.



36% find low-income assistance important

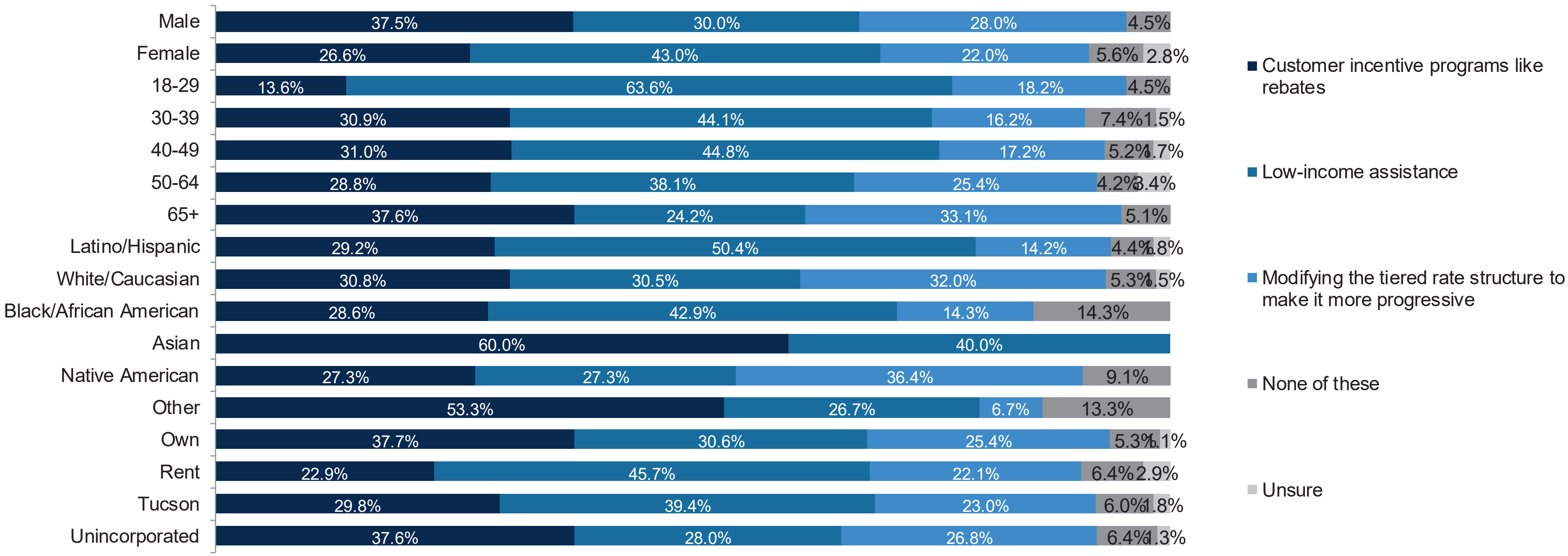
Question 5: Under the Incentives category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by gender, age, ethnicity, home type, and region

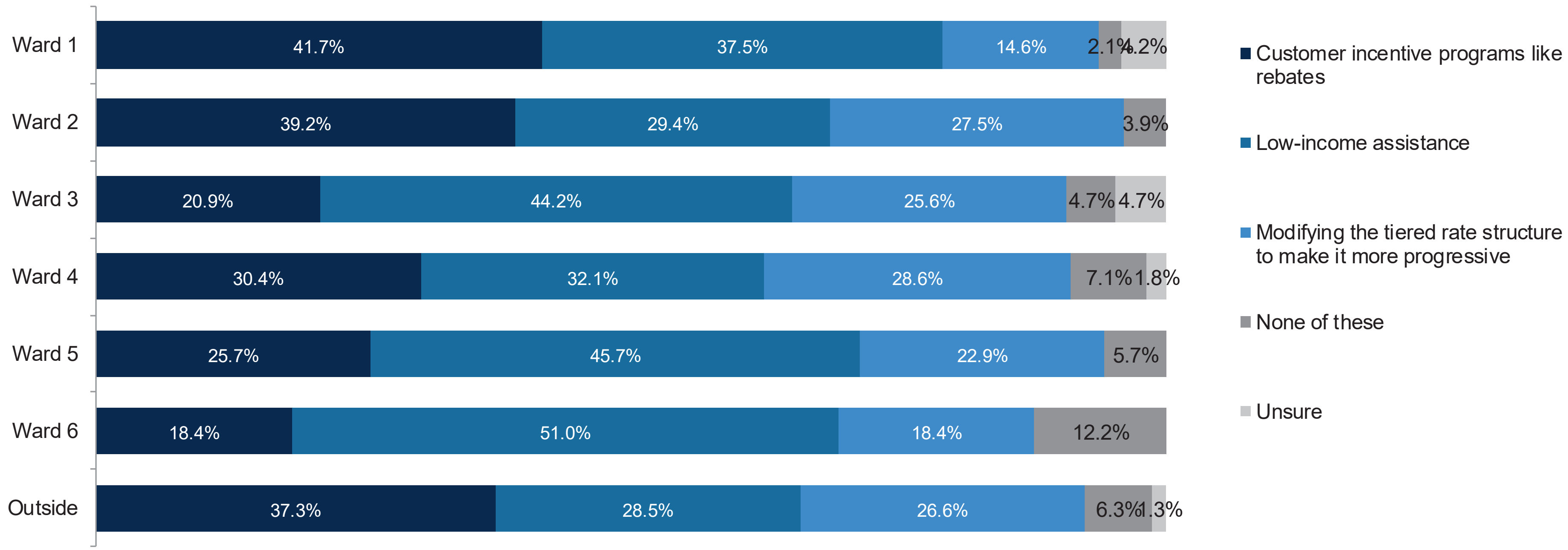
Question 5: Under the Incentives category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by Ward

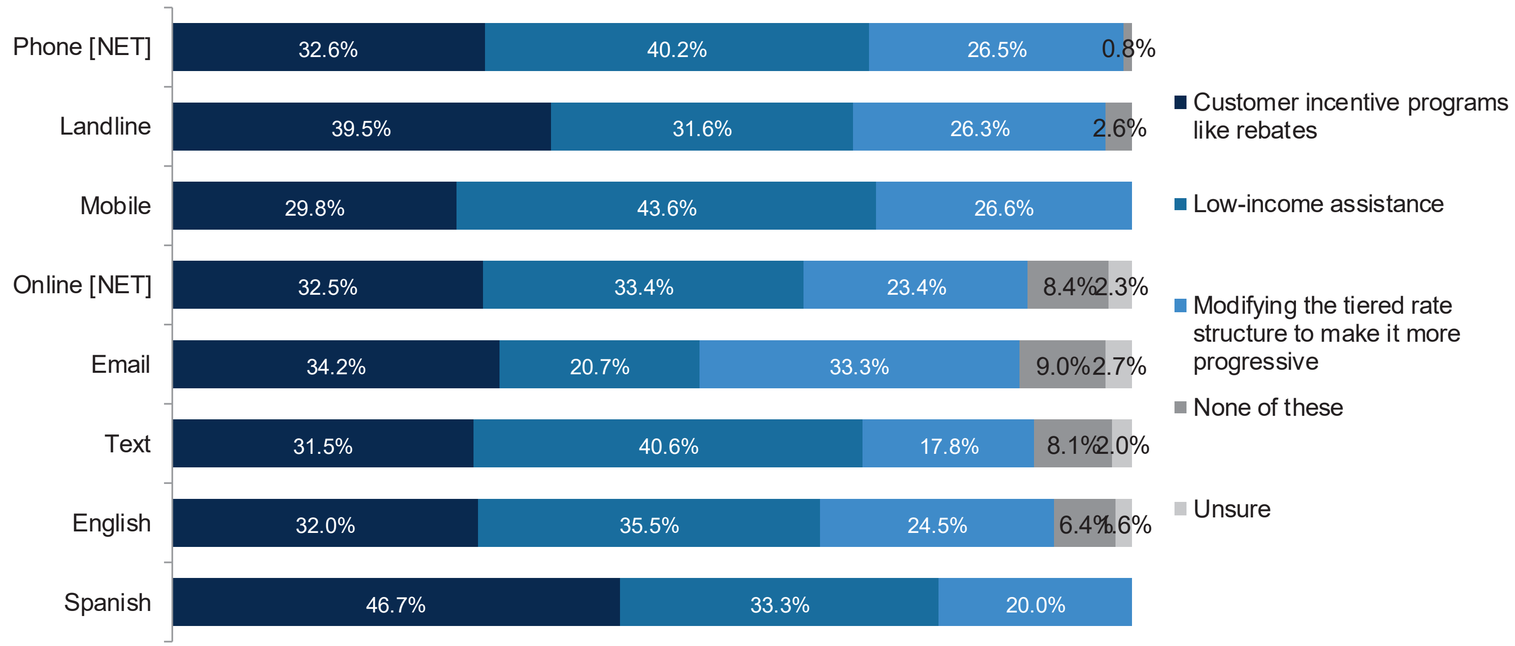
Question 5: Under the Incentives category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

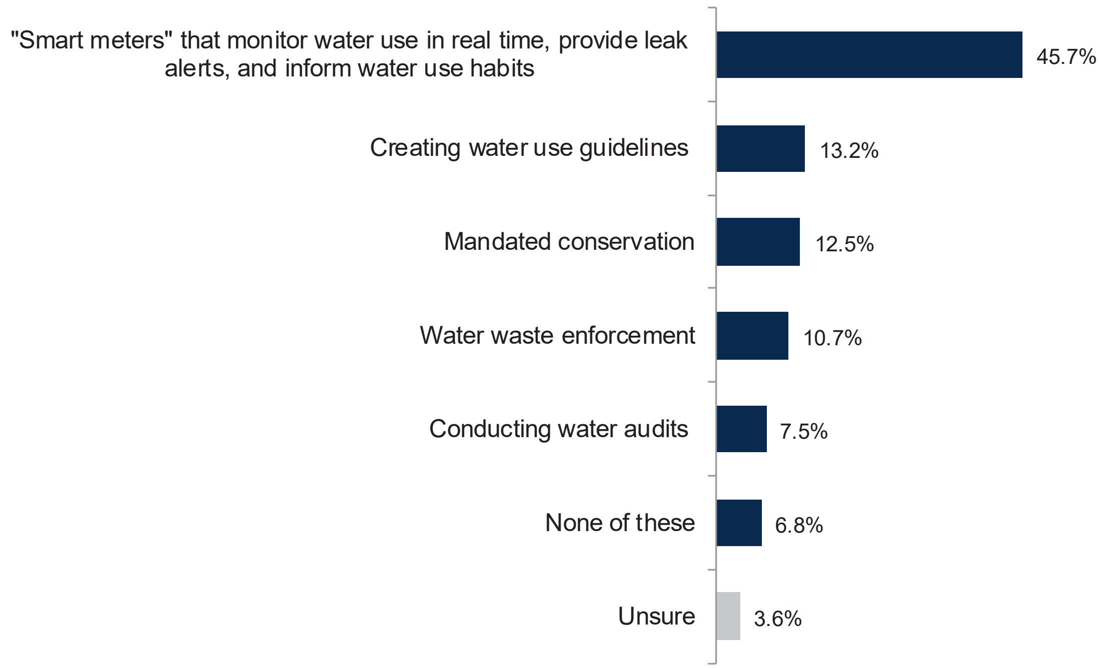
Results by survey mode and survey language

Question 5: Under the Incentives category, which program is most important to you? Choose one.



46% find smart meters the most important under the monitoring and mandating category

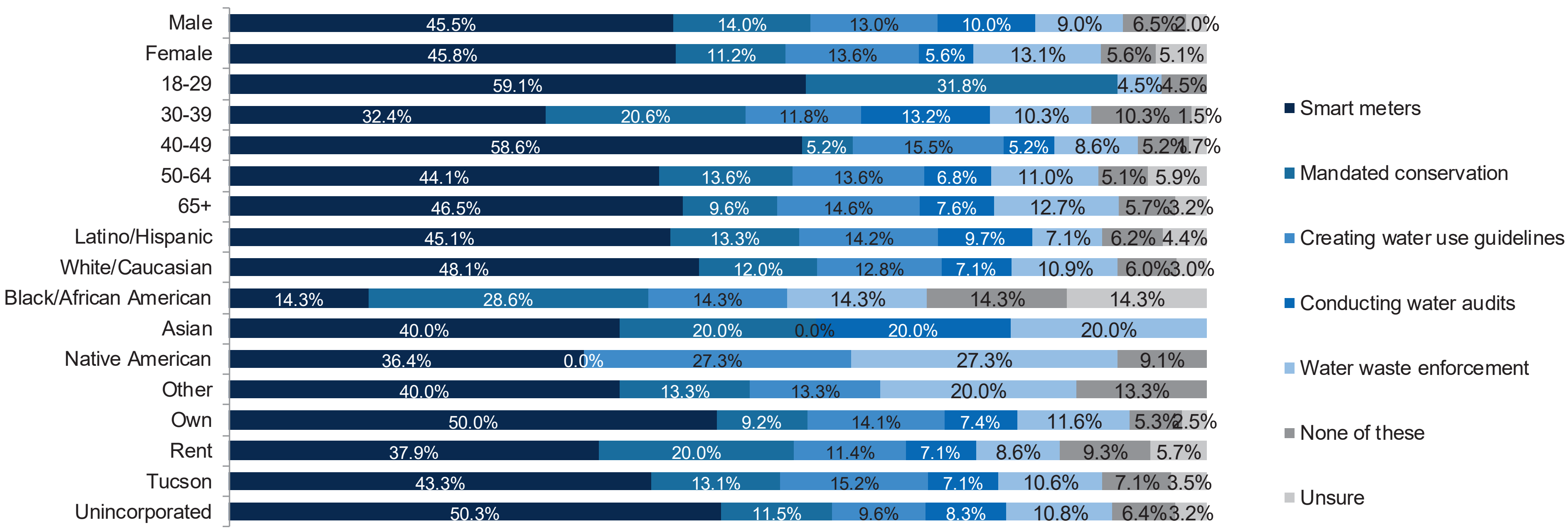
Question 6: Under the Monitoring and Mandates category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by gender, age, ethnicity, home type, and region

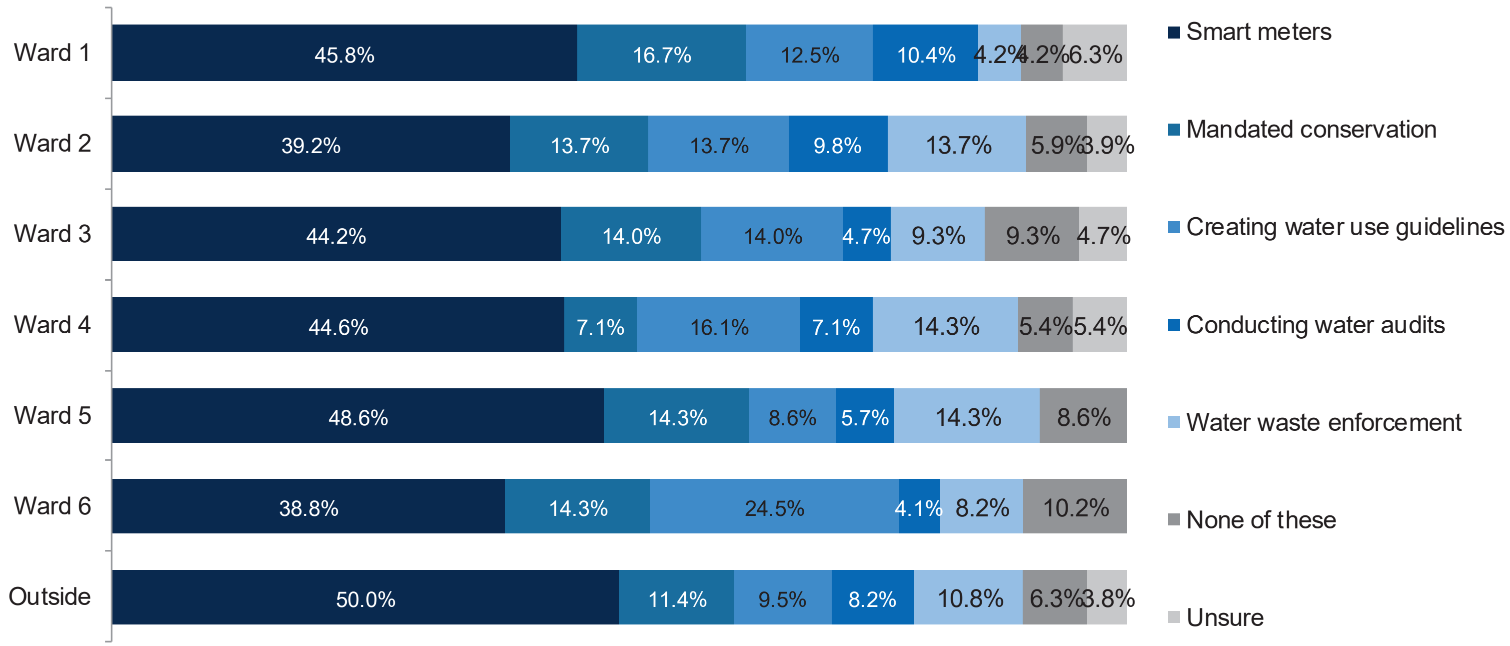
Question 6: Under the Monitoring and Mandates category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by Ward

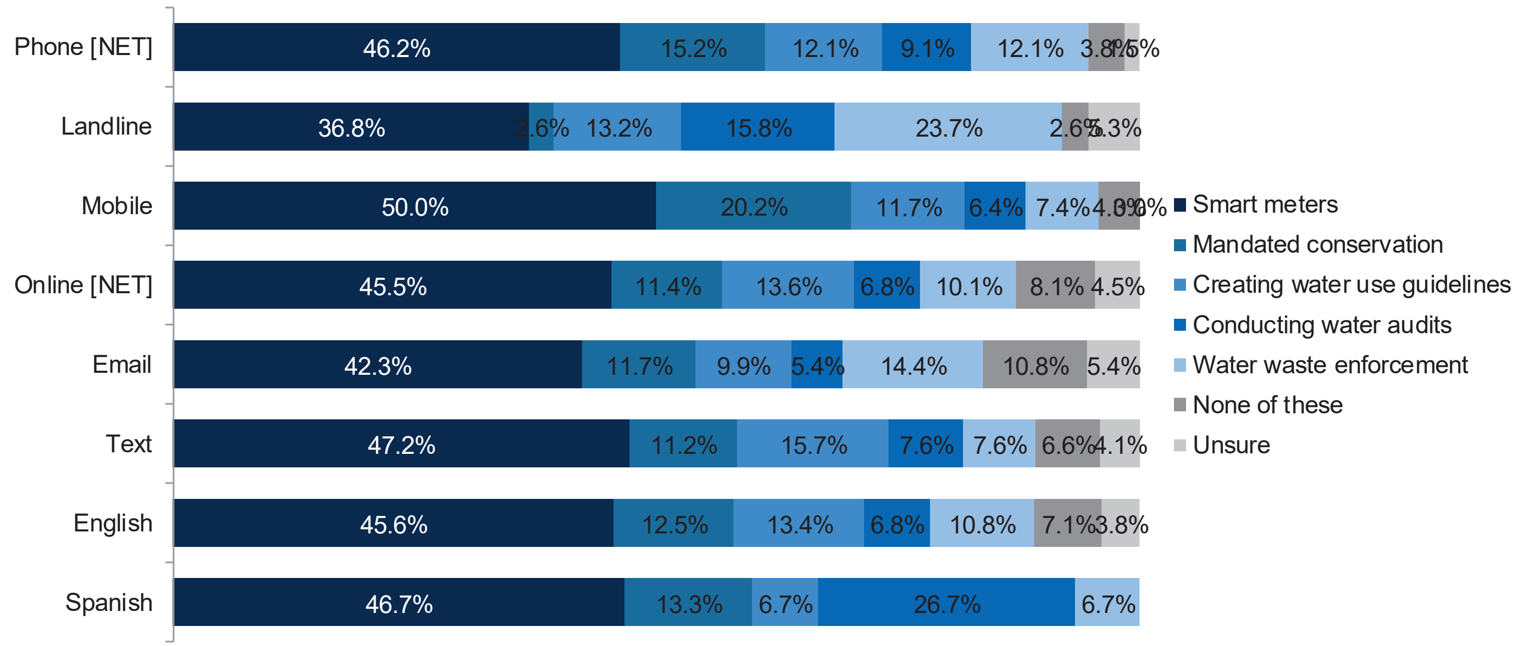
Question 6: Under the Monitoring and Mandates category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by survey mode and survey language

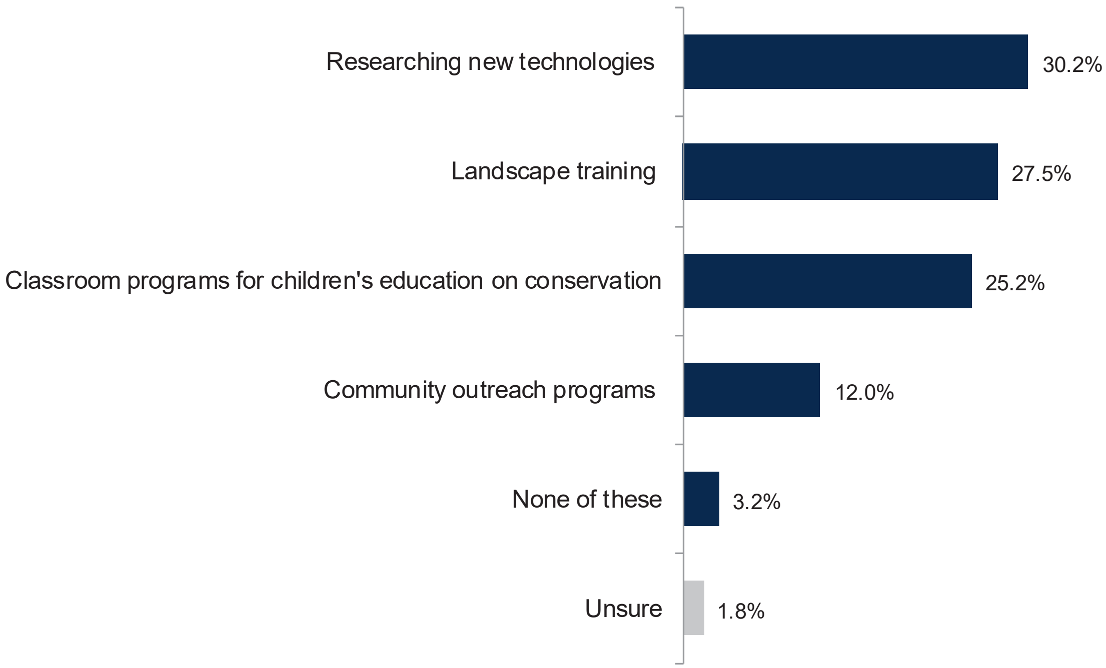
Question 6: Under the Monitoring and Mandates category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

30% find researching new technologies the most important under the education category

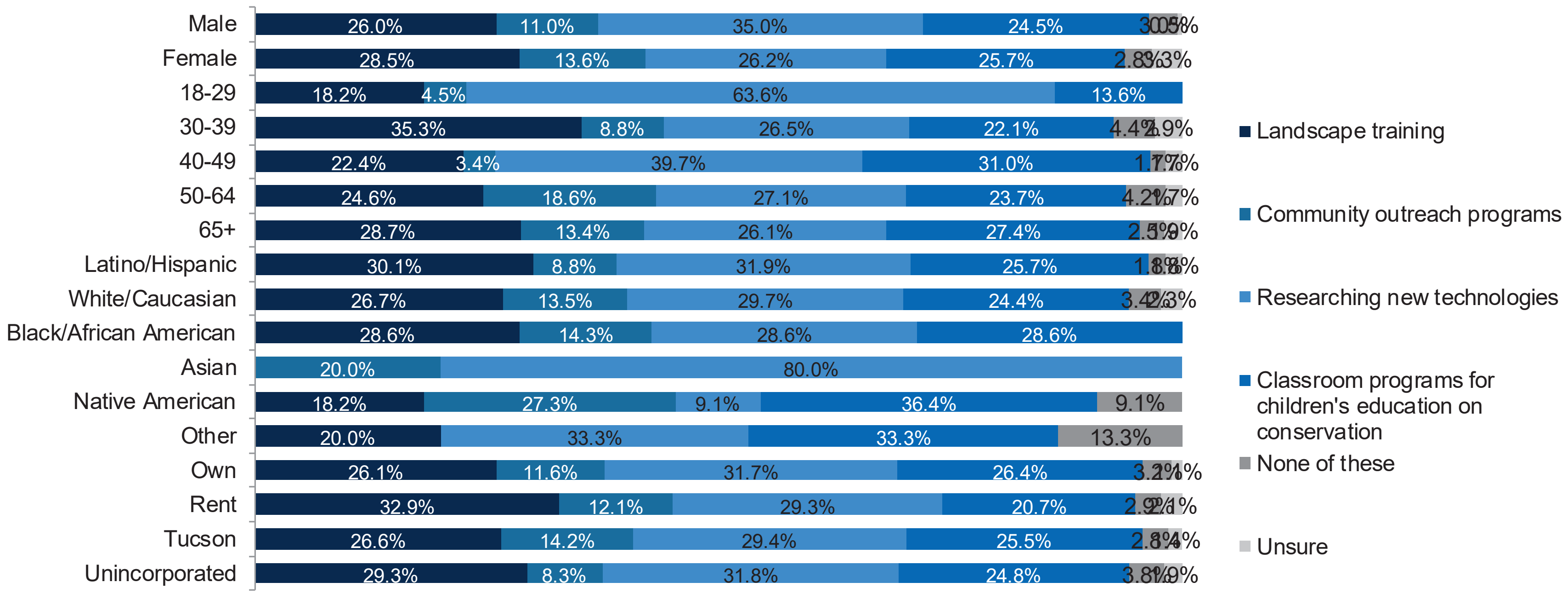
Question 7: Under the Education category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by gender, age, ethnicity, home type, and region

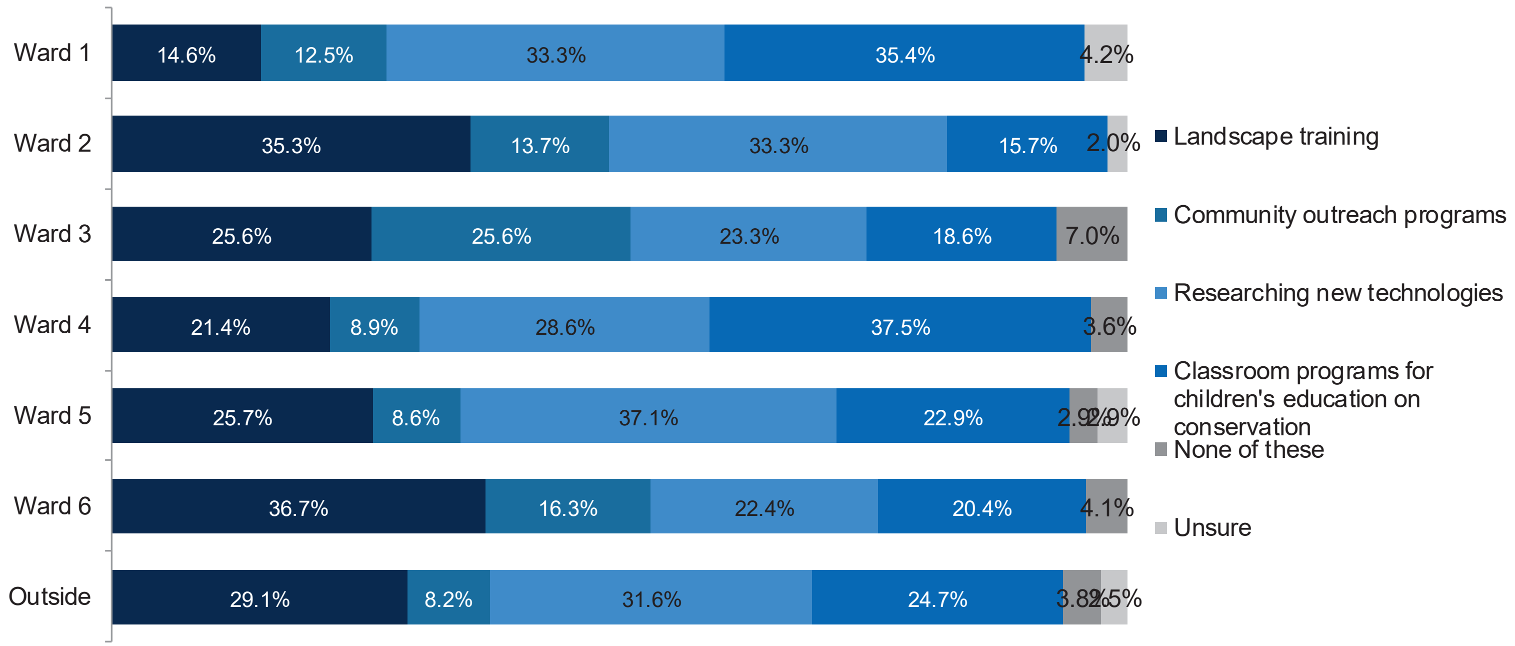
Question 7: Under the Education category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by Ward

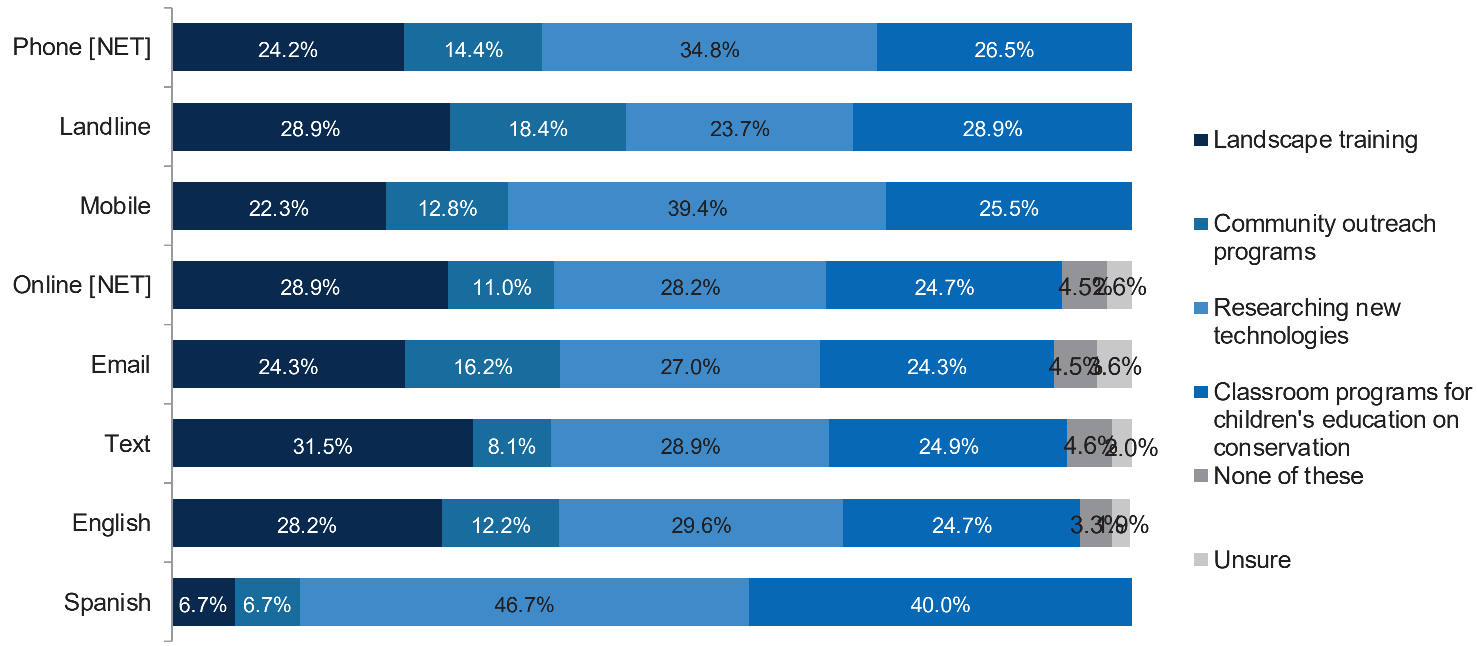
Question 7: Under the Education category, which program is most important to you? Choose one.



PROBOLSKY RESEARCH

Results by survey mode and survey language

Question 7: Under the Education category, which program is most important to you? Choose one.

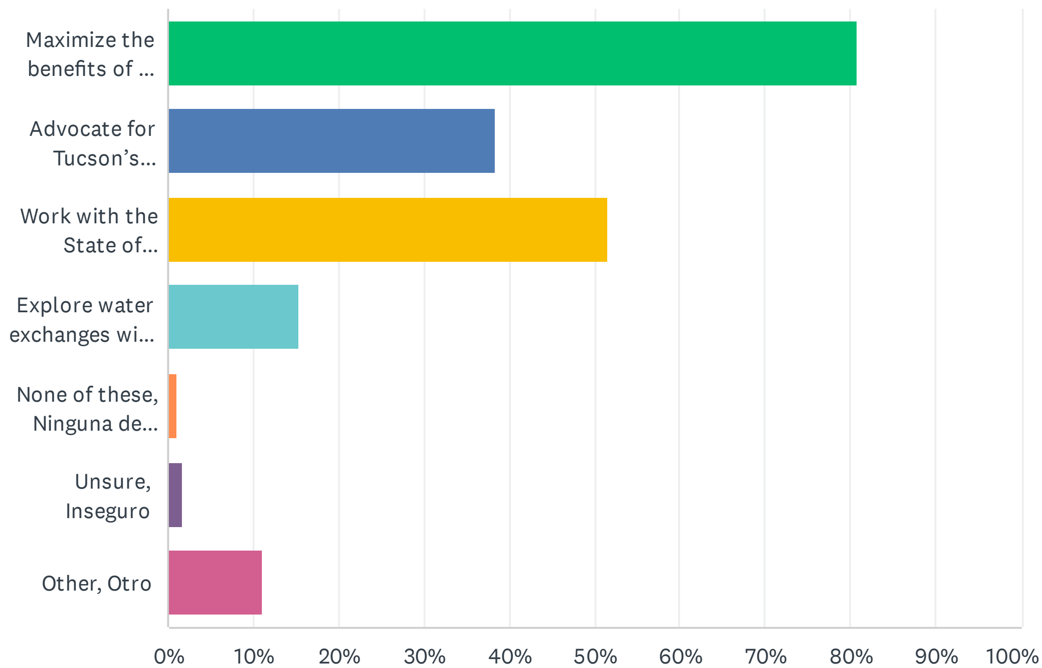


Appendix M

ONE WATER 2100 ONLINE SURVEY SUMMARY

Q1 Our drinking water comes from recovered Colorado River water delivered through the Central Arizona Project canal. Below are possible opportunities for surface water sustainability. Which of the following strategies seem most important to you? Choose two. Nuestra agua potable viene del agua recuperada del río Colorado que se suministra a través del canal del Proyecto Central de Arizona. Más adelante se presentan posibles oportunidades para la sostenibilidad de las aguas superficiales. ¿Cuál de las siguientes estrategias le parece más importante? Elija dos.

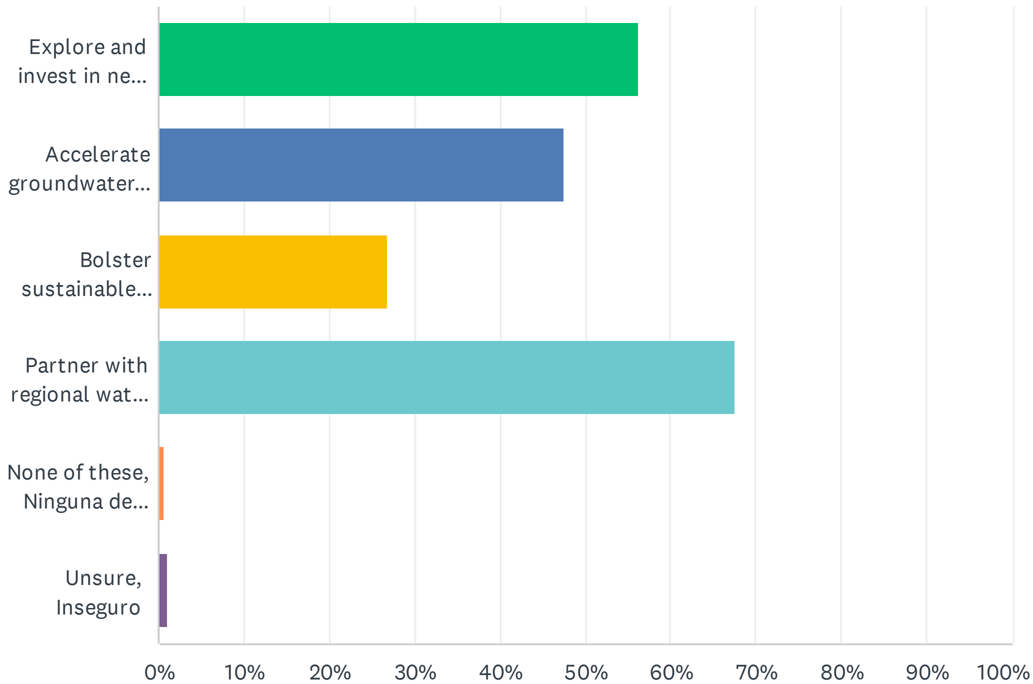
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Maximize the benefits of our current use of Colorado River water (Example: Continuing to store this water underground for future use.)Maximizar los beneficios de nuestro uso actual del agua del río Colorado (Ejemplo: Seguir almacenando esta agua en el subsuelo para su uso futuro.)	80.88%	571
Advocate for Tucson's allocation of Colorado River water through the Central Arizona Project in state and federal negotiations (Example: Tucson Water is actively participating in negotiations about how Colorado River water will be shared.)Luchar por la asignación del agua del río Colorado a Tucson a través del Proyecto Central de Arizona en las negociaciones estatales y federales (Ejemplo: Tucson Water participa activamente en las negociaciones sobre cómo se repartirá el agua del río Colorado.)	38.39%	271
Work with the State of Arizona to explore additional water supplies for the Central Arizona Project (Example: Treat brackish water near the canal to drinking water standards so that it can be delivered to cities)Trabajar con el Estado de Arizona para explorar suministros de agua adicionales para el Proyecto Central de Arizona (Ejemplo: Tratar el agua salobre cerca del canal para que cumpla con los estándares de agua potable y pueda ser entregada a las ciudades)	51.70%	365
Explore water exchanges with other water providers (Example: Las Vegas has offered to invest in a treatment plant in Southern California in exchange for additional Colorado River water.)Explorar intercambios de agua con otros proveedores de agua (Ejemplo: Las Vegas ha ofrecido invertir en una planta de tratamiento en el sur de California a cambio de agua adicional del río Colorado.)	15.30%	108
None of these, Ninguna de estas	0.99%	7
Unsure, Inseguro	1.70%	12
Other, Otro	11.05%	78
Total Respondents: 706		

Q2 Below are possible opportunities for groundwater sustainability. Which of the following strategies seem most important to you? Choose two.Más adelante se presentan posibles oportunidades para la sostenibilidad de las aguas subterráneas. ¿Cuál de las siguientes estrategias le parece más importante? Elija dos.

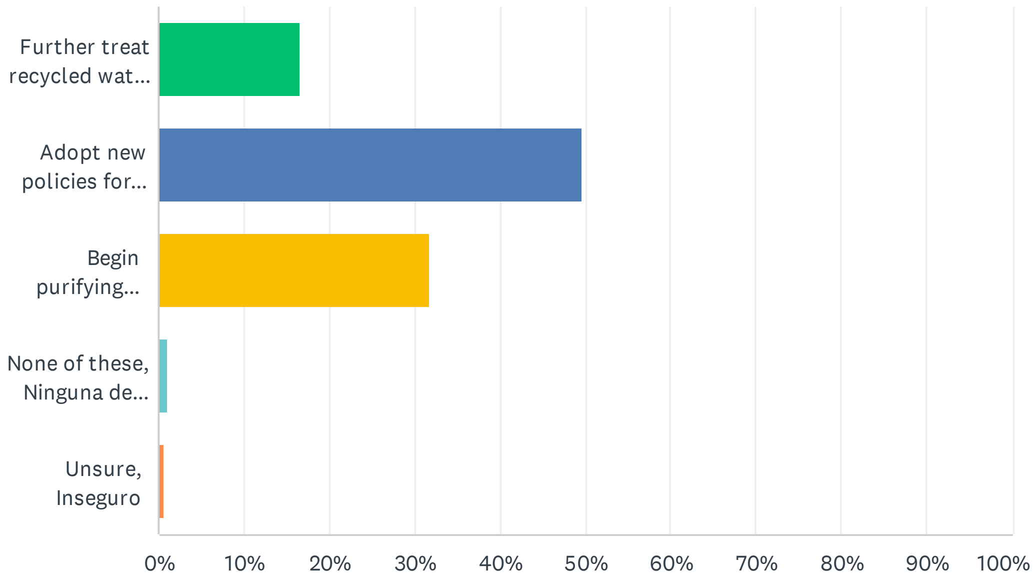
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Explore and invest in new treatment technologies to address unregulated, emerging water quality issues (Example: Two examples of unregulated contaminants are pharmaceuticals and personal care products.)Explorar e invertir en nuevas tecnologías de tratamiento para abordar problemas de calidad del agua no regulados y emergentes (Ejemplo: Dos ejemplos de contaminantes no regulados son los productos farmacéuticos y los productos de cuidado personal.)	56.23%	397
Accelerate groundwater cleanup efforts to make local supplies more available (Example: Some wells have been closed until the water can be treated to safe standards.)Acelerar los esfuerzos de limpieza de las aguas subterráneas para aumentar la disponibilidad de los suministros locales (Ejemplo: Se han cerrado algunos pozos hasta que el agua pueda ser tratada según las normas de seguridad.)	47.59%	336
Bolster sustainable groundwater management (Example: Build pipelines to bring Colorado River water to the southeast side of Tucson and reduce groundwater pumping in that area.)Reforzar la gestión sostenible de las aguas subterráneas (Ejemplo: Construir tuberías para llevar el agua del río Colorado a la zona sureste de Tucson y reducir el bombeo de aguas subterráneas en esa zona.)	26.77%	189
Partner with regional water organizations to protect the aquifer (Example: Work with other organizations to clean up contamination and ensure that the groundwater levels are balanced.)Colaborar con las organizaciones regionales del agua para proteger el acuífero (Ejemplo: Trabajar con otras organizaciones para limpiar la contaminación y garantizar el equilibrio de los niveles de las aguas subterráneas.)	67.56%	477
None of these, Ninguna de estas	0.71%	5
Unsure, Inseguro	1.13%	8
Total Respondents: 706		

Q3 Below are possible opportunities for recycled water use. Which of the following strategies seem most important to you? Choose one.Más adelante se presentan posibles oportunidades para el uso de agua reciclada. ¿Cuál de las siguientes estrategias le parece más importante? Elija uno.

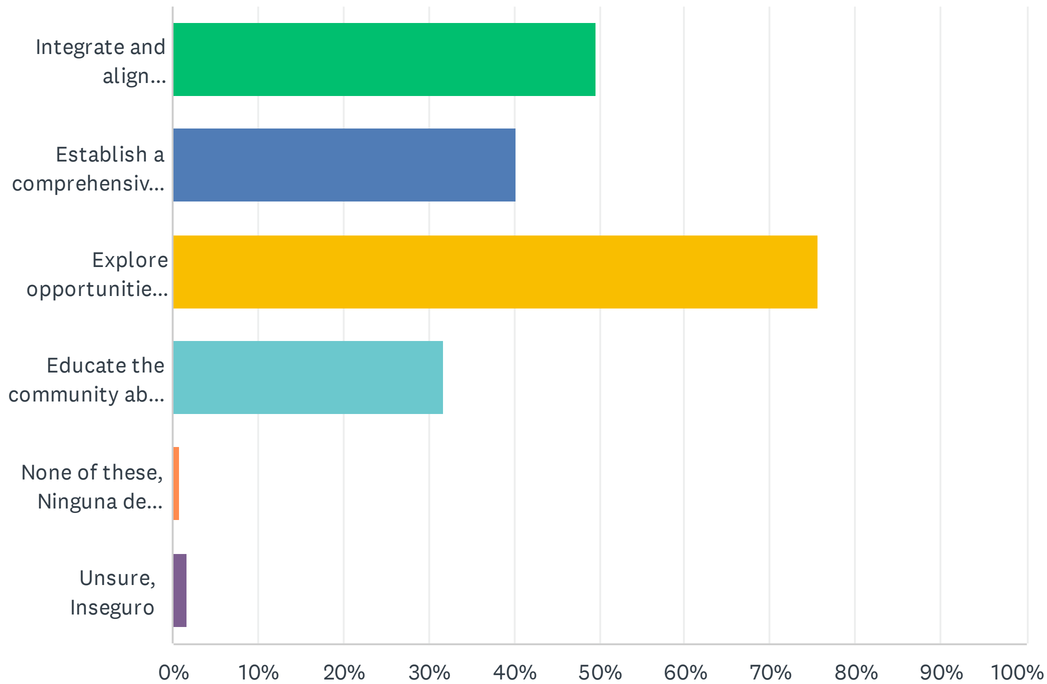
Answered: 706   Skipped: 0



ANSWER CHOICES	RESPONSES	
Further treat recycled water for custom uses (Example: Recycled water could be used in cooling towers for large buildings.)Tratar más el agua reciclada para usos personalizados (Ejemplo: El agua reciclada podría utilizarse en las torres de refrigeración de los grandes edificios.)	16.57%	117
Adopt new policies for water reuse in buildings (Example: Using rainwater, recycled water, and air conditioning condensate for toilet flushing.)Adoptar nuevas políticas de reutilización del agua en los edificios (Ejemplo: Utilizar el agua de lluvia, el agua reciclada y el condensado del aire acondicionado para las descargas de los inodoros.)	49.72%	351
Begin purifying recycled water to drinking water standards (Example: San Diego has begun using purified recycled water to augment their drinking water supply.)Empezar a purificar el agua reciclada para que cumpla con las normas de agua potable (Ejemplo: San Diego ha empezado a utilizar agua reciclada purificada para aumentar su suministro de agua potable).	31.87%	225
None of these, Ninguna de estas	1.13%	8
Unsure, Inseguro	0.71%	5
TOTAL		706

Q4 Below are possible opportunities for stormwater use. Which of the following strategies seem most important to you? Choose two.Más adelante se presentan posibles oportunidades para el uso de las aguas pluviales. ¿Cuál de las siguientes estrategias le parece más importante? Elija dos.

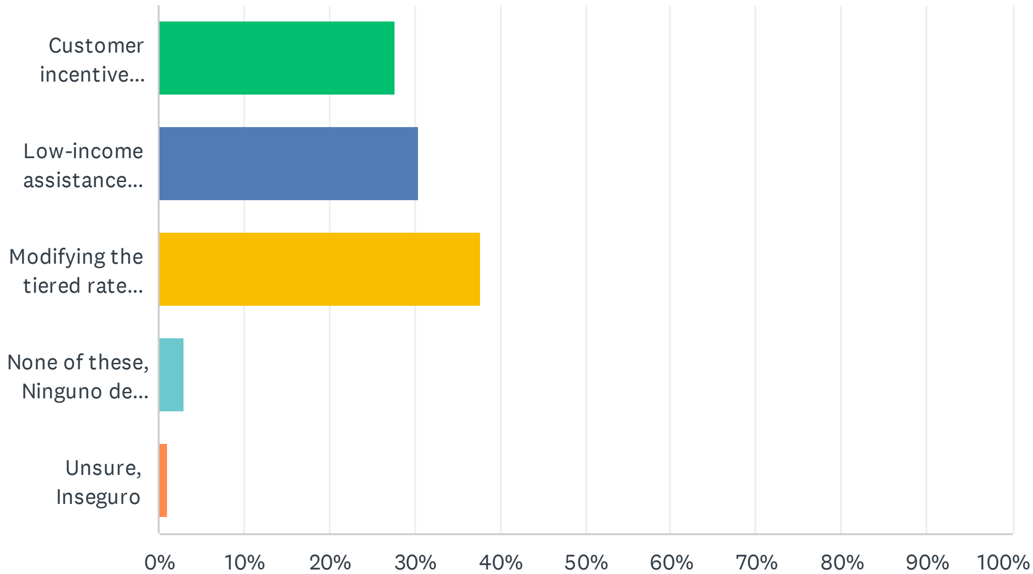
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Integrate and align stormwater standards, policies, and practices across the region (Example: Stormwater harvesting sites are not always designed and built using best practices. Creating a shared set of standards and policies would help ensure the performance of these sites.)Integrar y alinear las normas, políticas y prácticas sobre aguas pluviales en toda la región (Ejemplo: Los lugares de recogida de aguas pluviales no siempre se diseñan y construyen siguiendo las mejores prácticas. La creación de un conjunto compartido de normas y políticas ayudaría a garantizar el rendimiento de estos sitios.)	49.58%	350
Establish a comprehensive stormwater utility (Example: Expand the City's existing stormwater fee to fund services like flood control and large scale rainwater harvesting.)Establecer un servicio integral de aguas pluviales (Ejemplo: Ampliar la tasa de aguas pluviales existente en la ciudad para financiar servicios como el control de inundaciones y la recogida de aguas pluviales a gran escala	40.37%	285
Explore opportunities for large scale stormwater projects with multiple benefits (Example: Design detention basins to control flooding, harvest stormwater, and support native landscaping.)Explorar oportunidades para proyectos de aguas pluviales a gran escala con múltiples beneficios (Ejemplo: Diseñar cuencas de detención para controlar las inundaciones, recoger las aguas pluviales y apoyar el paisajismo nativo.)	75.64%	534
Educate the community about using rain and stormwater for landscaping (Example: An advertising campaign that teaches the public about how to support native plants and trees with rain and stormwater harvesting.)Educar a la comunidad sobre el uso de las aguas pluviales para la jardinería (Ejemplo: Una campaña publicitaria que enseñe al público cómo apoyar a las plantas y árboles nativos con la recolección de aguas pluviales y de lluvia.)	31.87%	225
None of these, Ninguna de estas	0.85%	6
Unsure, Inseguro	1.70%	12
Total Respondents: 706		

Q5 Under the Incentives category, which program is most important to you? Choose one.En la categoría de Incentivos, ¿qué programa es el más importante para usted? Elija uno.

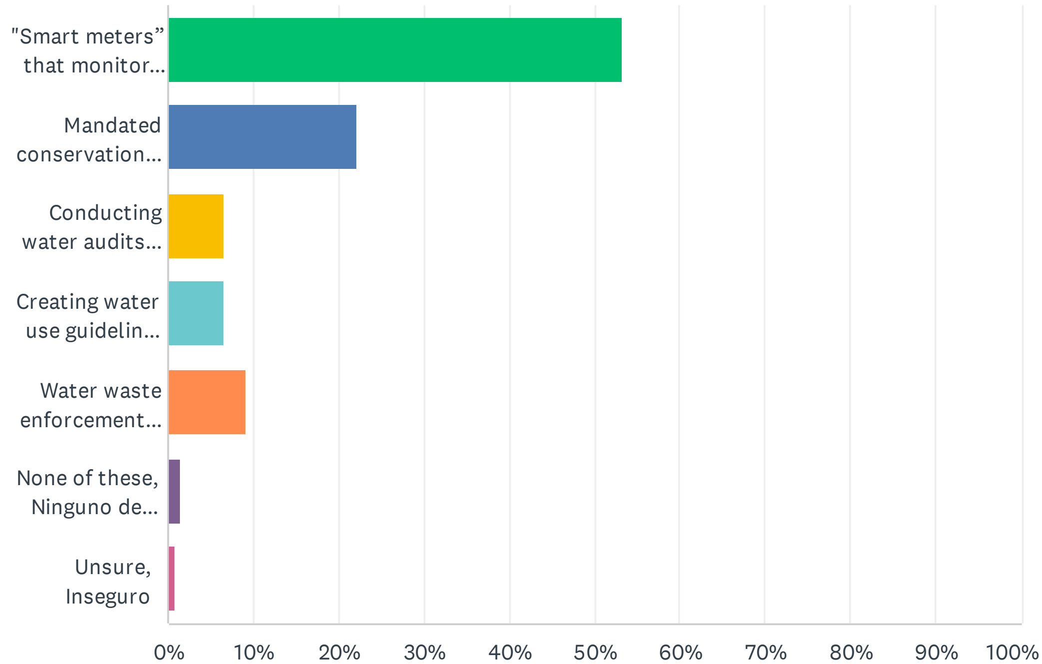
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Customer incentive programs like rebates (Example: Rebates for toilets and washer machines that are more efficient)Programas de incentivos para los clientes, como los reembolsos (Ejemplo: reembolsos por inodoros y lavadoras más eficientes)	27.62%	195
Low-income assistance (Example: Reduced or no-cost toilet replacement, rainwater harvesting systems, and emergency plumbing repairs)Ayudas a las rentas bajas (Ejemplo: Sustitución de inodoros a precio reducido o sin coste, sistemas de recogida de agua de lluvia y reparaciones de fontanería de emergencia)	30.59%	216
Modifying the tiered rate structure to make it more progressive (Example: Currently, the more water customers use, the more they pay per unit of water. This tiered rate structure could be made more progressive, making it more expensive the more water you use.) Modificación de la estructura tarifaria escalonada para hacerla más progresiva (Ejemplo: En la actualidad, cuanto más agua utilizan los clientes, más pagan por unidad de agua. Esta estructura tarifaria escalonada podría hacerse más progresiva, haciendo que sea más cara cuanto más agua se consuma.)	37.82%	267
None of these, Ninguno de estos	2.97%	21
Unsure, Inseguro	0.99%	7
TOTAL		706

Q6 Under the Monitoring and Mandates category, which program is most important to you? Choose one.En la categoría de Supervisión y Mandatos, ¿qué programa es el más importante para usted? Elija uno.

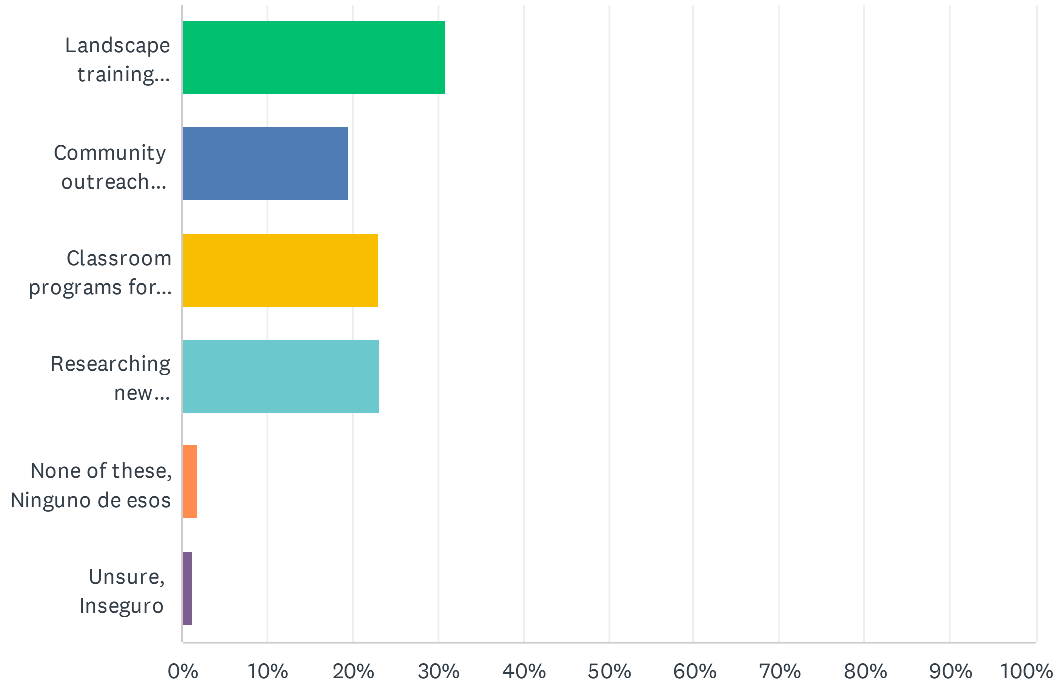
Answered: 706   Skipped: 0



ANSWER CHOICES	RESPONSES	
"Smart meters" that monitor water use in real time, provide leak alerts, and inform water use habits (Example: a website or app that notifies you when unusual water use is occurring)"Contadores inteligentes" que supervisan el uso del agua en tiempo real, proporcionan alertas de fugas e informan sobre los hábitos de uso del agua (Ejemplo: una página web o una aplicación que le notifica cuando se produce un uso inusual del agua)	53.26%	376
Mandated conservation (Example: Restrictions on how often you can water your landscape)Conservación obligatoria (Ejemplo: Restricciones en la frecuencia con la que se puede regar el jardín)	22.10%	156
Conducting water audits (Example: Personalized, step by step analysis of indoor and outdoor water uses)Realización de auditorías de agua (Ejemplo: Análisis personalizado, paso a paso, de los usos de agua en interiores y exteriores)	6.52%	46
Creating water use guidelines (Example: An efficiency reference point for each type of customer)Creación de directrices sobre el uso del agua (Ejemplo: un punto de referencia de eficiencia para cada tipo de cliente)	6.66%	47
Water waste enforcement (Example: City employees contact people that allow water to run off their property and into the road)Aplicación de la normativa sobre el derroche de agua (Ejemplo: Los empleados de la ciudad se ponen en contacto con las personas que permiten que el agua salga de su propiedad y llegue a la carretera)	9.07%	64
None of these, Ninguno de estos	1.56%	11
Unsure, Inseguro	0.85%	6
TOTAL		706

Q7 Under the Education category, which program is most important to you? Choose one.En la categoría Educación, ¿qué programa es más importante para usted? Elija uno.

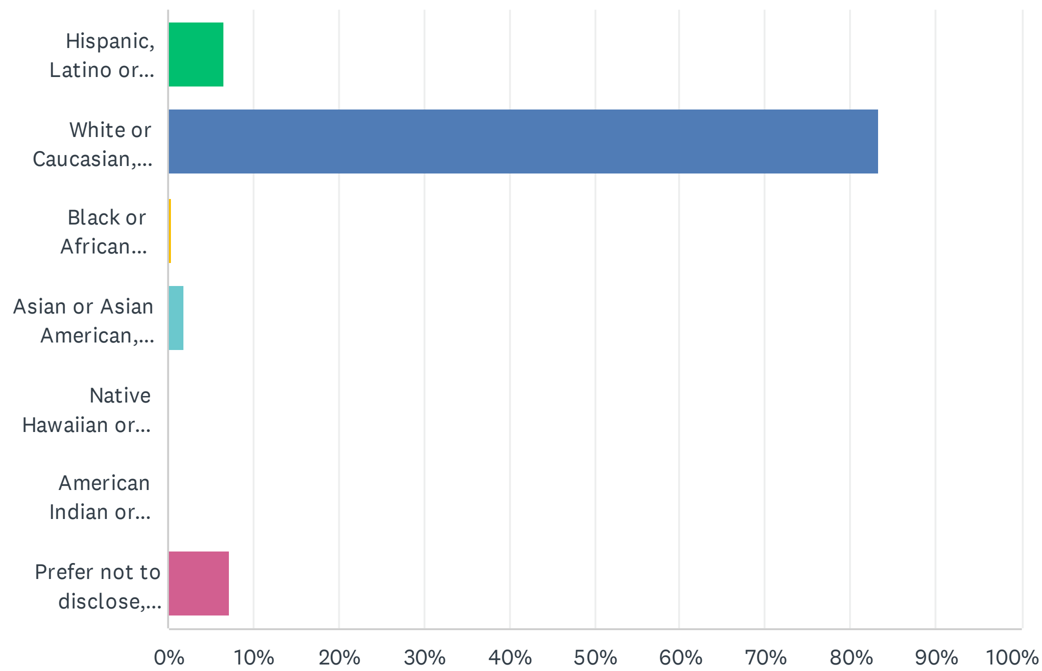
Answered: 706   Skipped: 0



ANSWER CHOICES	RESPONSES	
Landscape training (Example: Classes for homeowners and landscape professionals about water efficiency and native plants)Capacitación en paisajismo (Ejemplo: Clases para propietarios de viviendas y profesionales del paisajismo sobre la eficiencia del agua y las plantas nativas)	31.02%	219
Community outreach programs (Example: Advertising campaigns and websites)Programas de alcance comunitario (Ejemplo: Campañas publicitarias y sitios web)	19.55%	138
Classroom programs for children's education on conservation (Example: Presentations about water conservation, our water supplies, and the water cycles for grade schools)Programas de aula para la educación de los niños sobre la conservación (Ejemplo: Presentaciones sobre la conservación del agua, nuestros suministros de agua y los ciclos del agua para las escuelas primarias)	22.95%	162
Researching new technologies (Example: Toilets and washer machines that are more water efficient)Investigar nuevas tecnologías (Ejemplo: Inodoros y lavadoras que sean más eficientes en el uso del agua)	23.23%	164
None of these, Ninguno de esos	1.98%	14
Unsure, Inseguro	1.27%	9
TOTAL		706

Q8 For demographic purposes only, which of the following best describes your ethnic background? Solo con fines demográficos, ¿cuál de los siguientes describe mejor su origen étnico?

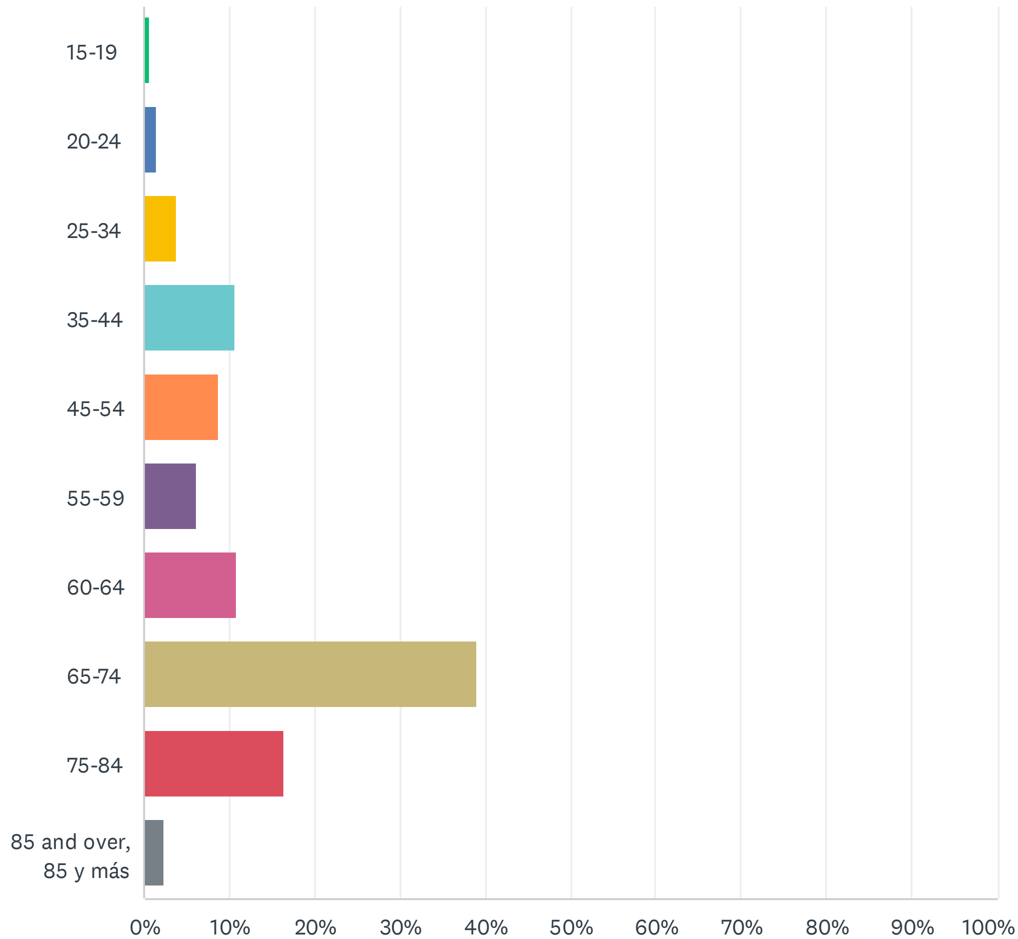
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Hispanic, Latino or Spanish origin, Origen Hispano, Latino o Español	6.52%	46
White or Caucasian, Blanco o Caucásico	83.29%	588
Black or African American, Negro o Afroamericano	0.42%	3
Asian or Asian American, Asiático Asiático Americano	1.98%	14
Native Hawaiian or Other Pacific Islander, Nativo Hawaiano u Otro Ssleño del Pacífico	0.28%	2
American Indian or Alaska Native, Indio Americano o Nativo de Alaska	0.28%	2
Prefer not to disclose, Prefiere no revelar	7.22%	51
TOTAL		706

Q9 Which of the following age groups best describes you? ¿Cuál de los siguientes grupos de edad te describe mejor?

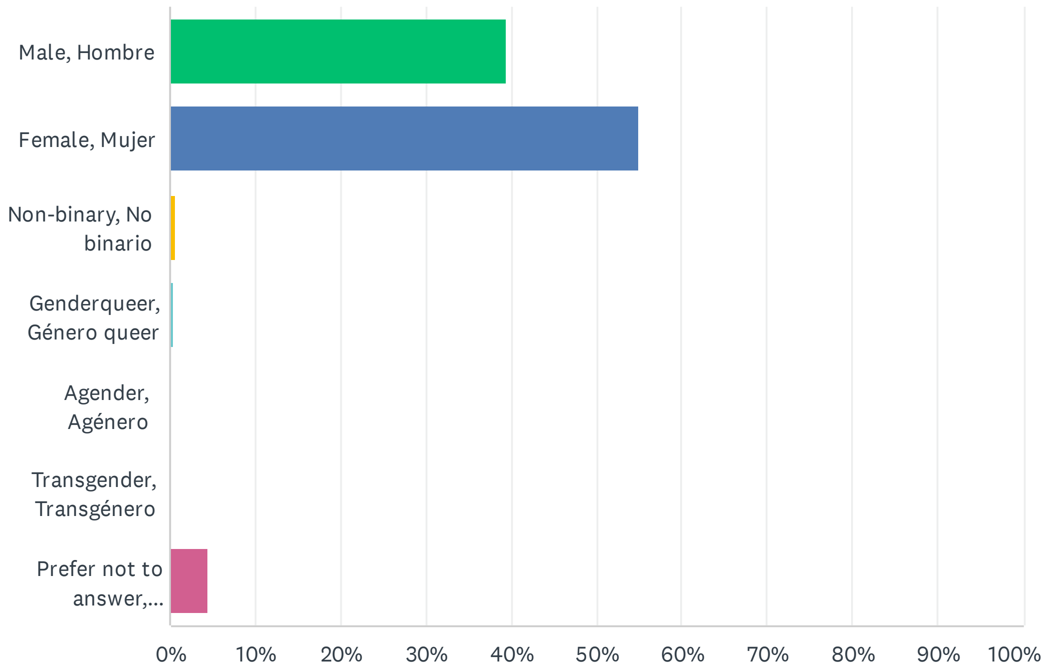
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
15-19	0.57%	4
20-24	1.42%	10
25-34	3.82%	27
35-44	10.76%	76
45-54	8.64%	61
55-59	6.23%	44
60-64	10.91%	77
65-74	38.95%	275
75-84	16.43%	116
85 and over, 85 y más	2.27%	16
TOTAL		706

Q10 Which of the following best describes you? ¿Cuál de los siguientes te describe mejor?

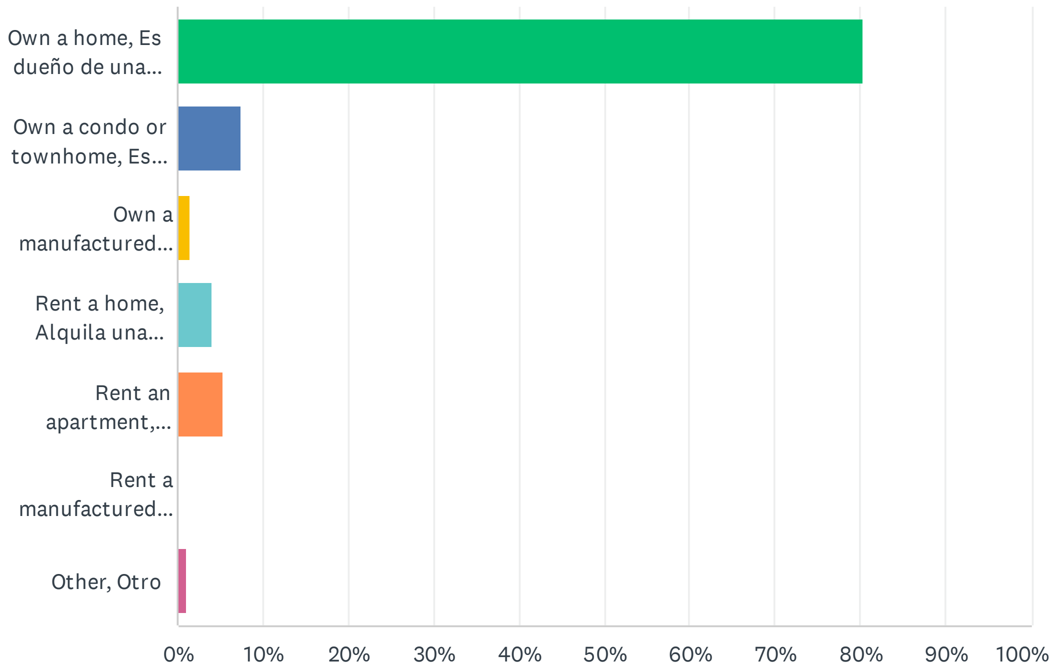
Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Male, Hombre	39.38%	278
Female, Mujer	55.10%	389
Non-binary, No binario	0.57%	4
Genderqueer, Género queer	0.42%	3
Agender, Agénero	0.14%	1
Transgender, Transgénero	0.00%	0
Prefer not to answer, Prefiere no contestar	4.39%	31
TOTAL		706

Q11 Do you rent or own your home, condo, townhome, or mobile home? ¿Alquila o es dueño de su casa, condominio, casa adosada o casa móvil?

Answered: 706 Skipped: 0



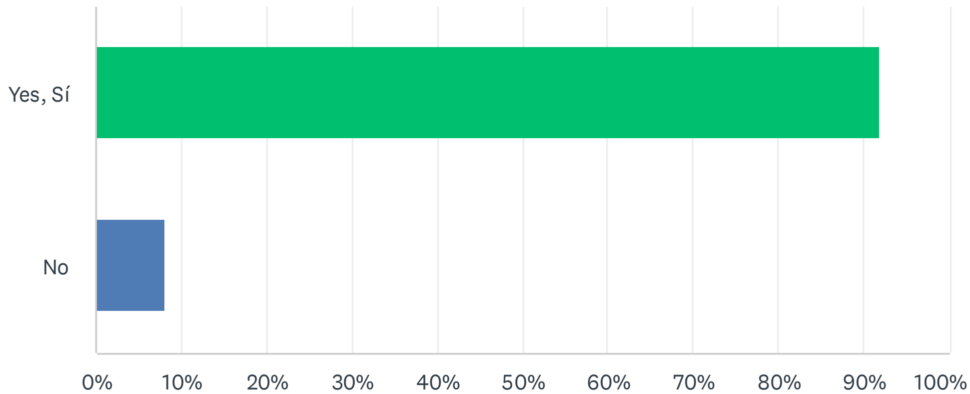
ANSWER CHOICES	RESPONSES	
Own a home, Es dueño de una casa	80.45%	568
Own a condo or townhome, Es dueño de un condominio o casa adosada	7.51%	53
Own a manufactured/mobile home, Es dueño de una casa prefabricada/móvil	1.42%	10
Rent a home, Alquila una casa	4.11%	29
Rent an apartment, condo, or townhome, Alquila un apartamento, un condominio o una casa adosada	5.38%	38
Rent a manufactured/mobile home, Alquila una casa prefabricada/móvil	0.14%	1
Other, Otro	0.99%	7
TOTAL		706

Q12 If you haven't already, please submit your email address to receive future updates about One Water 2100.Si aún no lo ha hecho, envíe su dirección de correo electrónico para recibir futuras actualizaciones sobre One Water 2100.

Answered: 386 Skipped: 320

Q13 Are you a Tucson Water customer?¿Es usted cliente de Tucson Water?

Answered: 706 Skipped: 0



ANSWER CHOICES	RESPONSES	
Yes, Sí	91.93%	649
No	8.07%	57
TOTAL		706

Q14 Please complete this survey by entering your zip code.Complete esta encuesta ingresando su código postal.

Answered: 706 Skipped: 0