BUREAU OF RECLAMATION

Lower Santa Cruz River Basin Study Final Report

Lower Colorado Basin Region
Phoenix Area Office

U.S. Department of the Interior

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Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, Native Hawaiians, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photos: Clockwise – Central Arizona Project pumping station, Lower Santa Cruz River Managed Recharge Project, Groundwater Savings Facility (farm), Lower Santa Cruz River Replenishment Project recharge basin, dry stream bed within a riparian area.

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Lower Colorado Basin Region
Phoenix Area Office

prepared by

Bureau of Reclamation
Phoenix Area Office

In Partnership with
Southern Arizona Water Users' Association
Arizona Department of Water Resources
Central Arizona Project
Cortaro-Marana Irrigation District
Pima Association of Governments
University of Arizona

Acronyms and Abbreviations

ADWR	Arizona Department of Water Resources
AF	acre-feet (1 AF = 43,560 cubic feet = 325,851 gallons)
AF/y	acre-feet per year
AMAs	Active Management Areas
AOEO	Arizona Office of Economic Opportunity
AR5	5th Assessment Report
AWS	Assured Water Supply
BS	Basin Study
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAP:SAM	Central Arizona Project Service Area Model
CASS	Central Arizona Salinity Study
CAVSARP	Central Avra Valley Storage and Recharge Project
CAWCD	Central Arizona Water Conservation District
CDO	Cañada del Oro/Saddlebrooke
CMID	Cortaro-Marana Irrigation District
CMIP	Coupled Model Intercomparison Project Climate Projections
DCP	Drought Contingency Plan
DOI	Department of the Interior
DTW	depth to water
ET	evapotranspiration
°F	degrees Fahrenheit
GCMs	Global Climate Models
GSF	Groundwater Savings Facility
GtC	Gigatons of carbon
GV	Green Valley
GW	Groundwater
HU	Housing unit
IPCC	Intergovernmental Panel on Climate Change

KERP	Kino Environmental Restoration Project
LID	low impact development
LSCR	Lower Santa Cruz River
LTSCs	Long-term Storage Credits
MAF	million acre-feet
NPV	net present value
NWRRDS	Northwest Recharge Recovery and Delivery System
PAG	Pima Association of Governments
RCM	regional climate model
RCPs	Representative Concentration Pathways
Reclamation	Bureau of Reclamation
SAVSARP	Southern Avra Valley Storage and Recharge Project
SAWUA	Southern Arizona Water Users' Association
SC/TV	Sabino Canyon/ Tanque Verde
SCR	Santa Cruz River
SECURE	Science and Engineering to Comprehensively Understand and Responsibly Enhance
SET	Southeast Tucson
TAF/yr	thousands of acre-feet per year
TAMA	Tucson Active Management Area
TSC	Technical Service Center (Reclamation)
UA	University of Arizona
VIC	Variable Infiltration Capacity Model
WaterSMART	Sustain and Manage America's Resources for Tomorrow program
WRF	Weather Research and Forecasting Model

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Appendix B - Hydroclimate Analysis

Appendix C - Supply and Demand Assessment

Appendix D - Groundwater Modeling Analysis

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Appendix F - Adaptation Strategy Descriptions

Appendix G - Economic and Trade-off Analyses

Chapter 1 Introduction

1.1 Study Area Water Resources and Challenges

The Bureau of Reclamation (Reclamation) joined with the Southern Arizona Water Users' Association (SAWUA) and five other non-federal cost-share partners[1] (Study Partners) in 2016 to conduct the Lower Santa Cruz River Basin Study (Study) in southern Arizona. The Study is the first direct assessment of the impacts of climate change and municipal growth on the Lower Santa Cruz River Basin's water supplies and demands.

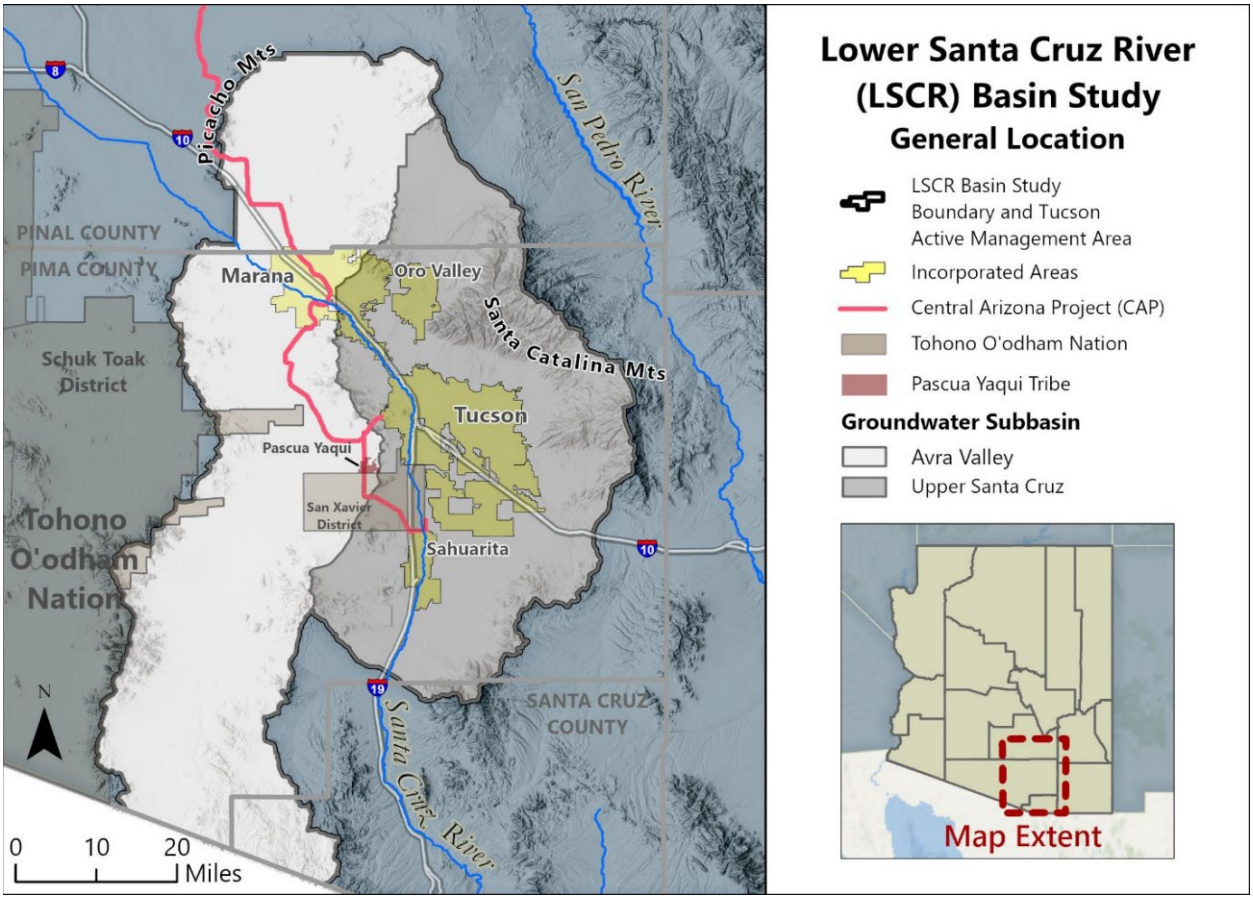


Figure 1-1 – General location map for the Lower Santa Cruz River Basin Study.

[1] Cost-share partners include the Southern Arizona Water Users' Association (SAWUA), the Central Arizona Water Conservation District (CAWCD), the Arizona Department of Water Resources (ADWR), the Pima Association of Governments (PAG), the University of Arizona, and the Cortaro-Marana Irrigation District (CMID).

The Study focuses on the 3,866 square-mile area defined as the Tucson Active Management Area (TAMA) in southern Arizona (Figure 1-1). Under Arizona's 1980 Groundwater Code (Code), areas with heavy reliance on non-renewable groundwater were designated as Active Management Areas (AMAs), which became subject to a new groundwater rights system that strictly limited groundwater withdrawals (Arizona Department of Water Resources, 1999).

The Study Area includes two major subbasins: the Avra-Altar Valley, which stretches from the Mexican border to near Picacho Peak, and the Upper Santa Cruz River subbasin, which starts at roughly the Santa Cruz County line and extends into Pinal County, north of the Santa Catalina Mountains. The greater Tucson region, which is situated within the Study Area, has a semi-arid climate, receiving an average of approximately 11 inches of precipitation a year. Precipitation is distributed between a summer monsoon season and a winter rainy season (Sheppard, Comrie, Packin, Angersbach, & Hughes, 2002).

From the development of the Tucson region in the 1800s until the 1990s, water users relied primarily on groundwater. As the population grew and agriculture and industry expanded, pumping greatly exceeded replenishment, leading to steep declines in groundwater levels. Beginning in the mid-1970s, reclaimed water was utilized to offset the demand for groundwater pumping.

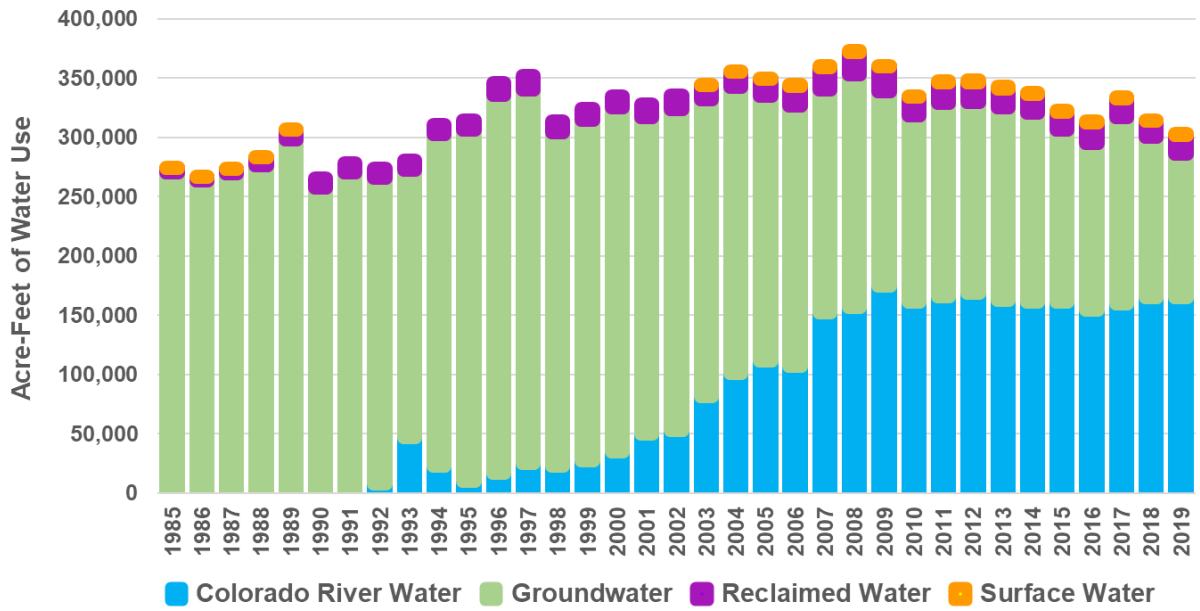


Figure 1-2 – Water Use by Source in the Tucson Active Management Area, 1985 – 2019, accessed from AMA Data | Arizona Department of Water Resources (azwater.gov), March 28, 2022.

However, groundwater conditions in Study Area did not improve significantly before the late 1990s, when the Central Arizona Project (CAP) began delivering large volumes of renewable Colorado River water. At present, groundwater, CAP water, and reclaimed water are the primary

supplies in the Study Area (Figure 1-2). Groundwater levels have rebounded in many parts of the Study Area, despite the population growing to over 1 million people in 2020. This is due to several factors including recharge of CAP water, significant reductions in residential per capita water use, and decreased agricultural groundwater use.

Still, local supply-demand imbalances persist due to a lack of infrastructure to transport renewable supplies to points of use, and the situation has been exacerbated by extended drought conditions. Parts of the Study Area without physical access to renewable supplies are experiencing groundwater declines near pumping sites. These declines have already resulted in land subsidence and the loss of riparian habitat. Water providers in these locations may need to deepen or relocate wells to maintain reliable service. Groundwater quality degradation and significantly increased pumping costs may occur if no action is taken to address these local supply-demand imbalances.

Anticipated municipal growth will compound these issues. Population growth projections for the Study Area range from approximately 100,000 to almost 350,000 for the Study Area through 2055 (Arizona Commerce Authority, 2022). Although per-capita water use is low in comparison with other Arizona communities (Western Resource Advocates, 2010), projections made in the Supply and Demand portion of this Study indicate that savings made through conservation may eventually be exceeded by new municipal demands, further discussed in Chapter 8.

Climate change poses threats on both the demand and supply sides of the water balance sheet. As temperatures rise, the water demand increases for cooling (especially related to air conditioning and power generation) and maintaining vegetation (evaporation and transpiration). This leads to higher rates of consumptive use by the municipal and agricultural sectors, as well as by natural ecosystems. On the supply side, changes in temperature and precipitation at the scale of the LSCR Basin will affect runoff, stream infiltration and recharge processes, impacting local surface and groundwater supplies. These impacts are discussed in detail in Chapter 7 and in the Hydroclimate Analysis Technical Memorandum.

At a larger scale, the Colorado River Basin is experiencing the driest conditions in more than 1,200 years (Woodhouse, Meko, McDonald, Stahle, & Cook, 2010) and these conditions are expected to continue into the future. Since CAP has a junior priority in the Lower Colorado River Basin, reductions in Colorado River supplies impact CAP water users significantly (Central Arizona Project, 2022a).

This Study considered the impacts of stresses to the Study Area's water supplies on the total amount of water stored in the regional aquifer and on local supply-demand imbalances. Study analyses evaluated the impacts of municipal growth, drought, and climate change within the LSCR Basin, as well as responses to reductions in CAP supplies. The Study assessed the impact of these stresses on surface hydrology, groundwater hydrology, and the ability of municipal water providers to meet their customers' demands. The subsequent chapters describe how the Study was formulated to address specific needs of the Study Partners, the technical approaches used to respond to these needs, and then details the methods and results of each analysis.

1.2 Study Authority

In 2009, Congress enacted the Science and Engineering to Comprehensively Understand and Responsibly Enhance (SECURE) Water Act (Act), which found that "global climate change poses a significant challenge to the protection and use of the water resources of the United States..." Section 9503 of the Act directed the Secretary of the Interior to establish a climate change adaptation program. To implement the SECURE Water Act, the Department of the Interior established the Sustain and Manage America's Resources for Tomorrow Program (WaterSMART) in 2010.

The WaterSMART program provides a framework for federal leadership and assistance to stretch and secure water supplies for future generations. Through WaterSMART, the Bureau of Reclamation (Reclamation) leverages federal and non-federal funding to work cooperatively with states, Tribes, and local entities as they plan for and implement actions to increase water supply sustainability through investments in existing infrastructure and attention to local water conflicts.

Reclamation developed the Basin Studies program as part of WaterSMART. These collaborative studies analyze the impacts of climate change and other factors on future water supplies and demands, identify risks, and develop adaptation strategies at the river basin scale. Basin Studies are technical assessments and do not provide recommendations or represent a statement of policy or position of Reclamation, the Department of the Interior, or the funding partners.

1.3 Study Cost-share Partners

This section provides a summary of the LSCR Basin Study non-federal cost-share partners (Figure 1-3) and their missions. The proposal for the LSCR Basin Study was developed by the Southern Arizona Water Users' Association. Other partners joined and contributed to the development of the Plan of Study after the proposal had been approved for funding.

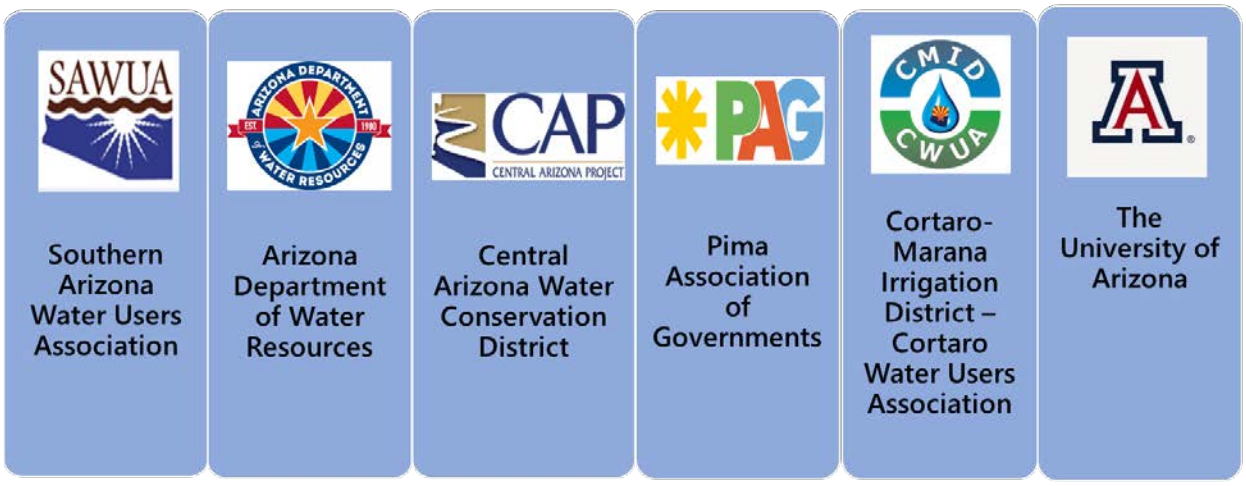


Figure 1-3 – Non-federal cost-share partners for the LSCR Study.

Southern Arizona Water Users' Association (SAWUA): SAWUA is comprised of 15 members, including the largest water providers in the Tucson region, wastewater reclamation entities, and agricultural water users (Figure 1-4). SAWUA member agencies have water management authority to provide municipal water and wastewater service to over 900,000 residents in the Basin. Founded in 1999, SAWUA coordinates in the development of effective water resource policy and planning in an effort to preserve and enhance the quality and quantity of the region's water resources.

Figure 1-4 – Members of the Southern Arizona Water Users' Association.

Central Arizona Water Conservation District (CAWCD), commonly referred to as Central Arizona Project (CAP): CAP serves as a collaborative partner and innovative leader in sustainable management and reliable delivery of water for Central Arizona. CAP is Arizona's single largest resource for renewable water supplies, delivering Colorado River water to Maricopa, Pinal, and Pima counties, where more than 80% of the state's population lives. CAP is managed by a popularly elected, 15-member Board of Directors, with 10 members from Maricopa County, four from Pima County, and one from Pinal County.

Arizona Department of Water Resources (ADWR): ADWR's mission is to safeguard the health, safety, and economic welfare of the public by protecting, conserving, and enhancing Arizona's water supplies in a bold, thoughtful, and innovative manner. ADWR administers the

State's water laws through the compilation and analysis of water supply data, coordination of research to augment water supplies for future demand, and development of policies that promote conservation and water availability.

Pima Association of Governments (PAG): PAG is a metropolitan planning organization for the greater Tucson region and an association of local, state, and tribal governments that works to build consensus among its members (Figure 1-5) and the public on regional planning for transportation, water quality, air quality, and economic vitality.

Figure 1-5 – Members of the Pima Association of Governments.

The University of Arizona (UA): The University of Arizona's mission is to improve the prospects and enrich the lives of the people of Arizona and the world through education, research, creative expression, and community and business partnerships. Specifically, the UA Center for Climate Adaptation Science and Solutions (CCASS) brings together a wealth of expertise at the UA to support sound management choices in the context of climate change, linking science, information needs of managers, and decision-making.

Cortaro-Marana Irrigation District (CMID) - CMID provides water to lands within the District, primarily for irrigation purposes. Additionally, CMID pursues all lawful activity that supports, sustains, promotes, and advances the economic viability of irrigated agriculture within its boundaries.

1.4 Study Organization

The Study entailed a high degree of collaboration between Reclamation, the Study cost-share partners, other local experts, and members of the public. Study management was coordinated by two Co-Study Managers, one representing Reclamation and the other representing the non-federal cost-share partners. A "Core Team" consisting of the Co-Study Managers and expert partners met weekly to discuss progress and strategy.

The Co-Study Managers solicited feedback on key Study decisions from participants at all levels of involvement and then provided direction to the staff who performed the technical work of the Study. These technical experts were drawn from Reclamation's Technical Service Center (TSC) in Denver, Colorado and from the staffs of the partner agencies. Figure 1-6 shows the relationships of the Study team, Sub-teams, and their associated membership. Major Study decisions were made by a consensus of the "Project Team", which was comprised of representatives from the six Study Partners. The Project Team was led by the Co-Study Managers. Members of the Project Team served as local experts in water resource and management topics such as hydrology, climate science, municipal water provision, wastewater treatment, environmental water use, and agriculture within the Basin. Project Team members also provided critical knowledge related to the Study's scope and objectives.

In addition to the Project Team, "Sub-teams" were formed to provide expertise on specific tasks. Participation was open to anyone with interest and expertise in the Sub-teams' focus area. Three sub-teams played key roles in accomplishing specific Study tasks.

The Municipal Demand Sub-team provided input on current and projected water demand for the municipal sector, delineating the areas within the Basin that were expected to gain population. The Sub-team also specified where renewable supplies would be recharged and where stored water would be recovered in a shortage situation and developed municipal supply-related evaluation criteria.

The Environmental Sub-Team provided input on current and projected water demand for the environment (i.e., riparian habitat), needs for habitat preservation, and opportunities for ecosystem restoration. They also focused on environmentally oriented and multi-benefit adaptation strategies and the development of environmentally focused evaluation criteria for the Trade-off Analysis.

The Outreach and Communications Sub-Team developed the public engagement plan and public awareness resources such as factsheets, presentations, and public meeting advertisements. They organized the Study's public meetings and documented feedback from the public so it could be communicated to the Project Team and other interested parties.

A Stakeholder Advisory Team was created accommodate members of the public who wished to be more involved in the Study than just attendance at public meetings. The Stakeholder Advisory Team provided an opportunity for individuals who were not associated with the Study Partners to give feedback on the general conduct of the Study.

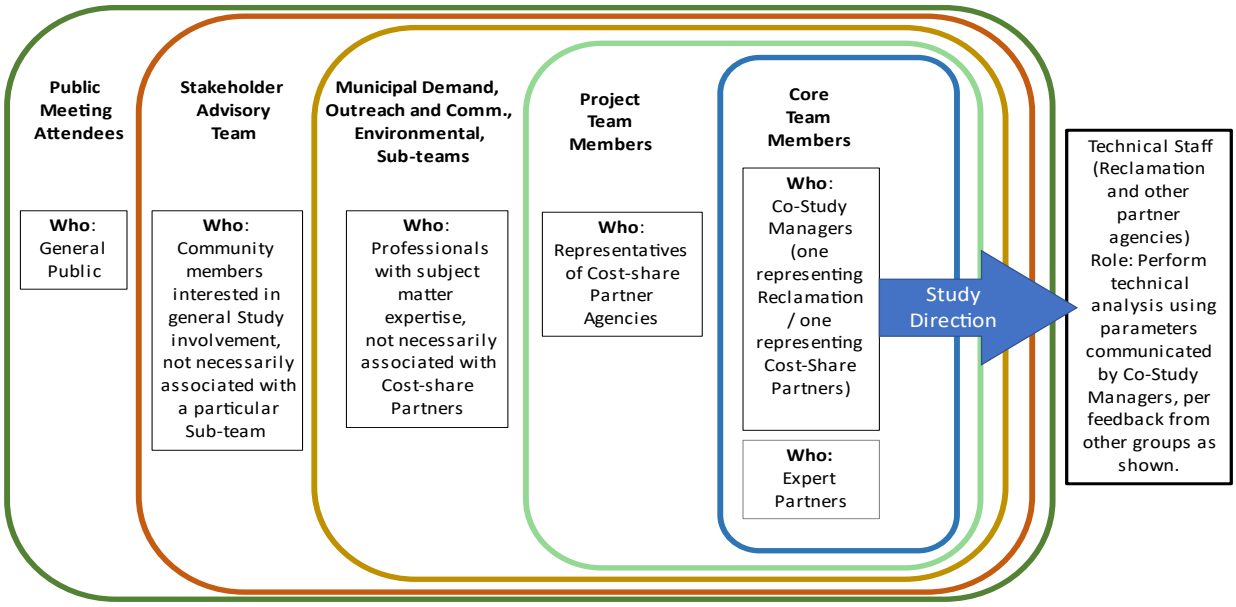


Figure 1-6 – LSCR Basin Study teams, sub-teams, and associated membership.

1.5 Stakeholder and Public Engagement

The Study's engagement process was designed with input from several partners. This section provides a brief overview of the Study's public engagement efforts, which are shown in Figure 1-7.

The Plan of Study (Appendix A) describes the objective of engaging regional stakeholders (interested parties not associated with the Study Partners) at key intervals within the Study process. The Pima Association of Governments played a critical role as the leader and host of local outreach and public engagement efforts. Input was solicited from industrial and tribal water users, environmental organizations, local university students and professors, and interested members of the public.

As the Study was being initiated, several informational meetings were held to encourage public participation. The public meetings were held at accessible venues including the University of Arizona's Water Resources Research Center and the PAG offices in downtown Tucson. Numerous presentations with opportunities for comment were made throughout the Basin Study process.

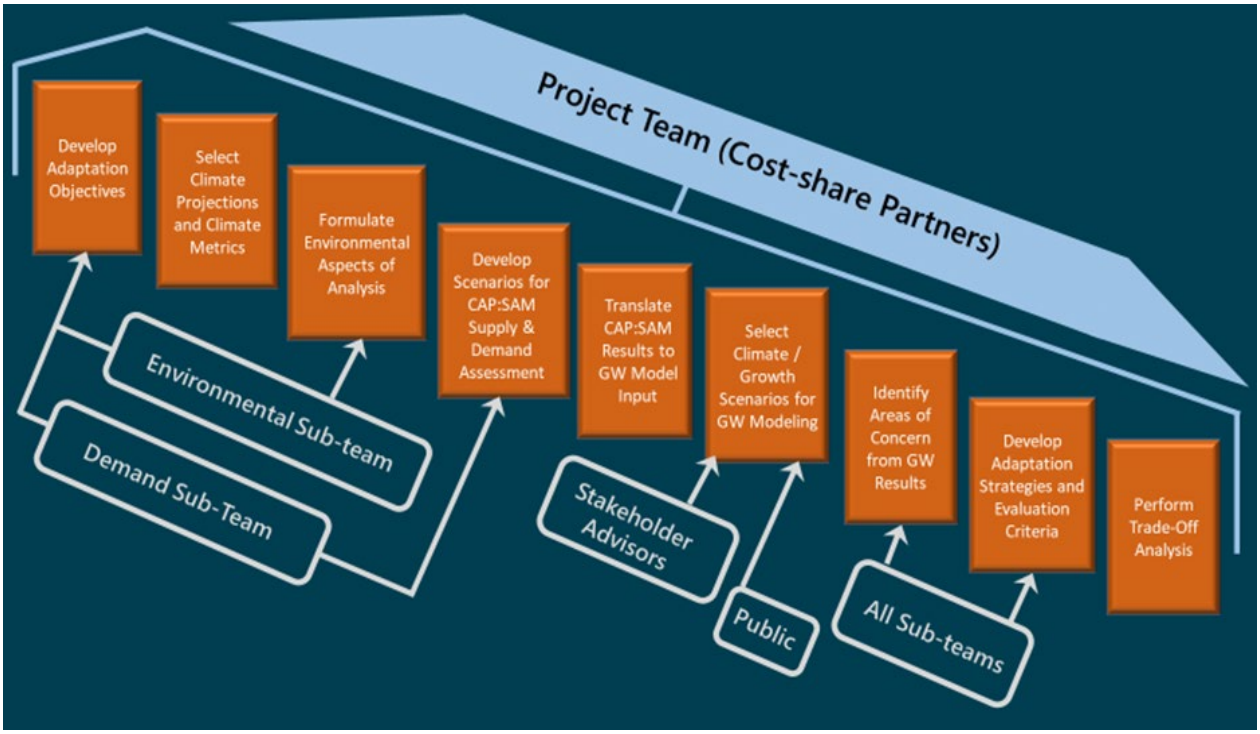


Figure 1-7 – Diagram of stakeholder and public engagement throughout the Study process.

Decision points at which stakeholder input was solicited included the development of requirements for the Hydroclimate Analysis, the formulation of scenarios for CAP's CAP:SAM planning model, assumptions used in the groundwater modeling, and the development of adaptation strategies and evaluation criteria.

Two public meetings were held to engage members of the public, both coordinated by PAG. The first meeting was held in November 2016 and included presentations by Reclamation and the Study Partners on the need for the Study and the planned activities. Comment cards were distributed to attendees to gather their observations and questions. A second public meeting was held in March 2018 and focused on the six proposed climate/municipal growth scenarios to be used in the Study's groundwater modeling. Meeting feedback was integrated into the final versions of the scenarios.

As the Study progressed, it became more efficient to hold joint "All Teams" meetings including the Study Partners, sub-team members, and Stakeholder Advisors. All Teams meetings were held to solicit input on climate modeling (December 2018) and present Hydroclimate Analysis results (October 2019).

Stakeholder input was also solicited at two All Teams workshops focused on developing adaptation strategies and evaluation criteria for the strategies. An in-person full-day workshop was held in November 2019 to obtain high-level input on adaptation strategies ahead of the

groundwater modeling results. The meeting was professionally facilitated and divided participants into diverse small groups to brainstorm adaptation measures. Workshop results are presented in Appendix E.

The second adaptation strategy workshop took place virtually due to the COVID-19 pandemic. By this time the groundwater modeling results had identified four areas of concern within the Basin, enabling the development of precisely targeted strategies. (Regional strategies were also suggested.) Feedback from this workshop was translated into specific strategies evaluated under the Trade-off Analysis.

In addition to Study meetings, the Co-Study Managers made presentations to a variety of local organizations and community meetings including:

- University of Arizona Water Resources Research Center
- PAG Environmental Planning Advisory Committee
- PAG Watershed Planning Sub-committee
- Arizona Hydrological Society - Tucson Chapter
- Arizona Hydrological Society Annual Symposium
- Sonoran Institute Santa Cruz River Research Days
- Pima County Flood Control Monthly Brown Bag
- Santa Cruz Watershed Collaborative Semi-annual Forum
- Central Arizona Water Conservation District Board Meeting

Chapter 2 Study Framework

2.1 Basin Study Elements

As required under the Reclamation Directives and Standards for Basin Studies, the LSCR Basin Study included four main components (Figure 2-1):

(1) Projections of future water supply and demand, considering specific impacts resulting from climate change;

(2) Analyses of how existing water infrastructure and operations will perform given current imbalances between water supply and demand and in the face of changing water realities due to climate change;

(3) Development of appropriate adaptation and mitigation strategies to meet current and future water demands; and

(4) A trade-off analysis of the mitigation strategies related to their ability to meet Study objectives (Bureau of Reclamation, 2016).

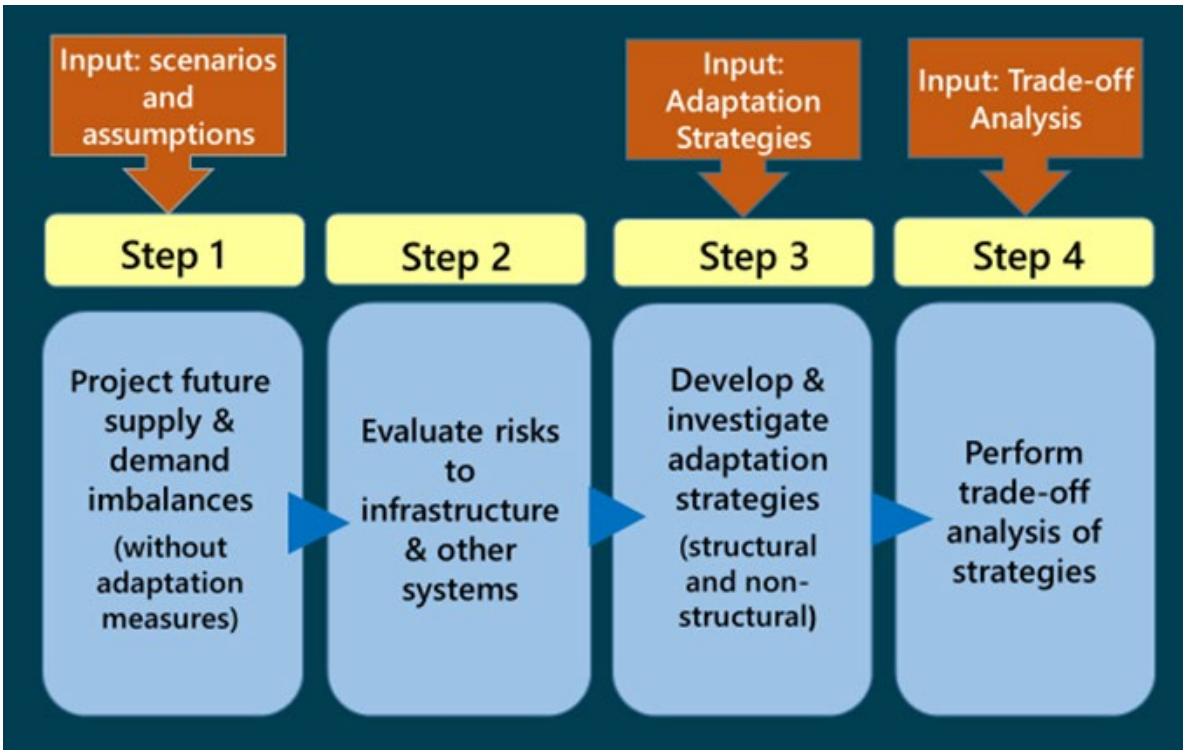


Figure 2-1 – The four components of a Reclamation Basin Study.

Municipal, agricultural, and industrial users rely on groundwater, CAP water, and reclaimed water for supplies. Of these, groundwater is the most vulnerable to changes in temperature and precipitation within the LSCR Basin. Study Partners wanted to understand how changes in the LSCR Basin's precipitation and temperature patterns could alter surface runoff, stream infiltration, and groundwater recharge, and the resulting impacts to the distribution of water supplies. Partners also wanted to evaluate the effects of the LSCR Basin's changing surface and groundwater hydrology on local environmental resources, particularly riparian areas. Finally, the Partners were concerned about the location and magnitude of new water demands, as well as the impact of cutbacks to municipal CAP supplies.

The Study Partners worked closely with Reclamation to develop a Plan of Study that was tailored to their needs, given the types of risks to water supplies, the highly variable, semi-arid climate, and the distinct seasonal precipitation patterns of the LSCR Basin. The partners had specific concerns that shaped the way the Study was conducted. In response to these concerns, Reclamation Technical Service Center staff collaborated with researchers at the University of Arizona to use advanced scientific products and methods as part of the Hydroclimate Analysis. The rationale behind the Study formulation is provided in the following sections, structured according to the four components of a Reclamation Basin Study.

2.2 Projection of Future Supply-Demand Imbalances

2.2.1. Evaluate high and low risk scenarios

To simplify the analysis, Study Partners requested the development of two climate scenarios encompassing the range of risk to water supplies within the LSCR Basin. To test the resilience of supplies and provide a conservative basis for adaptation planning, these partners requested a "high-risk" climate scenario in which water supplies would be put under significant stress. The partners chose to call this the "worse-case" scenario, to indicate that while this climate scenario would pose significant water supply risks, more extreme levels of climate change were still plausible. On the other end of the spectrum, they requested a "low-risk" or "best-case" climate scenario that would require a lower level of adaptation. More information on these scenarios is provided in Sections 3.1.1 and 3.1.2.

2.2.2. Investigate changes in seasonality and interannual variability

Seasonality is a key feature of the LSCR Basin climate. From mid-June to September, short, intense, localized monsoon events deliver approximately half of the average rainfall (Gelt, et al., 1999). Most of the remaining rainfall occurs during the "winter wet" period from October through March, when precipitation is more sustained and widespread but less intense. After the winter rains, the region undergoes a dry period with low to no precipitation before the start of the next monsoon.

Municipal water demand in the Study Area is also seasonal. Water delivery systems are designed to meet the peak use that occurs during the dry season. Municipal demand decreases once the monsoon starts and there is less need to use water outside (Wilson W. , 2020).

Changes in the time of onset and duration of the monsoon season could impact the Basin's municipal providers' ability to meet customer demands as well as the Basin's natural resources. For instance, late monsoon onset or early demise of the winter wet season could extend the summer demand peak period, stressing both delivery infrastructure and supplies. Shorter monsoon and winter wet seasons could reduce the amount of runoff available to recharge the local aquifer, reducing groundwater supplies. Partners requested that the Hydroclimate Analysis incorporate an investigation of changes to the onset and duration of the seasons.

LSCR Basin-wide temperature and precipitation also vary widely across years. This is due to the Basin's location between shifting mid-latitude and subtropical atmospheric circulation regimes, as well as its proximity to the Pacific Ocean, the Gulf of California, and the Gulf of Mexico. The local climate is also strongly influenced by seasonal to multi-year patterns in ocean temperature that affect the climate across the United States (i.e., El Niño-Southern Oscillation and the Pacific Decadal Oscillation) (Sheppard, Comrie, Packin, Angersbach, & Hughes, 2002).

The LSCR Basin's natural systems, however, are adapted to this variability. Floods provide significant volumes of recharge to the aquifer (Thomas, Behrangi, & Famiglietti, 2016) and provide the conditions necessary for certain types of riparian plants to germinate (Stromberg, Beauchamp, Dixon, Lite, & Paradzick, 2007). Due to the critical role that intra- and interannual variability plays in maintaining natural and engineered systems, Study Partners requested that the Hydroclimate Analysis investigate changes in variability by season.

2.2.3. Investigate changes in extreme temperature and precipitation

While changes in average annual temperature and precipitation are used to illustrate the magnitude of climate change, averages alone do not provide a full description of its effects. Many climate impacts are the result of changes in the frequency, intensity, and duration of extreme temperature and precipitation events (Field, et al., 2012). Impacts of extreme heat include mortality and heat-related illness, especially for vulnerable populations (Crimmins, et al., 2016). Heat waves stress water-limited vegetation (Gonzalez, et al., 2018) and drive municipal water and energy demand (Garfin, Jardine, Merideth, Black, & LeRoy, 2013). While extreme precipitation recharges the groundwater, the resulting flooding can impede transportation, generate health and safety hazards, degrade environmental quality, and damage critical infrastructure and property (Garfin, Jardine, Merideth, Black, & LeRoy, 2013).

Infrastructure is typically engineered to withstand climate extremes within the historical record (Maxwell, et al., 2018). More frequent, intense, and longer lasting temperature and precipitation extremes, beyond what systems are engineered for, can have severe consequences for many types of infrastructure. These include damage to roads, bridges, and pipelines, as well as to control mechanisms that cannot withstand flooding or extreme heat. Given these concerns, Study Partners requested that the Hydroclimate Analysis include an investigation of projected changes in the distribution of temperature and precipitation extremes.

2.2.4. Differentiate the water-related impacts of LSCR Basin-wide climate change and municipal growth

The underlying forces driving climate change are best mitigated on a global basis. On the other hand, water issues arising from municipal growth and land use change can be addressed directly by State and local governments. By identifying the effects of climate change on the LSCR Basin versus those impacts associated with population and municipal growth, Study Partners hoped to understand which challenges were most manageable at the state and local level. To this end, they developed six climate/municipal growth scenarios with unique combinations of LSCR Basin-wide climate change risk, population growth rates, and housing development patterns (compact to outward), and shortages to Central Arizona Project deliveries. These scenarios were designed to isolate the impacts of LSCR Basin-wide climate change and municipal growth on groundwater levels through the use of pair-wise comparisons. Results of this analysis are presented in Chapter 9 and Appendix D.

2.3 Evaluate Risks to Infrastructure and Other Systems

2.3.1. Identify locations at risk of groundwater decline

As discussed above, groundwater is the supply that is most vulnerable to impacts from climate change and municipal growth within the LSCR Basin Study Area. This is especially relevant for the water providers that do not have physical access to CAP supplies. Declines in groundwater levels are associated with increased pumping costs, degradation of groundwater quality, land subsidence, and the need to deepen or relocate wells. Riparian areas are also negatively impacted by declines in shallow groundwater levels. Study Partners used the groundwater modeling results, specifically the projected change in groundwater levels between 2020 and 2060 under the *worse-case scenario*, to identify the areas of the LSCR Basin vulnerable to groundwater level declines.

2.3.2. Incorporate analysis of impacts to riparian areas

Riparian areas occur along the interfaces of terrestrial and aquatic systems, on the banks of streams and other water bodies. While they occupy less than 2% of the land area in the Southwest (Baker, Folliott, DeBano, & Neary, 2005), they are among the most “diverse, dynamic and complex biophysical terrestrial habitats” (Naiman, Decamps, & Pollock, 1993). In the Tucson region, riparian areas are one of the few places with green vegetation year-round. Riparian areas support plant and animal habitat, provide recreational spaces, and serve as tourist attractions. They also help to stabilize streambanks, trap sediment, and improve water quality.

Changes in Basin-wide precipitation and temperature will impact local riparian areas. More frequent and intense droughts will cause riparian areas to contract. As perennial streams become intermittent, cottonwood and sycamore are replaced by more drought tolerant and often non-native species, such as salt cedar (Archer & Predick, 2013). These changes are associated with a reduction in canopy cover (Stromberg, Lite, & Dixon, Effects of Stream Flow Patterns on Riparian Vegetation of a Semi-arid River: Implications for a Changing Climate, 2010) and

decline in the diversity of bird species (Stromberg, Andersen, & Scott, Riparian Floodplain Wetlands of the Arid and Semiarid Southwest, 2012).

Given the importance of the LSCR Basin's riparian areas to ecological values, as well as their importance to recreation, tourism, and property values, Study Partners requested an analysis of impacts to these resources from changes in surface and groundwater hydrology.

2.4 Develop and Investigate Adaptation Strategies

2.4.1. Formulate a broad spectrum of adaptation strategies

The objective of the adaptation strategy development process was to brainstorm a range of projects that address the impacts of local supply and demand imbalances on a variety of water-use sectors, including the environment. The development of multi-benefit adaptation strategies was strengthened by the inclusion of non-market benefits in the evaluation criteria used in the Trade-off Analysis.

2.5 Perform Trade-off Analysis of Adaptation Strategies

2.5.1. Develop community-driven criteria for the Trade-off Analysis

In a manner similar to the development of adaptation strategies, Study Partners emphasized the development of a set of trade-off criteria that included both market and non-market benefits. The Trade-off Analysis was designed to evaluate both quantified and unquantified aspects of the adaptation strategies using data and expert judgment.

Chapter 3 Study Process Details

The Lower Santa Cruz River Basin Study included innovative scientific products and methods to address the Partner concerns detailed in the previous section. The scientific approaches used to address each partner concern are described below.

3.1 Hydroclimate Analysis

3.1.1. Focus on range of risk

Per the Partners' request, the Study focused on two plausible futures that would portray the range of risk to water supplies using the best available scientific information. The development of the Study's high and low risk scenarios began by considering a range of projections of global greenhouse gas emissions over time, called "Representative Concentration Pathways", or RCPs, developed as part of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

Figure 3-1 shows the range of Representative Concentration Pathways developed by the IPCC, with RCPs 4.5 and 8.5 denoted as the best-case and worse-case, respectively. RCP 4.5 represents a future where mitigation actions cause greenhouse gas emissions to stabilize by the middle of the century and then decline significantly, before leveling off around 2100. In RCP 8.5, little or no mitigation takes place and greenhouse gas emissions continue to increase, eventually stabilizing at the end of the century. These RCPs served as the basis for the best-case and worse-case climate scenarios. Additionally, a "current climate" scenario using the past 30 years of temperature and precipitation was analyzed for comparison purposes.

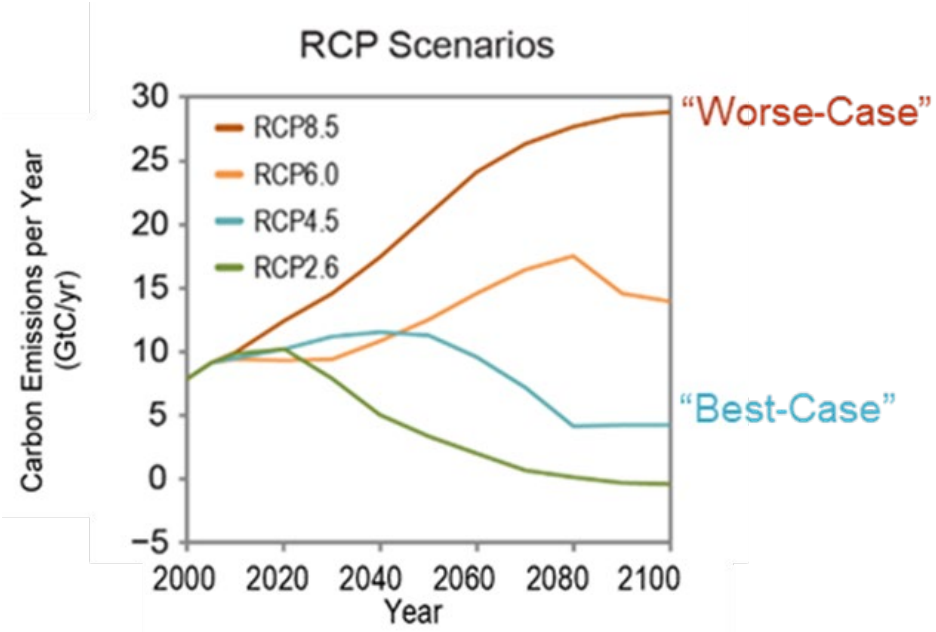


Figure 3-1 – Annual carbon emissions in gigatons of carbon per year by RCP. Adapted from Hayhoe, K., J. et al., 2017: Climate models, scenarios, and projections. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I.

3.1.2. Incorporation of a dynamically downscaled climate projection

The output of Global Climate Models (GCMs) is too coarse to use directly in a basin-scale hydrologic model. Therefore, a "downscaling" process was applied to generate climate projections with an appropriate level of spatial detail. Methods to generate these projections include statistical and dynamical downscaling (Figure 3-2). Statistical downscaling relies on empirical (observed) relationships between projections and historical observations. Statistical downscaling is computationally straightforward, and the output of many GCMs, using a variety of emissions scenarios, are readily available to researchers. However, statistical methods do not typically resolve the physical process responsible for the relationships between large-scale and local climate (Kotamarthi, L., Hayhoe, Castro, & Wuebbles, 2016).

In contrast, dynamical downscaling uses GCM outputs as input to a higher resolution regional climate model (RCM). The RCM numerically simulates atmospheric processes that take place at a finer scale than the GCM. A key advantage of dynamical downscaling is its ability to simulate extremes outside of the historical record. However, the complexity and computational expense of running an RCM limits the number of models and scenarios that can be evaluated using dynamic downscaling (Kotamarthi, L., Hayhoe, Castro, & Wuebbles, 2016). Kotamarthi et al. note that, "Dynamic downscaling output is often limited to a higher [emissions] scenario and should provide the upper boundary for making assessments."

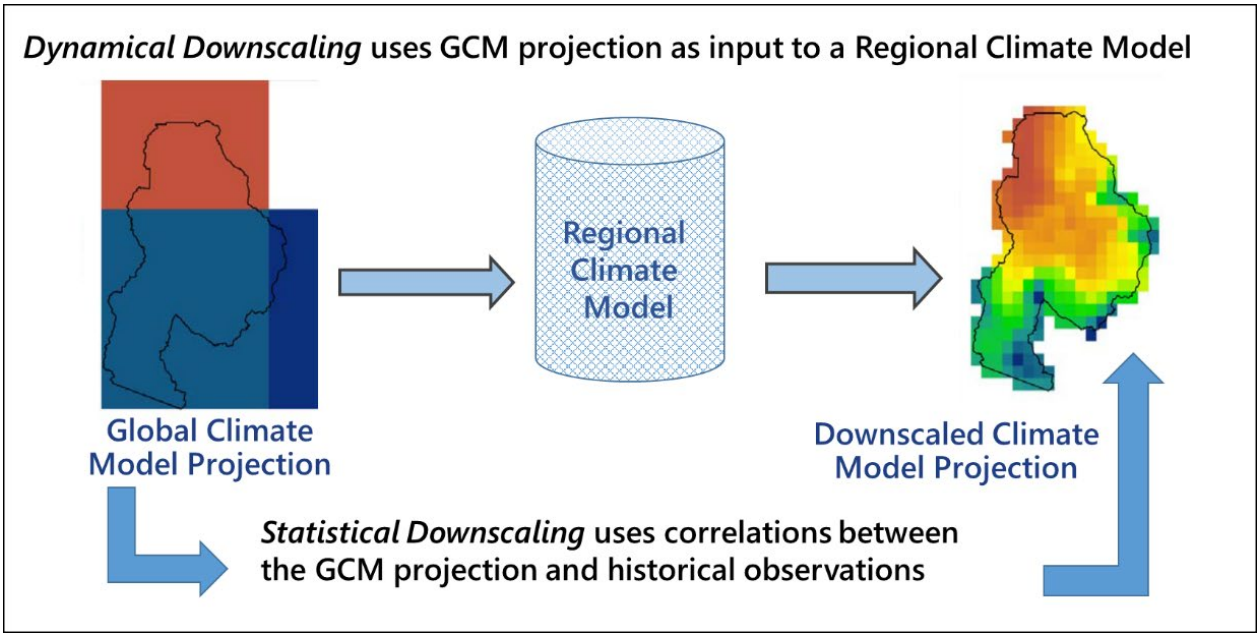


Figure 3-2 – Conceptual diagram of statistical and dynamical downscaling.

Recent research assessing the impact of downscaling techniques on projected flows for the Salt, Verde, and Colorado Rivers had found that projections using the same Global Climate Model were significantly lower when using dynamical downscaling than when using a statistical downscaling method (Mukerjee, 2016). Consistent with the goal of developing a "risk-based" scenario, and to avoid the possibility of statistically downscaled climate projections underestimating the true level of risk to water supplies, the Study Partners endorsed the use of a dynamically downscaled climate projection for its worse-case climate scenario. (Until this time, Reclamation Basin Studies used statistically downscaled projections exclusively). For more detail on downscaling techniques used in this Study, see Chapter 7.

3.1.3. Selection of dynamically downscaled climate projections

Reclamation staff and the Study Partners analyzed the available dynamically downscaled climate projections, particularly the way each one reproduced the timing of the region's North American Monsoon. The partners originally recommended the use of two of the dynamically downscaled climate projections available from the North American Regional Climate Change Assessment Program (MPI-ESM and HadGEM2), both dynamically downscaled with the Weather Research and Forecasting Model, [WRF]). However, the WRF-HadGEM2 projection proved to be unusable for technical reasons, leaving the WRF-MPI projection to represent the worse-case. Reclamation staff felt that the use of the dynamically downscaled climate projection was appropriate given the Study's emphasis on adaptation planning.

No comparable dynamically downscaled GCMs using RCP 4.5 were available. After a rigorous evaluation of the options, the MPI-ESM climate model run under an RCP 4.5 emissions scenario, downscaled using statistical Locally Constructed Analogs, or LOCA procedure, was selected as the best-case projection.

As a consistency check, the output of the dynamically downscaled WRF-MPI under RCP 8.5 was compared with a statistically downscaled version (LOCA method) of the MPI that also used the RCP 8.5 emissions scenario. This analysis demonstrated that the dynamically downscaled WRF-MPI projection fit well within the range of precipitation and temperature changes seen in the larger LOCA model ensemble. Results of this comparison are detailed in the Hydroclimate Analysis.

3.1.4. Simulation of seasonality, variability, and extremes

To represent the inherent inter- and intra-annual variation of the Basin's climate, Reclamation's TSC staff developed a statistical "weather generator". A weather generator is a numerical tool that resamples an input timeseries many times, while preserving key statistics of the distribution. This weather generator produced large groups (ensembles) of precipitation and temperature time series that represented a plausible range of rainfall amounts and daily patterns for each of three seasons, based on historical climate records.

This weather generator simulated the three distinct seasons: monsoon, winter wet, and dry (Figure 3-3). The weather generator ensembles for the best- and worse-case scenarios were used as input to a surface hydrology model to estimate the statistical distributions of future streamflow. By generating an ensemble of 100 timeseries for temperature and precipitation, it was possible to perform an analysis of changes in extreme values, defined here as the top 10% of each distribution. Results of the extremes analysis are presented in Chapter 7.

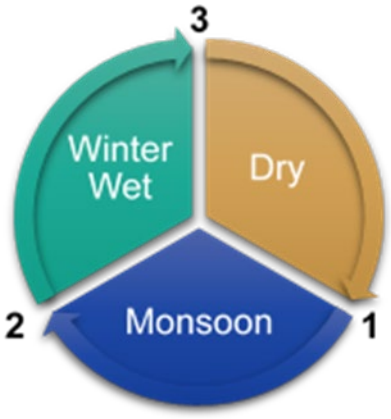


Figure 3-3 – Conceptual diagram of seasons in the LSCR Basin.

3.1.5. Selection of surface water hydrology model

Earlier Reclamation Basin Studies had concentrated on humid climates and had success using the Variable Infiltration Capacity Model (VIC) to model surface hydrology. However, initial tests of VIC did not properly simulate the surface flows in the LSCR Basin Study Area. Runoff in the Study Area is highly sensitive to antecedent moisture, meaning that under dry conditions, a large amount of precipitation is retained by the soils rather than converted to surface flow (Brooks, Folliott, & Magner, 2013). To address these concerns, Reclamation TSC staff selected the

Sacramento Soil Moisture Accounting Model, run by the National Weather Service's Colorado Basin River Forecast Center as the best choice of a surface hydrology model for the Study Area. The model was adjusted to run the ensembles produced by the weather generator. The volume of stream infiltration estimated by the SAC-SMA model served as input for the Groundwater Modeling analysis.

Figure 3-4 provides an overview of how each of the steps described above were linked together. Downscaled Global Climate Model projections of precipitation and temperature provided input to the weather generator, which produced an ensemble of 100 plausible sequences of future precipitation and temperature each for RCP 4.5 and RCP 8.5. These ensembles were input into the SAC-SMA surface hydrology model. The results of the surface water modeling are presented in Section 4.4. Estimates of streamflow recharge from the surface water modeling also served as input to the groundwater modeling, discussed further in Chapter 9.

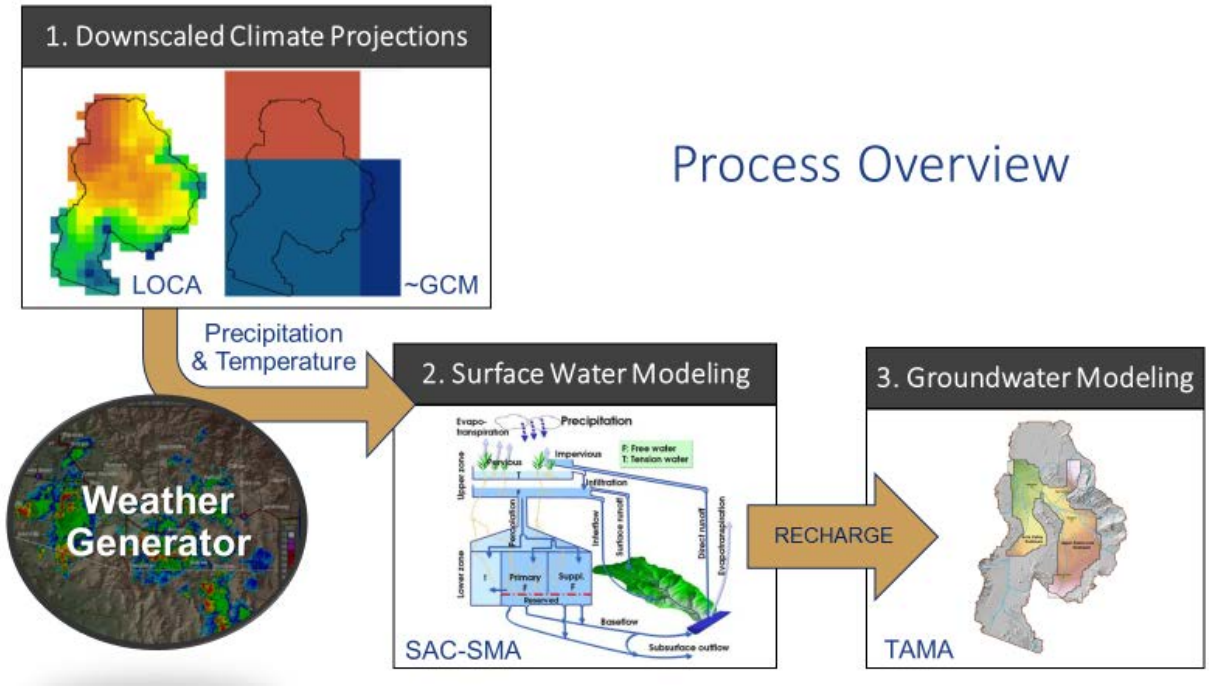


Figure 3-4 – Conceptual overview of basin-wide climate and surface water model inputs to groundwater model.

3.2 Supply and Demand Assessment

The Supply and Demand Assessment focused on human demands for water, as well as the volumes of CAP and reclaimed water available for recharge within the LSCR Basin. It was developed using the CAWCD's state-of-the-art Central Arizona Project Service Area Model (CAP:SAM). CAP:SAM is not a hydrologic model: it projects demands for water using a range

of assumptions regarding climatic, socio-economic, and behavioral factors through time. CAP:SAM also simulates the rules and policies that govern how water is managed within the Service Area (Maricopa, Pinal, and Pima counties).

With stakeholder input, Study Partners developed a set of six scenarios (Figure 3-5) that specified a range of municipal growth types (compact, official, and outward) and rates of population growth (slow, medium, and rapid) described further in Chapter 8. Each scenario included a time-series of shortages to CAP water deliveries based on expert opinion that corresponded with the current climate or an IPCC emissions scenario (RCP 4.5 or RCP 8.5).

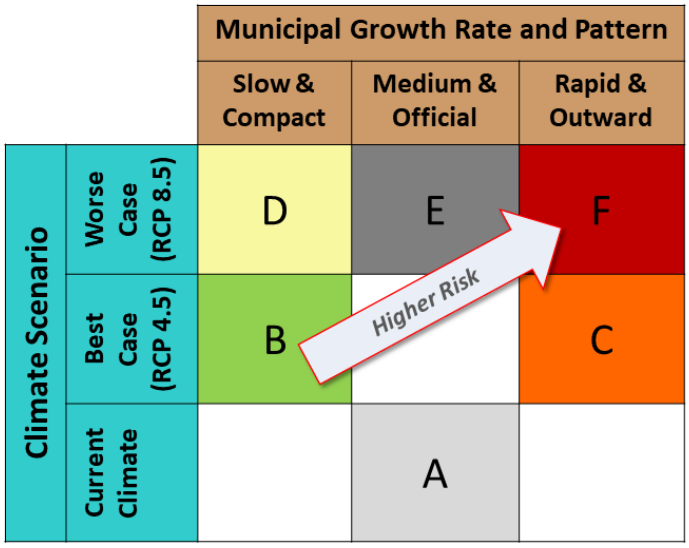


Figure 3-5 – Diagram of the scenarios used in the Supply and Demand Analysis.

CAP:SAM projects demands by water provider over time. Local subject matter experts translated these demands into site-specific estimates of groundwater pumping and artificial recharge of CAP and reclaimed water within the LSCR Basin. These estimates were then used as input to the groundwater model.

3.3 Groundwater Modeling

3.3.1. Scenario development

The purpose of the Study's Groundwater Modeling Analysis was to identify the Basin's future supply-demand imbalances in need of adaptation. Six scenarios, analogous to those used in the Supply and Demand Assessment, were developed.

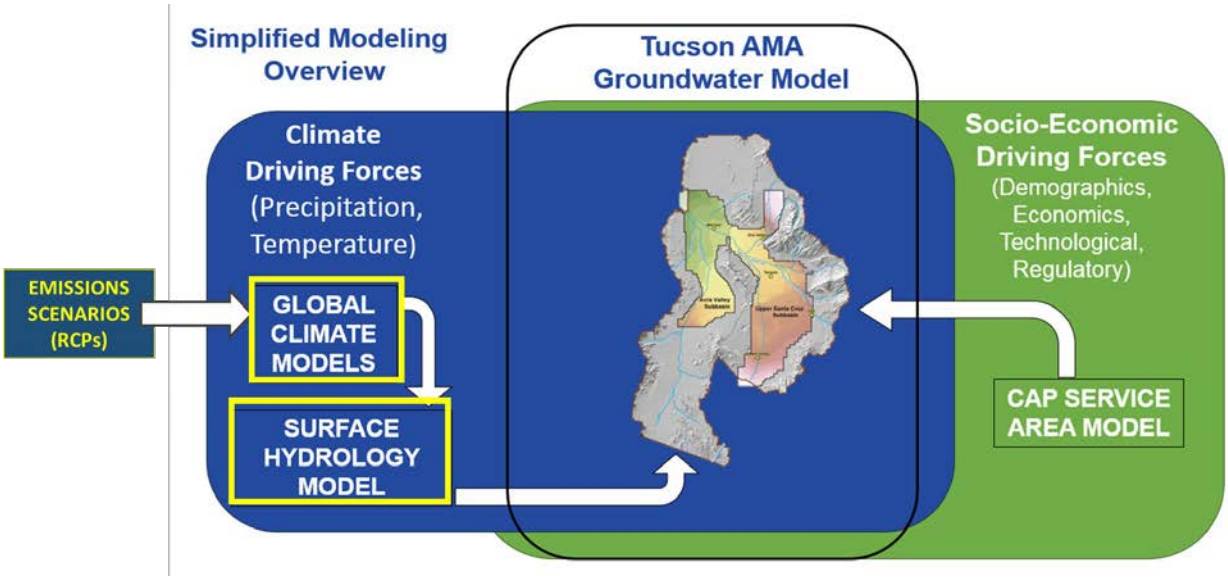


Figure 3-6 – A simplified diagram of modeling for the Groundwater Analysis.

Each groundwater model scenario combined elements of the Hydroclimate Analysis and the Supply and Demand Assessment (Figure 3-6). Estimates of stream recharge were taken from the Hydroclimate Analysis under either the current, best-case, or worse-case climate. CAP:SAM results provided estimates of municipal, industrial, and agricultural demand under a municipal growth rate and pattern (slow/compact, medium/official, rapid/outward). Groundwater modeling scenarios also included the sequences of CAP shortages developed as part of the Supply and Demand Assessment. The scenarios were configured to allow pairwise comparisons to isolate the impacts of climate and municipal growth over the watershed.

3.3.2. Identification of locations at risk of groundwater decline

Reclamation staff performed six runs of the groundwater model from 2020 to 2060, one for each scenario, generating six maps of projected groundwater level change over this time period. For the purposes of this Study, the projections assumed that no new infrastructure or adaptation measures would be implemented other those already planned. The model output identified areas where groundwater would decline without some type of adaptation. The maps identified riparian areas at risk of groundwater decline that are important for land, vegetation, and wildlife management within the LSCR Basin

3.4 Adaptation Strategies and Criteria Development

3.4.1. Community-wide outreach to solicit adaptation strategies

Reclamation held two workshops to develop concepts for adaptation strategies. Participants included staff from Partner organizations, local subject matter experts, and stakeholders who expressed interest in Study participation, including private citizens. The purpose of

Workshop 1 was to brainstorm a wide variety of strategies for areas known to be vulnerable to declining groundwater levels, in preparation for the groundwater model results. Workshop 2 presented the groundwater modeling results and refined adaptation strategies consistent with findings of the modeling. Proposed strategies included traditional infrastructure solutions as well as nature-based strategies.

3.4.2. Development of community-driven strategy-evaluation criteria

Prior to Workshop 1, the Demand Sub-team and Environmental Sub-team developed draft lists of criteria for evaluating the adaptation strategies. As with adaptation strategies, participants endorsed a set of criteria with traditional cost and benefit information (capital cost, unit cost, volume of water made available) and non-market criteria, such as the benefits to riparian areas and quality of life. Feedback was elicited on these draft criteria as part of the first adaptation strategy workshop. In Workshop 2, participants confirmed their support for these criteria. Draft evaluation criteria were refined by Reclamation staff to facilitate the Trade-off Analysis and avoid double-counting of benefits and costs.

3.5 Trade-off Analysis

The Trade-off Analysis served to identify the strengths and weaknesses of each adaptation strategy. It allowed for both quantified and unquantified effects to be evaluated together in a single assessment, considering a range of impacts along economic, environmental, and social dimensions.

The breadth of adaptation strategies and evaluation criteria posed some challenges for the Trade-off Analysis. Many strategies could not be directly compared because they addressed different supply-demand imbalances. Reclamation TSC staff performed a number of rankings, all presented in Table 4-5. If a strategy addressed a local imbalance, it was compared with others addressing the same imbalance, and with all strategies addressing local imbalances. LSCR Basin-wide strategies were compared with each other. Finally, weighted scores were used to rank all the strategies together.

Chapter 4 Summary of Findings

4.1 Background: Study Time Horizon

The Study time horizon begins in 2020. Downscaled Global Climate Models results were available through 2100. However, the Partners recognized that due to the high levels of uncertainty associated with the rules of Colorado River operations, it was only reasonable to use the CAP:SAM model results through 2060. Therefore, groundwater level projections were generated only from 2020 to 2060. A conceptual diagram of the Study's analyses and their respective time horizons is presented Figure 4-1.

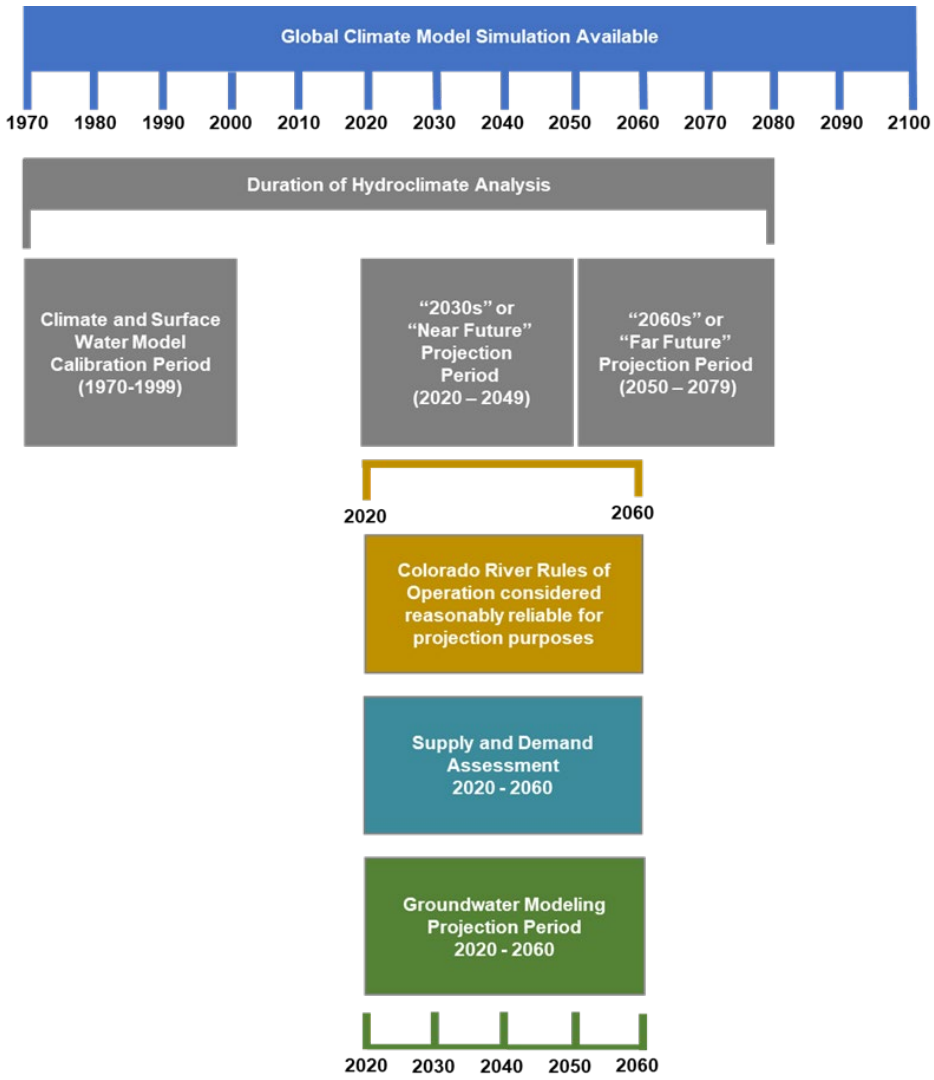


Figure 4-1 – Diagram of Study analyses time periods.

From the hydroclimate perspective, Reclamation uses the World Meteorological Organization standard of a 30-year period (World Meteorological Organization, 2017) to develop climate projections. In order to cover the period of 2020 – 2060, it was necessary to develop climate projections for two future time periods: 2020-2049, described as the 2030s or "near future", and 2050 - 2079, described as the 2060s or "far future". The Hydroclimate Analysis presents results for both these periods.

4.2 Background: Spatial Domains

The Study utilized several models, each with its own unique spatial domain. These spatial domains were reconciled as best as possible, but some differences in the spatial extent of the models' output remained. These differences were considered acceptable for the level of planning being undertaken in the Study.

The Hydroclimate Analysis included surface water modeling using the Sacramento Soil Moisture Accounting Model. Due to the way in which the SAC-SMA basins are configured in the model, results were developed for an area that contained basins upstream of the LSCR Basin (Tucson Active Management Area), some of which are located in Mexico. The northwest portion of the LSCR Basin was excluded, as it drains further north into Pinal County. The outline of the Hydroclimate Analysis relative to the LSCR Basin (TAMA) boundaries and the groundwater model domain is shown in Figure 4-2.

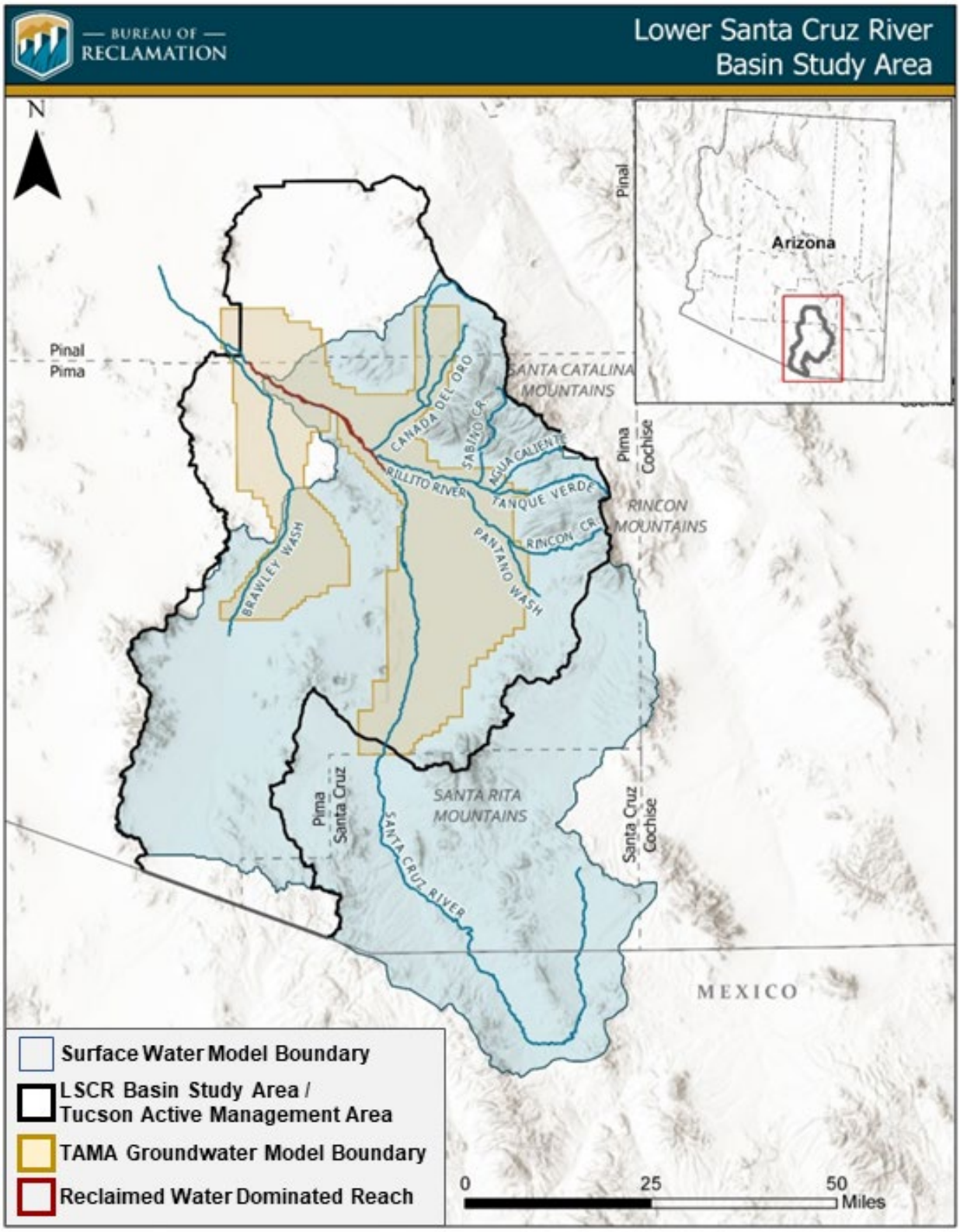


Figure 4-2 – Extent of surface water modeling using SAC-SMA model in comparison to the LSCR Basin (Tucson Active Management Area) and the TAMA Groundwater Model domain.

4.3 Climate Analysis Results

4.3.1. Average changes in temperature and precipitation

As explained in Chapter 7, the time-series from each of the best and worse case climate projections were input into the weather generator to create two ensembles of 100 plausible realizations of temperature and precipitation. These ensembles simulated the future variability of the climate within the SAC-SMA model domain under the Study's two climate projections. Projected changes from the model calibration period of 1970-1999 are presented in Table 4-1 below.

Table 4-1 – Summary of Climate Change Analysis Results, compared to 1970 – 1999 historic period

Statistic	Best-Case 2020-2049	Best-Case 2050-2079	Worse-Case 2020-2049	Worse-Case 2050-2079
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″
Change in Average Dry Season Precipitation	-0.27″	-0.55″	0.28″	0.05″
Precipitation RSD* compared to 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) is calculated by normalizing the standard deviation to the mean of the 30-year period and presented as a percentage. RSD for temperature was < 2%.
Changes in average temperature and precipitation from calibration period 1970 – 1999 under the best and worse climate cases, for the periods 2020 – 2049 (2030s) and 2050 – 2079 (2060s).

All models and climate scenarios consistently identify increases in temperature through time. Increases are larger under the worse-case climate, which represents higher future greenhouse gas emissions. Precipitation changes are more variable than temperature. The best-case climate scenario shows relatively minimal change in seasonal precipitation; in the worse-case climate scenario, total precipitation decreases in the monsoon and winter wet seasons. An increase in the variability of precipitation implies that longer droughts as well as more intense rainstorms are likely.

4.3.2. Changes in temperature and precipitation extremes

Changes in the top ten percent of the distribution of temperature and precipitation values (compared to the historical period of 1970 – 1999) are presented in Figure 4-3 and Figure 4-4. Extreme temperatures increase consistently in every season, with the largest increases occurring in the dry and monsoon seasons, which are the spring and summer months when extreme temperatures pose the largest public health risk.

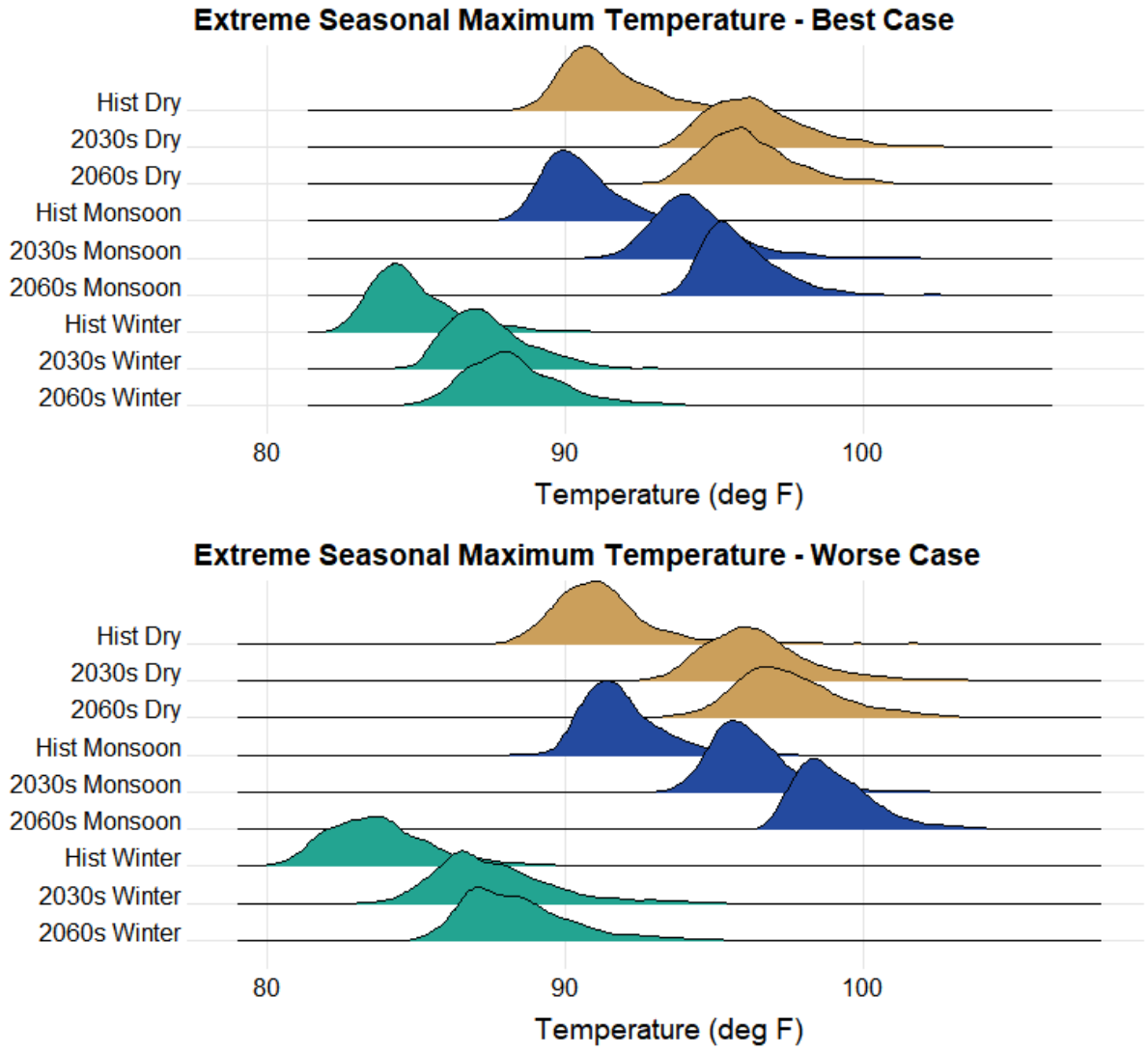


Figure 4-3 – Projected changes in extreme values (top 10% of distribution) for temperature (compared to 1970 -1999 historic period).

Figure 4-4 illustrates changes in the distribution of the precipitation values in the top 10 percent of each 30-year simulation. For the best-case, the general magnitude of extreme events increases, while in the worse-case climate scenario, an increase in larger individual events, particularly in the winter season, is apparent.

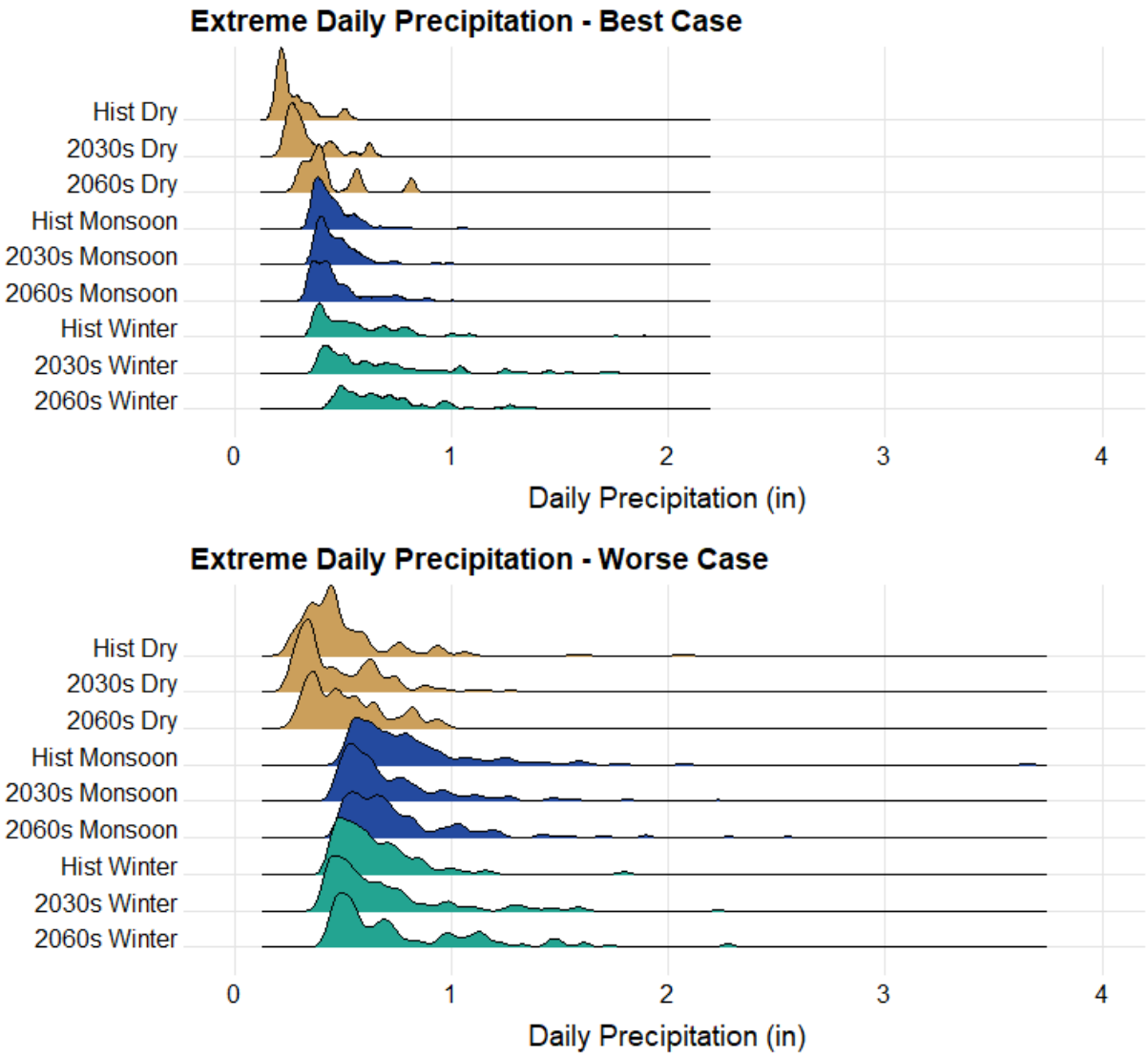


Figure 4-4 – Projected changes in extreme values (top 10% of distribution) for precipitation (compared to 1970 -1999 historic period).

These results should be considered in the context of their technical constraints: statistical downscaling (best-case) is restricted in its ability to forecast events outside of the historical range, while dynamical downscaling is not.

4.4 Surface Water Modeling Results

4.4.1. Change in streamflow by season

Changes in streamflow for the monsoon and winter wet seasons, calculated as a fraction of the simulated historical period flow, are presented in Figure 4-5 and Figure 4-6. Note that these

figures have scales tailored to the range of model results. This has been done to highlight the detail within each season's range of values.

Changes in the total monsoon seasonal streamflow result from changes in the length of the season, intensity, and frequency of storms. In the near future period (2020 – 2049), the best-case scenario has a consistently longer monsoon season, resulting in more total flow. Streamflow decreases in some subbasins in the far future (2050 – 2079). Under the worse-case scenario, the near future appears to be a transition time, with generally shorter, but highly variable monsoon season length. In the far future, the longer monsoon season results in an apparent recovery of streamflow; however, streamflow events are less frequent, and likely more extreme, consistent with the increase in individual large precipitation events under this scenario.

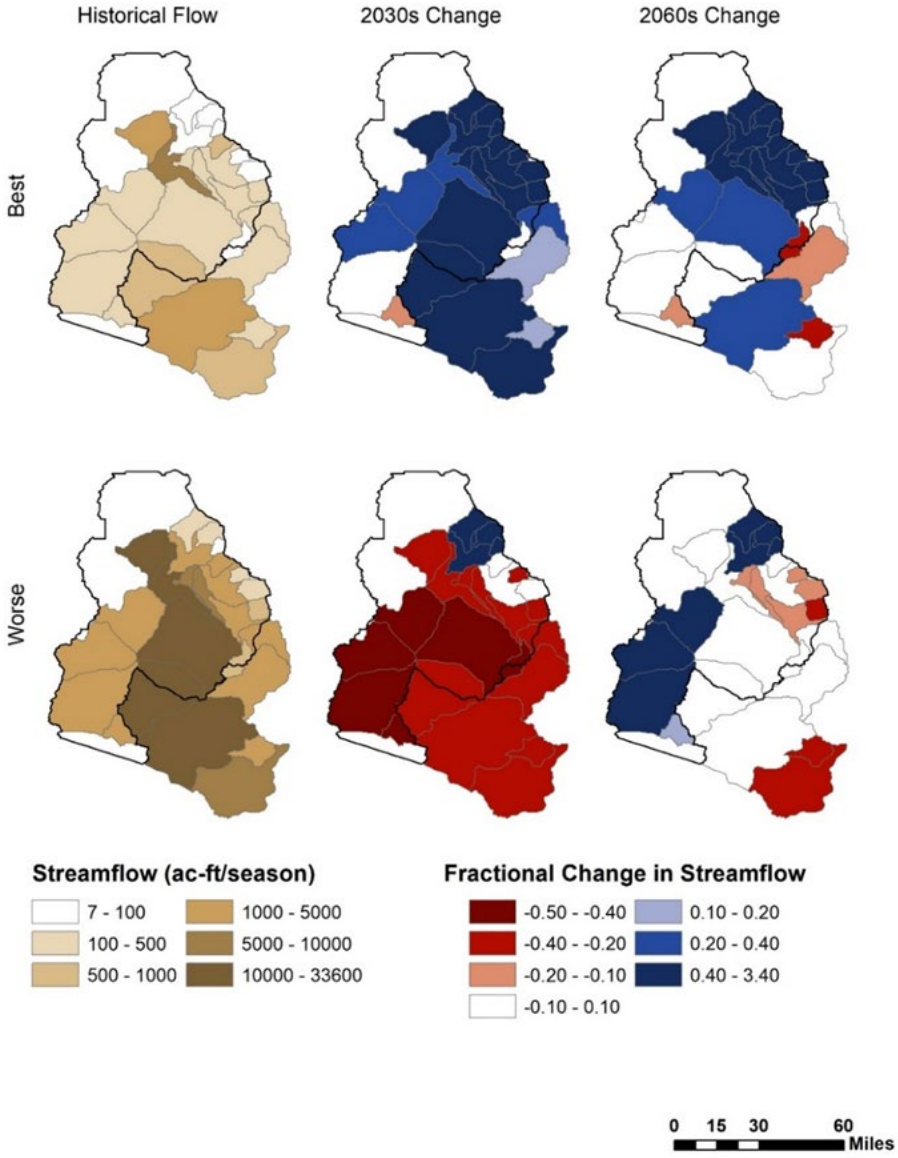


Figure 4-5 – Projected changes in monsoon season streamflow for best-case and worse-case climate scenarios.

The winter season shortens into the future under both scenarios. In the best-case scenario, the large events get consistently larger, which compensates for the shortening of the season in terms of streamflow. In the worse-case scenario, total winter precipitation is consistently less under both future periods and this change in precipitation is reflected in reduced streamflow. Large precipitation events do not increase in the near future, resulting in little compensation for the shortening of the season. However, in the far future, more extreme precipitation likely results in some streamflow recovery.

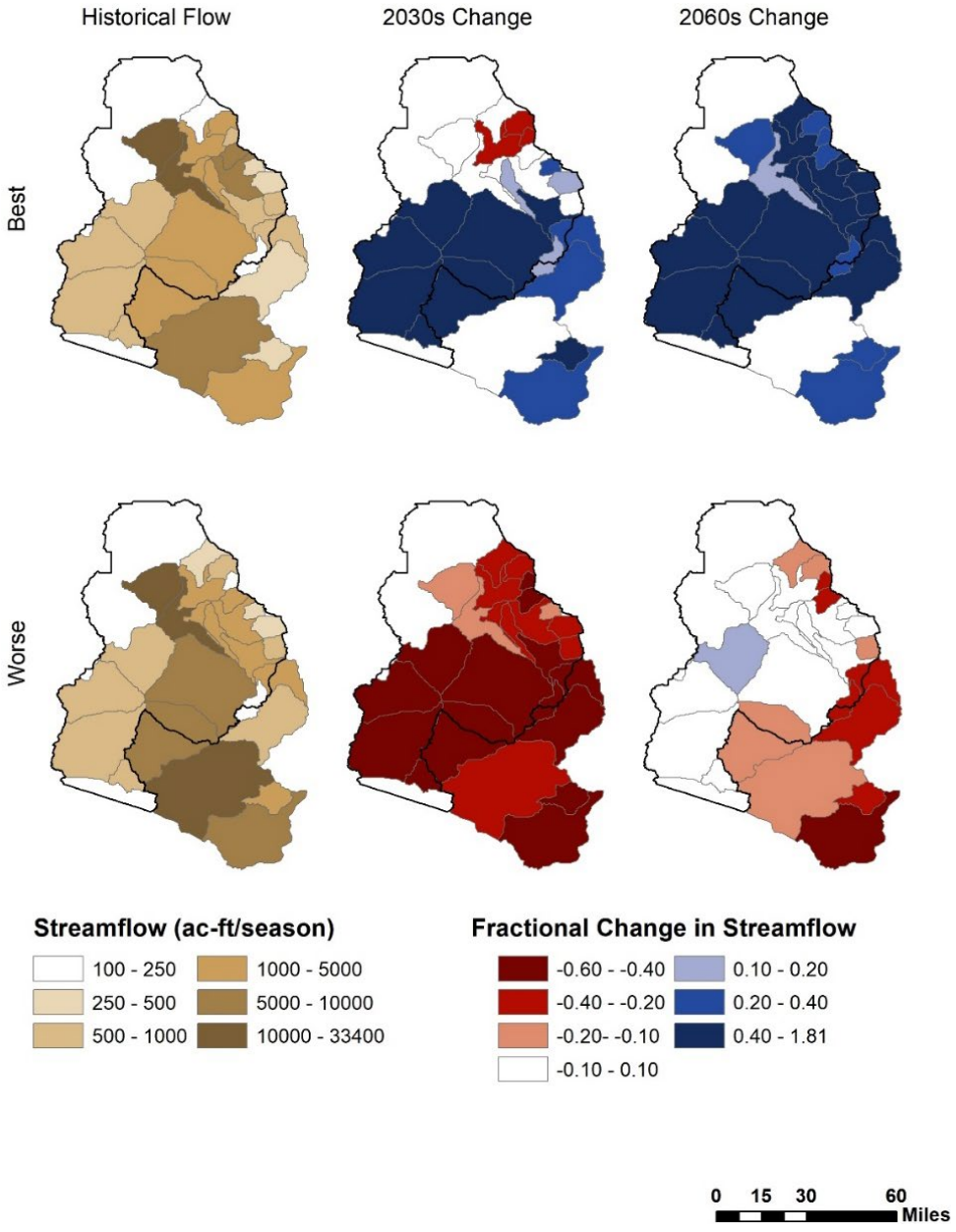


Figure 4-6 – Projected changes in winter wet season streamflow for best-case and worse-case climate scenarios.

Most streams in the basin are intermittent or ephemeral (other than those that are supported by discharge of reclaimed water). Reclaimed water, as defined by state law, is water that has been treated or processed by a wastewater reclamation facility. To address the Study Partners' concerns about changes in the condition of the Basin's riparian areas, Reclamation staff modeled changes in the number of dry days for each month of the year for the streams within the model domain. A soil moisture analysis was also performed using the SAC-SMA model. These results are presented in Chapter 7.

4.5 CAP:SAM Supply and Demand Projections

The CAWCD developed projections of municipal, industrial, and agricultural water demand using their state-of-the-art Central Arizona Project Service Area Model (CAP:SAM). CAP:SAM scenarios include assumptions regarding the rate and type of municipal growth. Municipal growth can be slow, medium, or rapid, with each rate corresponding to a low, medium, or high rate of population growth as projected by the Arizona Office of Economic Opportunity.

CAP:SAM also takes into account whether municipal growth is "Compact" (primarily located in existing urban areas), "Official" (reflecting the growth pattern used by the Pima Association of Governments), or "Outward" (more housing in suburban and exurban areas) (Figure 4-7). Outward growth leads to more housing in areas without direct access to the infrastructure that conveys renewable water supplies.

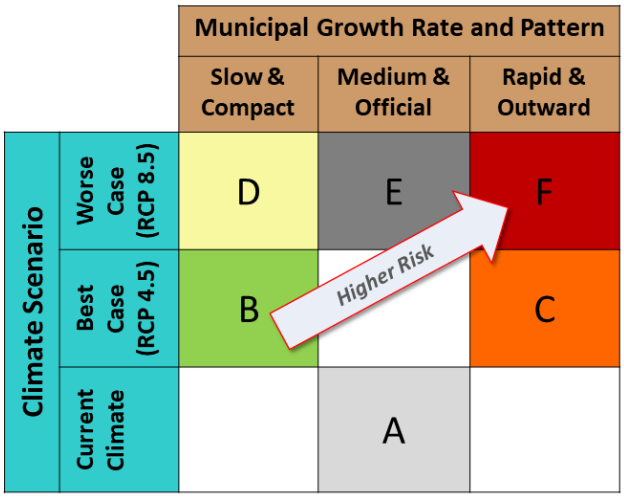


Figure 4-7 – Climate and Municipal Growth Scenarios for Supply and Demand Assessment.

CAP:SAM scenarios incorporate the availability of CAP water due to shortages on the Colorado River. The availability of CAP water is highly dependent on the operating rules of the Colorado River, which have not yet been established past 2026. Recognizing the high levels of uncertainty regarding future Colorado River operations, Partners decided that it was reasonable to make CAP:SAM projections only through the year 2060.

To represent plausible sequences of future CAP shortages, CAWCD staff developed three representative "traces", or shortage sequences, for the period from 2020 to 2060. The traces were designed to align with three climate scenarios: current, best-case (based on RCP 4.5), and worse-case (based on RCP 8.5) (Figure 4-8).

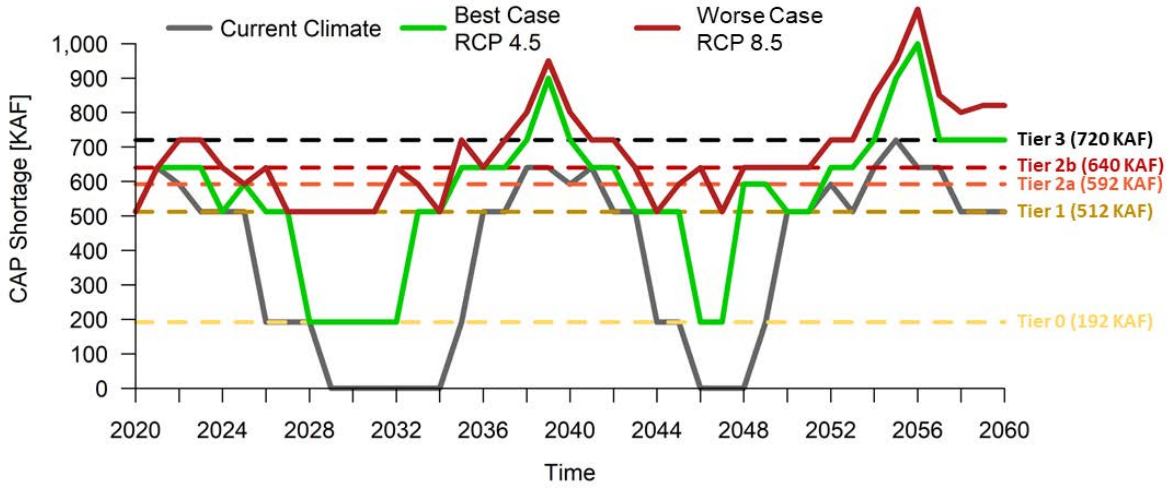
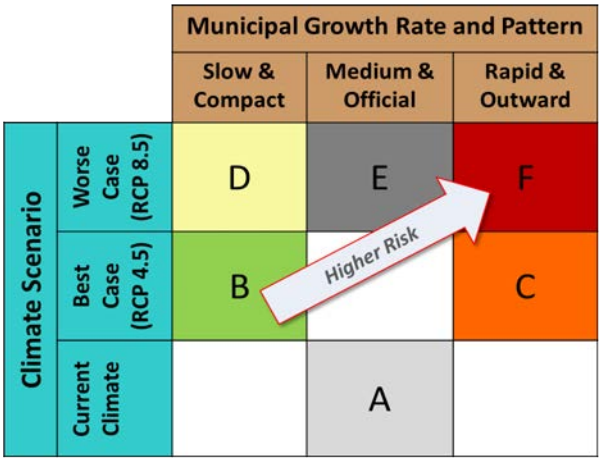


Figure 4-8 – CAP shortage sequences for the three climate categories (RCP 4.5, current climate, RCP 8.5) and shortage tiers from the Colorado River Drought Contingency Plan.

Under the ADWR Assured Water Supply Program, groundwater withdrawals made in excess of the program's limits must be offset through the recharge of an equal volume of renewable supplies within the same AMA. Table 4-2 presents projections of the volume of pumped groundwater that would need to be replenished under the Assured Water Supply Program rules between 2020 and 2060, as well as the volume in 2060, for each CAP:SAM scenario. Comparing scenarios with the same climate but different growth patterns (B versus C; D versus F), demonstrates that the rate and pattern of municipal growth is the primary driver of the replenishment requirement under the AWS Program rules.

Table 4-2 – Projections (in acre-feet) of the Cumulative Volume Groundwater Pumping (2020 – 2060) Subject to Replenishment in the Tucson Active Management Area under the Assured Water Supply Program Rules



CAP:SAM Scenario	Volume Subject to AWS Rules in 2060 (AF)	Volume Subject to AWS Rules From 2020 to 2060 (AF)
A	12,700	330,100
B	8,800	231,000
C	34,400	517,400
D	9,500	250,600
E	14,300	368,400
F	38,100	570,000

4.6 Groundwater Modeling Results

The Study's Groundwater Modeling Analysis utilized the Tucson AMA Regional Groundwater Flow Model developed by ADWR, augmented with model enhancements funded by CAWCD. The groundwater modeling scenarios combined the projections of streamflow recharge developed in the Hydroclimate Analysis with the CAP:SAM estimates of water provider demand and availability of CAP supplies (Figure 3-6), using the same climate and municipal growth scenarios as the Supply and Demand Analysis (Figure 4-7). Local subject matter experts translated these demands and supplies into site-specific estimates of groundwater pumping and artificial recharge within the LSCR Basin.

Scenarios were selected to allow pairwise comparisons that would isolate the effects of climate change and municipal growth over the watershed, described further in Chapter 9. To enhance the capacity of managers to be prepared for future risks, the scenario with the highest level of emissions, municipal growth, and CAP shortages (Scenario F), was used as the basis for adaptation planning.

Figure 4-9 presents the projected change in groundwater levels from 2020 to 2060 under the six groundwater modeling scenarios. The Avra Valley sub-basin is located on the western side of the model domain. This sparsely populated area is the location of two large CAP Underground Storage Facilities operated by the City of Tucson, the Central Avra Valley Storage and Recharge Project (CAVSARP) and the Southern Avra Valley Storage and Recharge Project (SAVSARP). Comparison of the scenarios demonstrates that the higher the stress on water resources, the more stored water will be recovered from CAVSARP and SAVSARP, lowering groundwater levels at these facilities. This water had been stored specifically for future shortages; therefore, this decline in groundwater levels at this location was not considered a concern by the Study Partners.

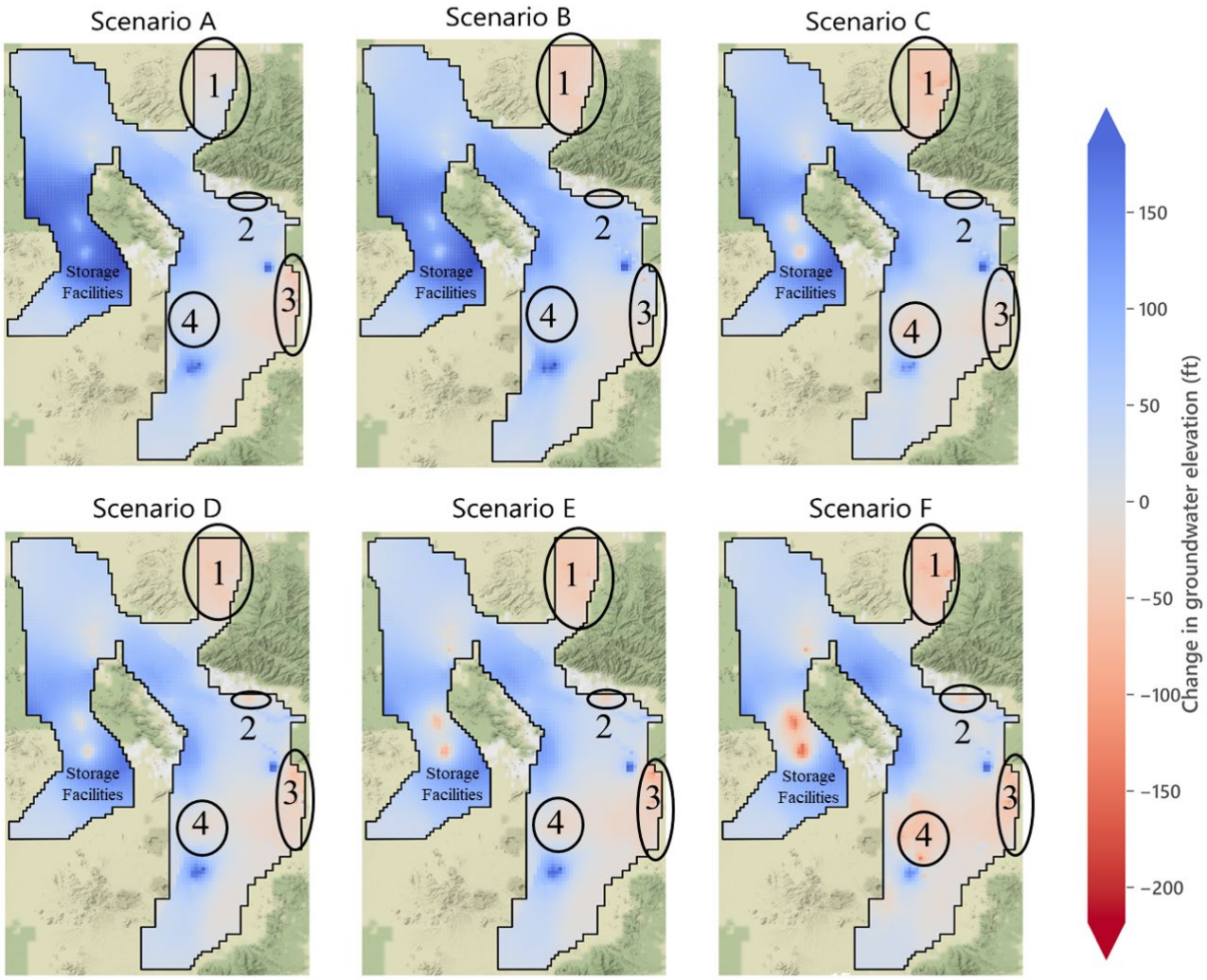


Figure 4-9 – Projected change in groundwater elevation from 2020 to 2060 under the six LSCR Basin-wide climate/municipal growth scenarios.

Two of these areas of concern feature high-value riparian areas that provide natural amenities, habitat for a variety of species, and recreational opportunities (Sabino Canyon/Tanque Verde and Southeast Tucson). Adaptation in these areas is critical to maintain the shallow groundwater on which the riparian vegetation depends.

Adaptation Strategy Development

4.7.1. Site-specific and regional adaptation strategies

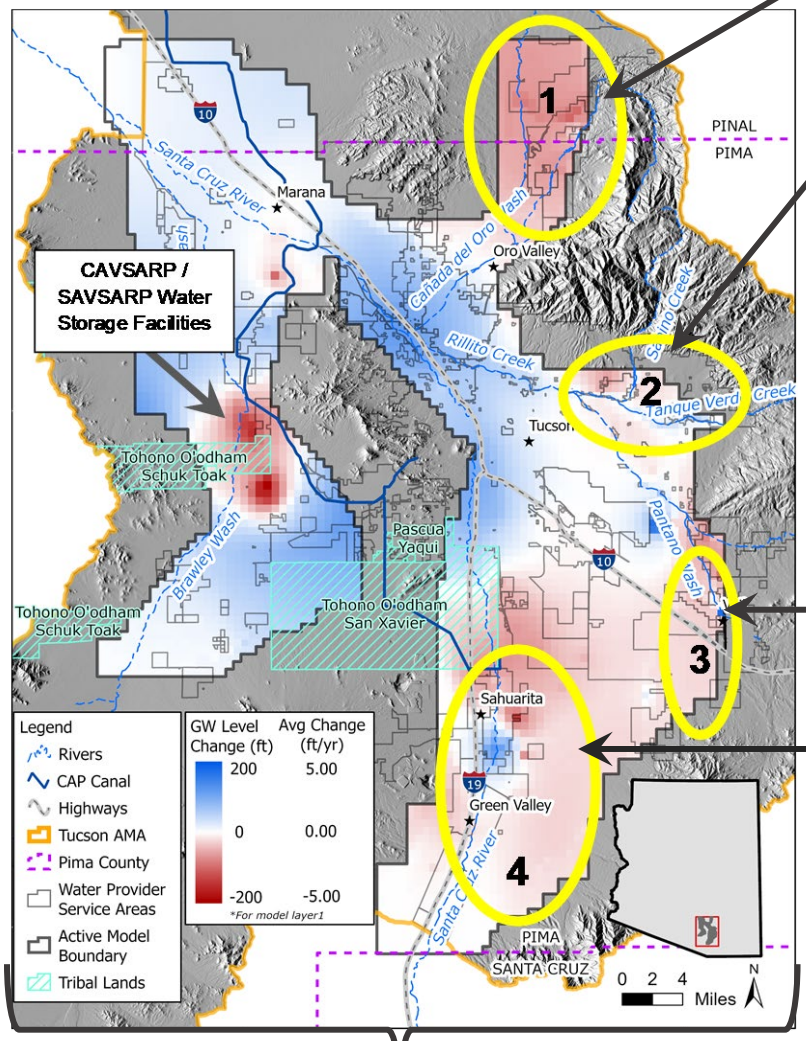
Adaptation strategy workshop participants formulated ideas to address areas of local supply-demand imbalance, as well as strategies that could apply across the LSCR Basin (Figure 4-10). Generally, strategies to address local imbalances consisted of providing access to renewable supplies, either by direct transmission or through connection to a provider with access. Another common strategy was to strategically site new water reclamation facilities in these areas of imbalance, to benefit from the recharge or use of reclaimed water.

	Canada Del Oro Adaptation Strategies
CDO-1	Convey CAP water for in-stream recharge
CDO-2	Convey recycled water for in-stream recharge
CDO-3	Construct new regional wastewater reclamation plant with in-stream recharge

	Sabino Canyon / Tanque Verde Adaptation Strategies
SC/TV-1	Extend reclaimed water system to replace outdoor potable uses, support environmental needs
SC-TV-2	Replace municipal provider groundwater pumping with wheeled renewable supplies
SC/TV-3	Replace groundwater pumping by private wells with renewable supplies from municipal provider

	Southeast Tucson Adaptation Strategies
SET-1	Wheel renewable supplies to small providers without direct physical access to CAP
SET-2	Phased construction of regional wastewater reclamation facilities with recharge of recycled water

	Green Valley Adaptation Strategies
GV-1	Extend Farmers Investment Company (FICO) Groundwater Savings Facility
GV-2	In addition to GV-1, extend pipeline for environmental enhancement in agricultural off-season
GV-3	Construct new regional wastewater reclamation plant with in-stream recharge



	Regional Adaptation Strategies
REG-1	Site-based Stormwater Management using Low Impact Development Methods
REG-2	Large Stormwater Multi-purpose, Multi-use Basins and Channels
REG-3	Upland Restoration
REG-4	Desalination of Ocean Water with Pipeline from Sea of Cortez, Mexico

Figure 4-10 – Map of adaptation strategies by area of concern.

4.7.2. Development of community-generated evaluation criteria

Study Partners requested a set of evaluation criteria that included benefits to the environment and quality of life, as well as traditional costs and benefits, such as water volume, reliability, and project cost. The initial evaluation criteria were developed by Sub-teams created to address specific water sectors. These were vetted and expanded by the wide range of participants who attended the adaptation strategy workshops. Participant feedback was synthesized, and suggested criteria were distilled into three sets: (1) water for society, (2) water for the environment, and (3) broader considerations. As a final step, the criteria were refined by the Reclamation economist conducting the Trade-off Analysis. The final evaluation criteria are presented in Table 4-3.

Table 4-3 – List of Final Evaluation Criteria

Criterion	Description	Measurement	Directionality
(1) Water Supply Reliability Benefit	Benefit from reducing future shortages anticipated for the Study Area.	Monetized	Benefit
(2) Capital Cost	Cost of construction or implementation (upfront cost).	Monetized	Cost
(3) O&M Cost	Cost of operation and maintenance (ongoing cost).	Monetized	Cost
(4) Aquifer Benefit	Improvements in groundwater levels to reduce pumping costs, prevent subsidence, or improve general aquifer condition.	0 to 3	Benefit
(5) Quality of Life Benefit	Improvements in recreation, aesthetics, health, safety, heat island effect, or cultural resources.	0 to 3	Benefit
(6) Leverage Existing Resources	Utilizes or enhances existing investments or infrastructure.	0 to 3	Benefit
(7) Barriers to Implementation	Obstacles from public perception, regulations, administrative complexity, or physical limitations.	-3 to 0	Cost
(8) Riparian Impact	Changes to riparian habitat and conditions.	-3 to 3	Cost/Benefit
(9) Water Quality Impact	Changes in the chemical, physical, or biological characteristic of water resources.	-3 to 3	Cost/Benefit
(10) Flood Risk Impact	Changes in flood risk (probability or consequences).	-3 to 3	Cost/Benefit

4.7 Trade-off Analysis

Twenty-four partner representatives rated the strategies using the criteria described in the previous section. Water supply benefits, as well as capital and operation and maintenance costs were calculated for each adaptation strategy. Qualitative criteria were evaluated using a low to high scale, which varied depending on whether the criterion was considered either a cost, a benefit, or both. In addition, participants were asked to rate the level of importance assigned to each of the ten (monetary and non-monetary) criteria on a scale of 0 for "Not important" to 3 for "High Importance". This process allowed for the development of weighted and unweighted scoring for each of the alternatives. Criterion importance weights are presented in Table 4-4.

Table 4-4 – Importance Scores of Evaluation Criteria

Criterion	Average Score	Applied Weight
(1) Water Supply Reliability Benefit	2.79	100%
(2) Capital Cost	2.25	81%
(3) O&M Cost	2.38	85%
(4) Aquifer Benefit	2.75	99%
(5) Quality of Life Benefit	2.08	75%
(6) Leverage Existing Resources	1.96	70%
(7) Barriers to Implementation	1.96	70%
(8) Riparian Impact	2.04	73%
(9) Water Quality Impact	2.25	81%
(10) Flood Risk Impact	1.96	70%

(Color intensity indicates relative rank among strategies)

The Trade-off Analysis results are summarized in Table 4-5 and described in more detail in Chapter 11 and Appendix G. The Trade-off Analysis demonstrated that each strategy came with a unique set of costs and benefits, and a full adaptation plan for the Basin would most likely combine a number of these strategies to address all four areas of concern, as well as regional strategies where benefits could accrue over a large geographic area.

Table 4-5 – Adaptation Strategy Rankings

Adaptation Strategy	Strategy Type	Total Score	Normalized Score	Location Rank	Areas of Concern Rank	Overall Rank
CDO-1	Transport CAP supplies for in-stream recharge	4.13	0.75	1st	3rd	6th
CDO-2	Transport reclaimed water supplies for in-stream recharge	2.89	0.53	3rd	9th	13th
CDO-3	Construct regional water reclamation facility with in-stream recharge	2.96	0.54	2nd	7th	10th
SC/TV-1	Extend reclaimed system, support environmental needs	3.83	0.70	3rd	5th	8th
SC/TV-2	Wheel CAP supplies directly to replace municipal gw pumping	4.17	0.76	1st	1st	4th
SC/TV-3	Replace gw pumping by private wells with renewable municipal supplies	3.99	0.73	2nd	4th	7th
SET-1	Wheel CAP supplies to replace municipal gw pumping	4.15	0.76	1st	2nd	5th
SET-2	Construct regional water reclamation facility with in-stream recharge	2.30	0.42	2nd	11th	15th
GV-1	Substitute agricultural gw pumping with renewable supplies	3.33	0.61	1st	6th	9th
GV-2	Extend agricultural water transport infrastructure, use for off-season environmental enhancement	2.95	0.54	2nd	8th	11th
GV-3	Construct regional water reclamation facility with in-stream recharge	2.64	0.48	3rd	10th	14th
REG-1	Site-based Stormwater Management using Low Impact Development	4.71	0.86	2nd	-	2nd
REG-2	Large Stormwater Multi-purpose Basins and Channels	4.43	0.81	3rd	-	3rd
REG-3	Upland restoration	5.48	1.00	1st	-	1st
REG-4	Desalination of ocean water with pipeline from Sea of Cortez, Mexico	2.91	0.53	4th	-	12th

Areas of concern addressed by each strategy uses abbreviations is defined in Figure 4-10
Note: Color intensity indicates relative rank among strategies.

Chapter 5 Current Climate, Physical Hydrology, and Water Supplies

5.1 Physical Setting

5.1.1. Climate

The Lower Santa Cruz River Basin (Basin) is located in Arizona's Sonoran Desert at 32.2° N latitude, one of the hottest and driest regions in the United States (Garfin, Jardine, Merideth, Black, & LeRoy, 2013). Annual temperatures at the Tucson International Airport average a minimum of 57.3 °F and a maximum of 84.0 °F, with high daily and seasonal variability typical of mid-latitude desert climates (Bureau of Reclamation, 2020). Elevations range from 1,860 feet above mean sea level near Red Rock to 9,453 feet above mean sea level at Mount Wrightson, located in the southeastern part of the Basin (Mason & Hipke, 2013). Figure 5-1 and Figure 5-2 illustrate the elevation range and mountainous areas within the LSCR Basin.

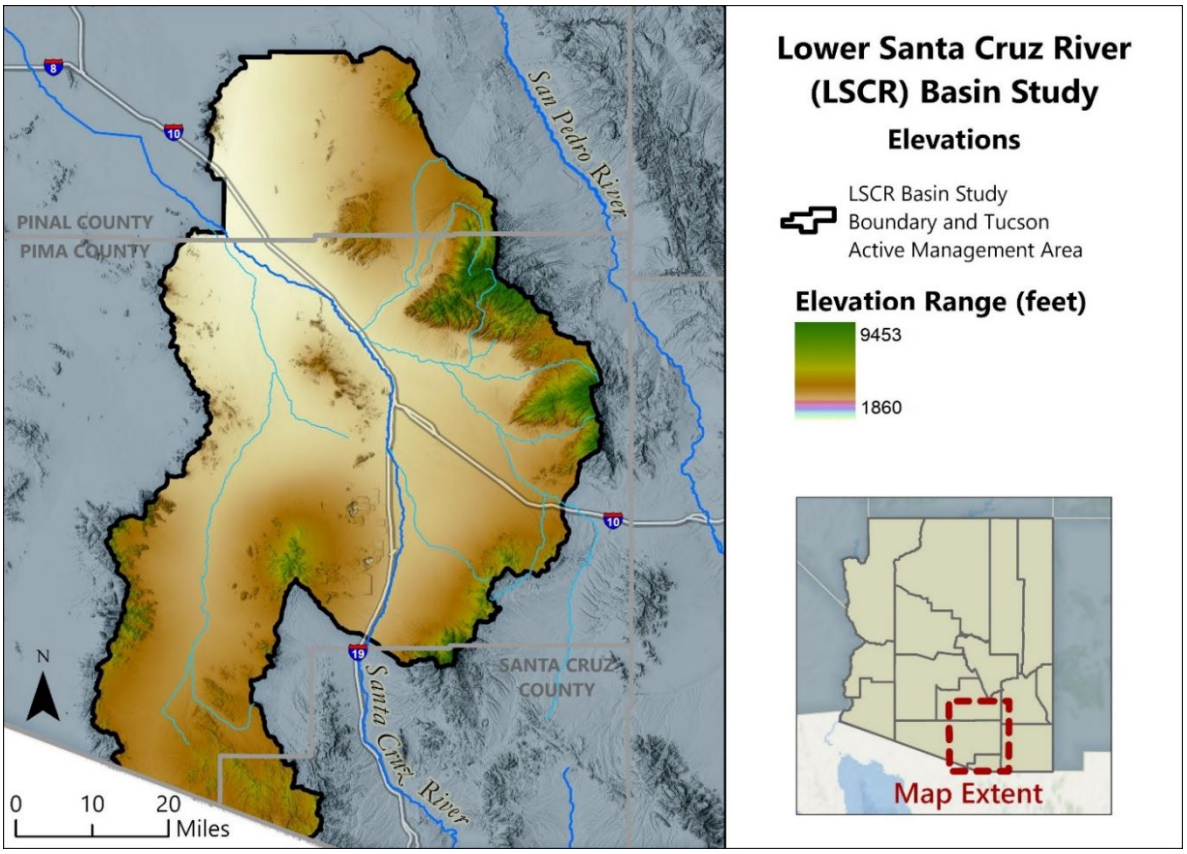


Figure 5-1 – Elevation range of the LSCR Basin Study Area (Tucson Active Management Area).

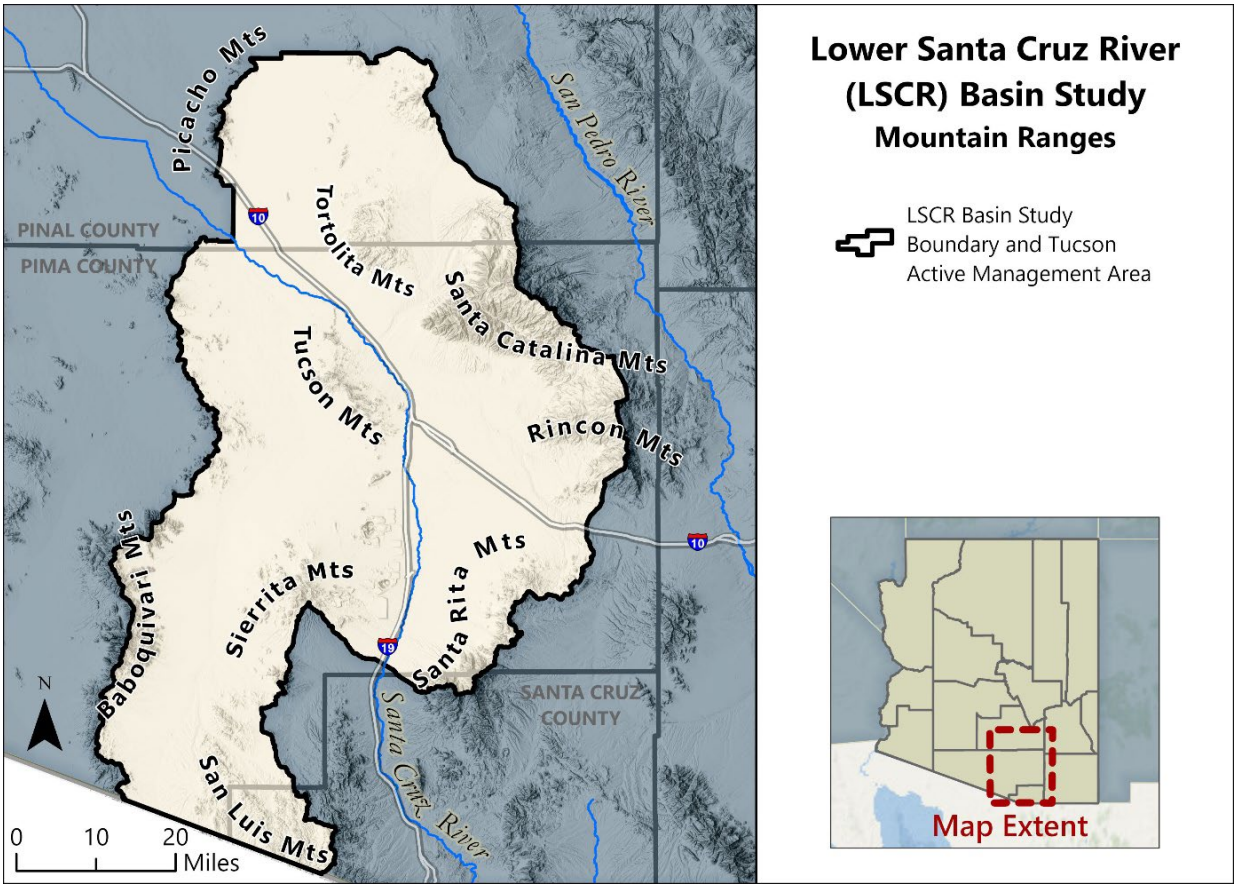


Figure 5-2 – Mountain ranges in the LSCR Basin Study Area.

The climate is semi-arid at lower elevations with annual precipitation ranging from 11 to 16 inches. In the mountains, precipitation can total as much as 30 inches per year (Arizona Department of Water Resources, 2016a). The greater Tucson area, which is situated within the Basin, receives an average of approximately 11 inches of precipitation a year, which is distributed between a summer monsoon season and a winter rainy season (Sheppard, Comrie, Packin, Angersbach, & Hughes, 2002). From mid-June to September, the North American Monsoon delivers high-intensity, localized rainfall events that typically last less than an hour. These monsoon events provide approximately 52% of average rainfall (Gelt, et al., 1999).

Most of the remaining rainfall is delivered between October and March. This period includes the winter rainy season, which is characterized by heavy cloud cover and rainfall events of longer duration (hours to days). These storms are lower in intensity and cover a wider area than summer monsoon events (Gelt, et al., 1999). Basin-wide precipitation also varies widely across years (Sheppard, Comrie, Packin, Angersbach, & Hughes, 2002).

Vegetation in the lower elevations is sparse and consists primarily of creosote, mesquite, and cacti. The higher rainfall volumes in the upper elevations of the mountains around the LSCR Basin's edges support conifers and deciduous trees such as aspen, Douglas fir, and oak (Arizona Department of Water Resources, 2016b).

5.1.2. Surface water hydrology

The Santa Cruz River (SCR) and its tributaries are the major surface water drainages within the LSCR Basin. The SCR enters from the southeast and exits to the northwest (Figure 5-3). Major tributaries to the SCR include Rillito Creek, Tanque Verde Creek, Pantano Wash, Sabino Creek, Cañada del Oro Wash, and Brawley Wash (Arizona Department of Water Resources, 2016b). The SCR runs for approximately 60 miles within the Study Area (Arizona Department of Water Resources, 1999).

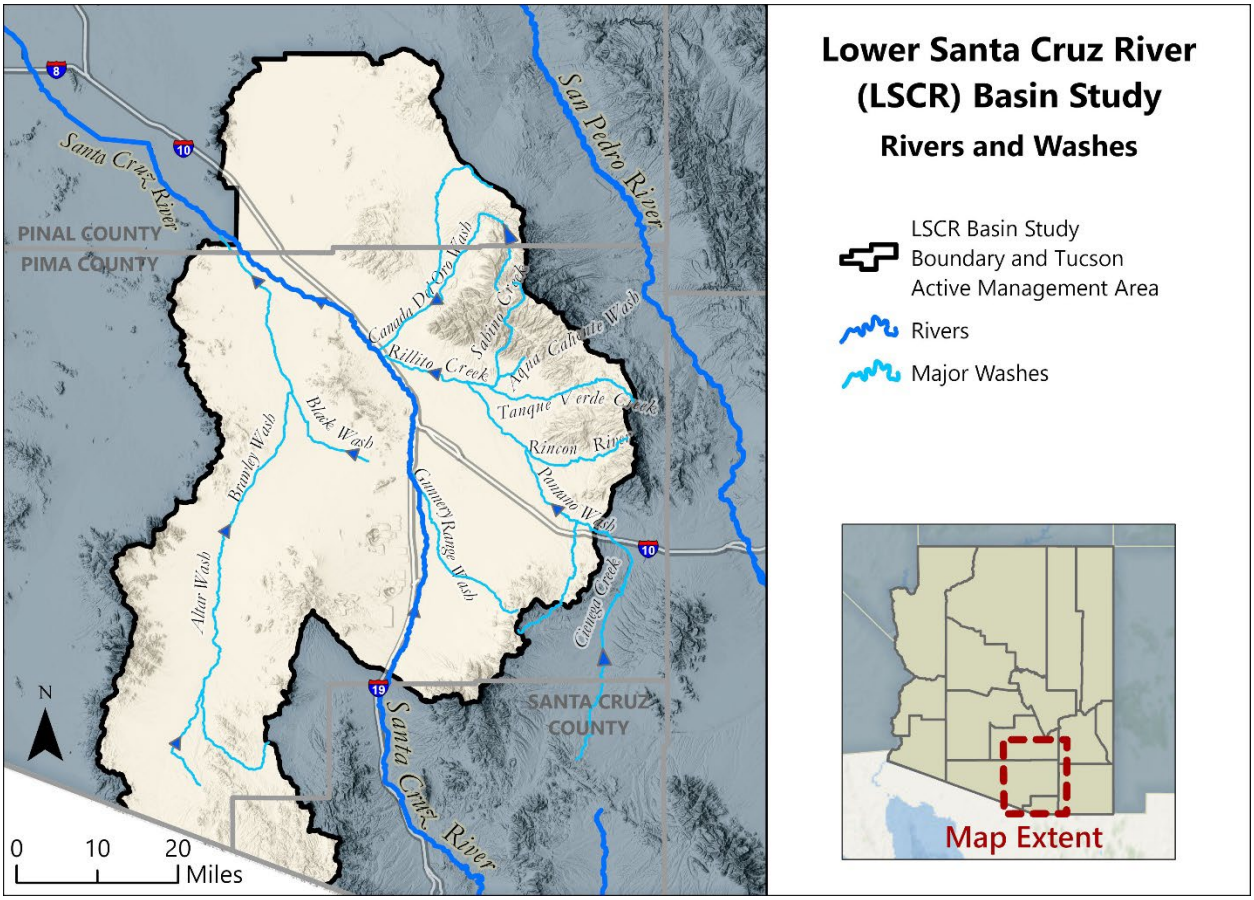


Figure 5-3 – Rivers and washes in the Study Area, arrows denote flow direction.

Most reaches of the SCR within the LSCR Basin do not have streamflow except following rainstorms. Rainfall events that generate runoff provide surface water flow to normally dry stretches of the SCR and its tributaries. These flows support riparian (streamside) ecosystems before infiltrating and recharging the Basin's aquifers. The geology of the regional aquifers allows runoff to infiltrate relatively quickly and easily (Wilson, Matlock, & Jacobs, 1998).

5.1.3. Groundwater hydrology and conditions

The Basin's geology is characterized by broad, gently sloping alluvial basins, separated by north to northwest trending fault-block mountains. The sedimentary deposits known as basin-fill deposits make up the regional aquifer (Arizona Department of Water Resources, 2016b). The mountain ranges between alluvial basins are generally composed of impermeable bedrock, forming distinct hydrogeologic boundaries. Figure 5-4 shows the depth to bedrock within the LSCR Basin. The regional aquifer is deepest in areas where the depth to bedrock is high.

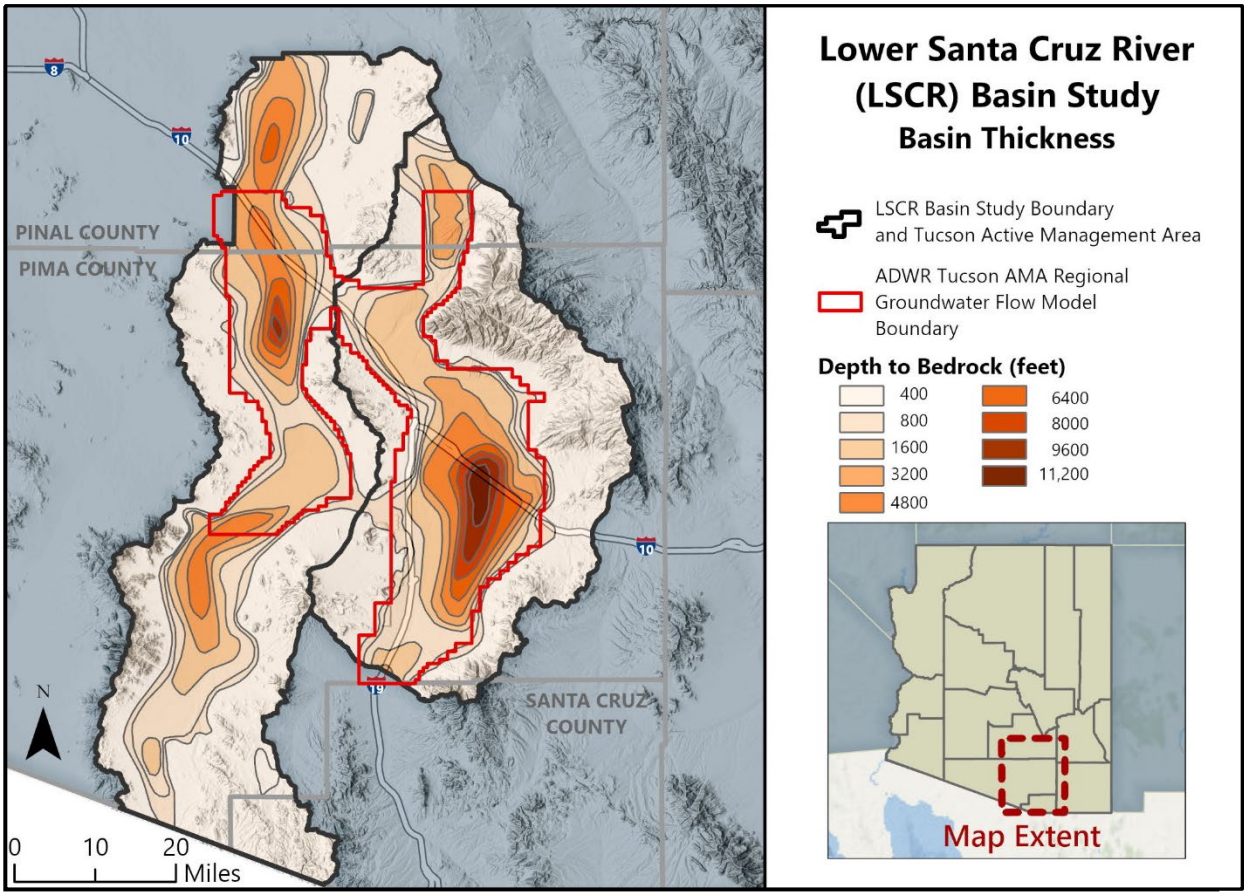


Figure 5-4 – Depth to bedrock in the LSCR Basin.

Groundwater in the regional aquifer is generally unconfined to semi-confined to depths of about 1,000 feet below land surface. Groundwater flow within the regional aquifer is generally from the south and southeast to the north and northwest, except in the Cañada del Oro drainage, where groundwater flows south before entering the main basin (Mason & Hipke, 2013) (Figure 5-5).

Historically, the largest source of recharge to the regional aquifer has been mountain-front recharge and streambed recharge along the SCR and its major tributaries. Mountain-front recharge occurs along the margins of the Basin. In these areas, rainfall and snowmelt generate surface flows that infiltrate into the alluvial material and enter the regional aquifer. Based on

results of the latest TAMA Groundwater Flow Model, the long-term annual averages of mountain-front and stream recharge are estimated at 30,100 AF and 38,500 AF respectively, for a total of 68,600 AF of natural recharge per year (Mason & Hipke, 2013). A revised estimate of mountain-front recharge was out of the scope of this Study.

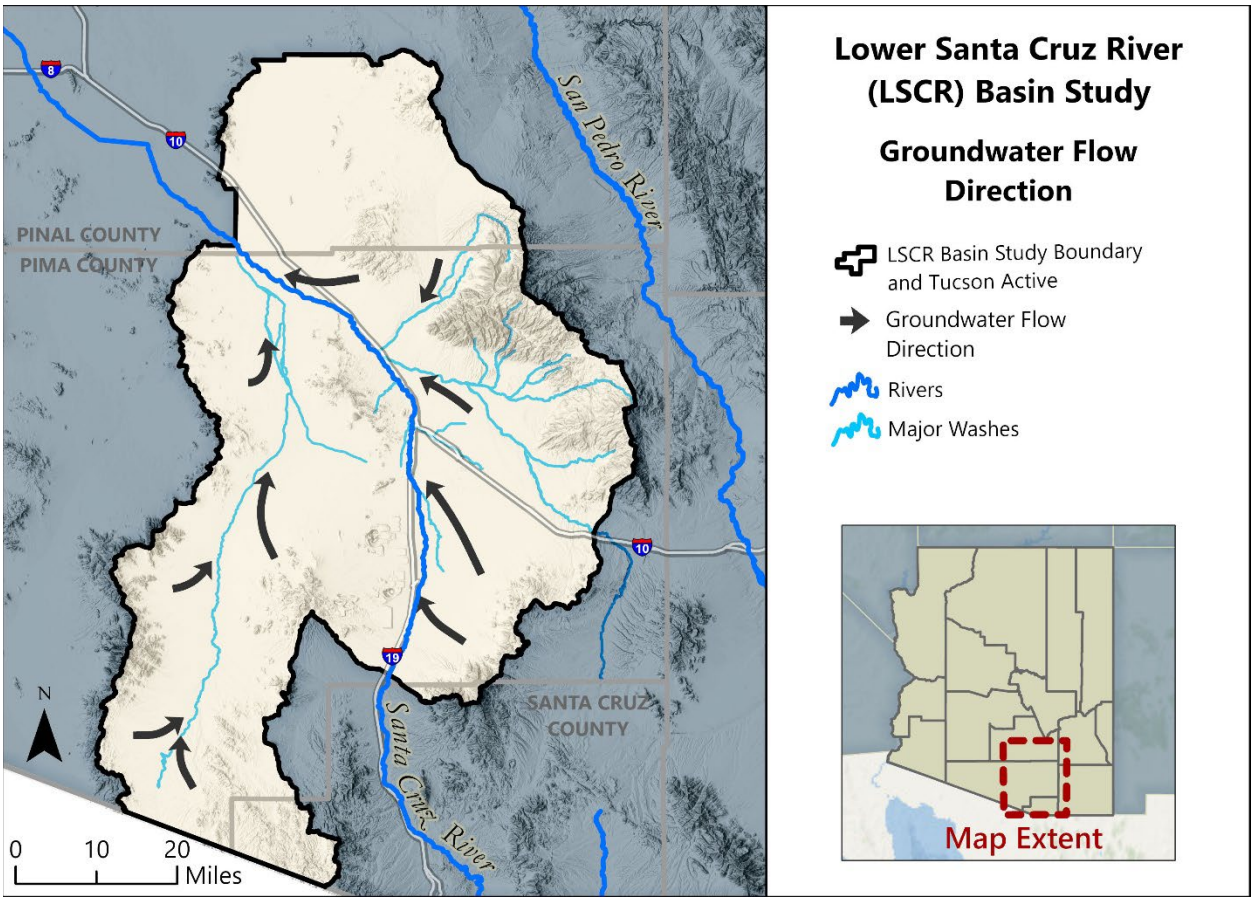


Figure 5-5 – Map of groundwater flow direction. (Source: Personal communication, Wally Wilson)

Groundwater is discharged from the regional aquifer through pumping, underflow, and evapotranspiration (ET). ET loss results from water consumption by plants whose roots can access groundwater, called phreatophytes (Robinson, 1958). These losses occur in riparian corridors located along the SCR and its major tributaries where groundwater is shallow enough to support phreatophytes.

5.2 Water Supplies

Presently, groundwater, CAP water, and reclaimed water are the primary water supplies in the Study Area (Figure 5-6).

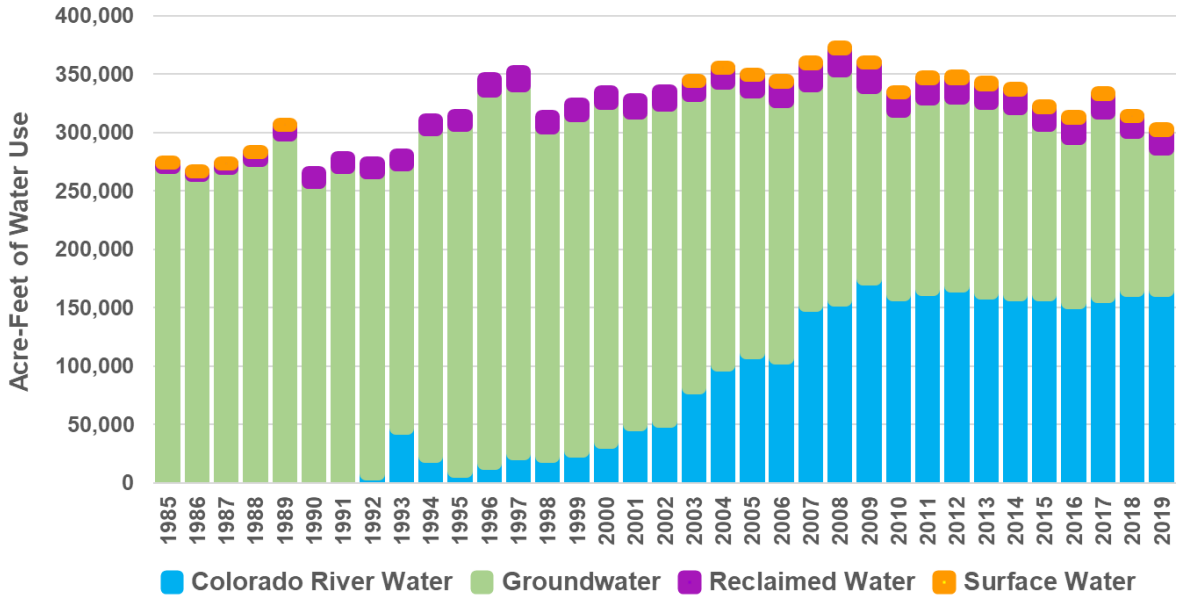


Figure 5-6 – Water use by source in the LSCR Basin, 1985 – 2019.

5.2.1. Surface water

Most flows within the main surface water drainages of the LSCR Basin occur in response to rainfall events or snowmelt, as described in earlier sections. Flow events generated by direct precipitation in the valleys are usually of short duration, especially during the monsoon season where runoff events occur on the timescale of minutes to hours. Some winter storms may last for several days and can generate substantial prolonged flow events (Arizona Department of Water Resources, 2016b). In most parts of the LSCR Basin, surface water is not sufficiently reliable to meet demands. However, precipitation-driven surface flows support riparian areas, which provide important habitat for wildlife and provide significant aesthetic and recreational values. The combined effects of drought and climate change pose risks to the natural systems that rely on surface water. In addition, long-term declines in surface water flow could impact groundwater recharge by reducing the opportunity for streambed infiltration of runoff that eventually reaches the regional aquifer.

5.2.2. Groundwater

Groundwater pumping for agricultural, municipal, and industrial purposes is the largest source of water withdrawals from the LSCR Basin's regional aquifer. Groundwater development for farming and to support the City of Tucson began as early as 1900. Initially, most groundwater in the LSCR Basin was used for irrigation, but by the mid-1970s, irrigation withdrawals began to decline due to urbanization and agricultural retirement. At the same time, municipal and industrial demands began increasing along with the population (Arizona Department of Water Resources, 2016a).

Groundwater pumping in excess of natural recharge rates, often referred to as overdraft or "groundwater mining" caused water levels in the regional aquifer to decline substantially between 1940 to 2010. Widespread declines of 100 feet to 250 feet occurred, reducing overall aquifer storage. The TAMA Groundwater Flow Model simulated a storage loss of 6.6 million AF between 1940 and 2010 (Arizona Department of Water Resources, 2016a).

In addition, several smaller cones of depression have formed in areas of localized groundwater withdrawals. For example, in the Green Valley-Sahuarita area, a cone parallels the Santa Cruz River, reflecting localized pumping that caused water levels to decline about 100 to 150 feet between 1940 and the early 1980s.

Risks associated with declining groundwater levels include increased pumping costs, degradation of groundwater quality, the need to deepen or relocate wells, and land subsidence. Land subsidence occurs when groundwater is withdrawn to such an extent that portions of an aquifer become dewatered and, due to the weight of overlying land, the aquifer material becomes compacted. In addition to reducing the storage capacity of the aquifer, this results in a drop in elevation at the land surface and can result in cracks and earth fissures at the land surface. As early as the 1940s, water-level declines of up to several feet per year resulted in aquifer-system compaction and measurable land subsidence in Tucson Basin and Avra Valley (Evans & Pool, 2000).

Today, groundwater levels have rebounded in many parts of the LSCR Basin, despite the population growing to over 1 million people in 2020. This is due to several factors including recharge of CAP water, significant reductions in residential per capita water use, and decreased agricultural groundwater use, discussed further in Chapter 6.

5.2.3. CAP water

The Central Arizona Project is a 336-mile-long system of canals, tunnels, pumping plants, and pipelines that brings water from Lake Havasu on the Colorado River to points in Maricopa, Pinal, and Pima Counties (Figure 5-7). Colorado River water delivered through the CAP is the largest renewable source of water in the LSCR Basin. Annual CAP water allocations for the LSCR Basin total 263,298 AF/year. Approximately 196,798 AF/year is for subcontracts with municipal water providers (Arizona Department of Water Resources, 2022b). An additional 66,000 AF/year is subcontracted to the Tohono O'odham Nation for use by the San Xavier and Schuk Toak Districts, but due to lack of storage facilities, some of the Tohono O'odham Nation water is delivered to Groundwater Savings Facilities in another Active Management Area.

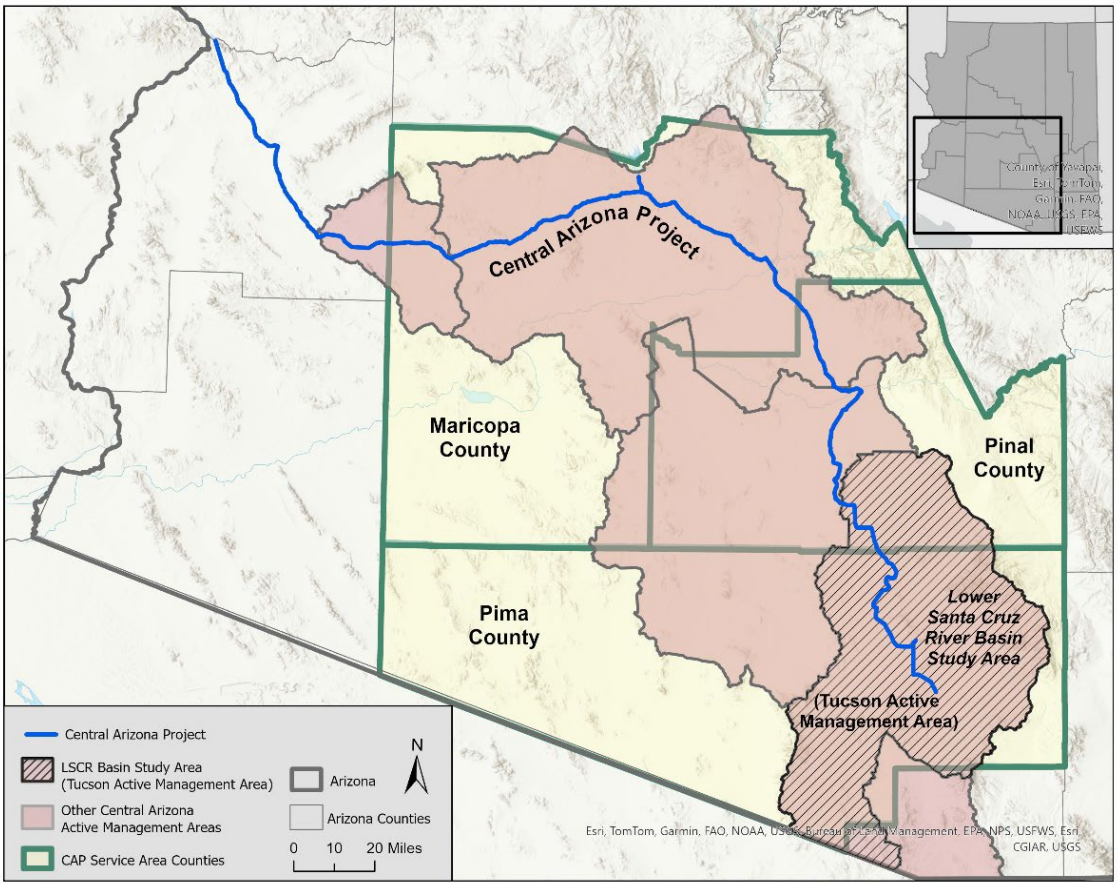


Figure 5-7 – Central Arizona Project Service Area Counties, Central Arizona Active Management Areas, and Central Arizona Project Alignment.

Under the Colorado River Basin Project Act of 1968, CAP water has a junior priority when there is insufficient mainstem Colorado River water available to deliver a total of 7.5 million acre-feet to Arizona, California, and Nevada (Central Arizona Project, 2019b). This means that in times of shortage, the CAP's supply of Colorado River water is cut before the supplies of more senior users (Central Arizona Project, 2022b).

In recent years, several actions have served to reduce the risk of shortages to Colorado River water users, including the CAP. In 2007, the Bureau of Reclamation adopted the "Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead". These guidelines identified changes in operation to the river's two major reservoirs under hotter, drier conditions and defined the method for distributing cuts at various tiers of reservoir elevations. This action helped share the risk of shrinking water supplies between the Upper and Lower Colorado basins (Paskus, 2020).

In 2019, the Drought Contingency Plan (DCP) Authorization Act was passed. The DCP is a set of agreements designed to protect the Colorado River system through voluntary reductions and increased conservation (Central Arizona Project, 2022b). The Upper Basin portion of the plan

protects elevations at Lake Powell and authorizes storage of conserved water in the Upper Basin. The Lower Basin DCP requires Arizona, California, and Nevada to contribute additional water to Lake Mead storage and creates additional flexibility to incentivize voluntary conservation of water to be stored in Lake Mead (Water Education Foundation, n.d.).

Despite these efforts, the Bureau of Reclamation reduced releases from Glen Canyon Dam and Hoover Dam in 2022 due to ongoing drought, low runoff conditions in the Colorado River Basin, and declining reservoir levels. In the Lower Basin, the reductions represent the first shortage declaration (Bureau of Reclamation, 2021b). There is a probability of ongoing shortage declarations in subsequent years, including the possibility of lower shortage tiers, meaning greater shortage volumes and reductions to CAP sub-contractors' entitlements (Arizona Department of Water Resources, 2022a).

Figure 5-8 shows the impact of the DCP tiers on CAP deliveries within the Tucson AMA. Due to the large volume of municipal and Indian entitlements held by entities within the Tucson AMA, only small reductions of CAP deliveries occur under DCP Tiers 1, 2a, and 2b. Larger reductions of CAP supplies do occur at DCP Tier 3.

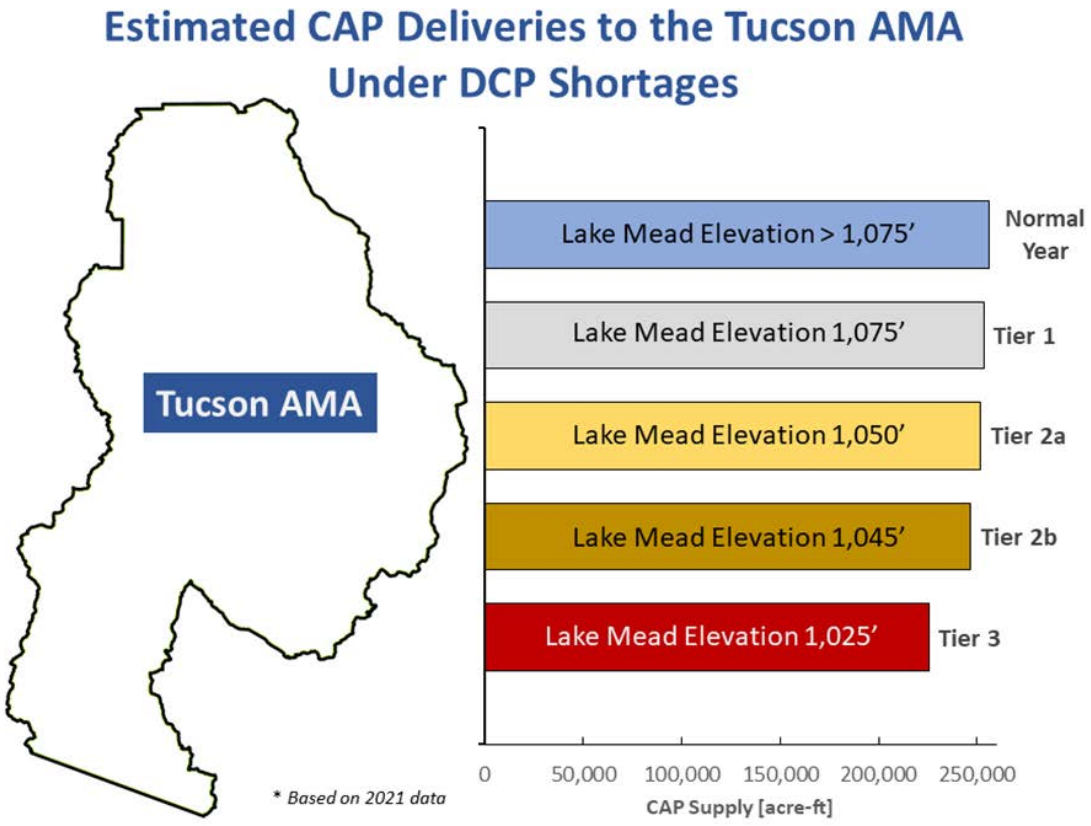


Figure 5-8 – Total volume of CAP water to be delivered to the Tucson Active Management Area under a range of shortages defined by the Drought Contingency Plan. Values include water delivered to farms on the San Xavier and Schuk Toak Districts of the Tohono O'odham Nation. (Source: CAP, personal communication, 2022)

Figure 5-9 describes how the reductions of CAP supplies would be distributed under a DCP Tier 3 shortage. In 2021, about 113,000 acre-feet of the TAMA's Municipal and Indian priority CAP supplies was used to meet current needs, while about 66,000 acre-feet were stored in state-certified facilities for the long term. Under a Tier 3 shortage, CAP supplies would be reduced by 11%, most likely impacting the amount of CAP water available for long-term storage and avoiding impacts to existing users.

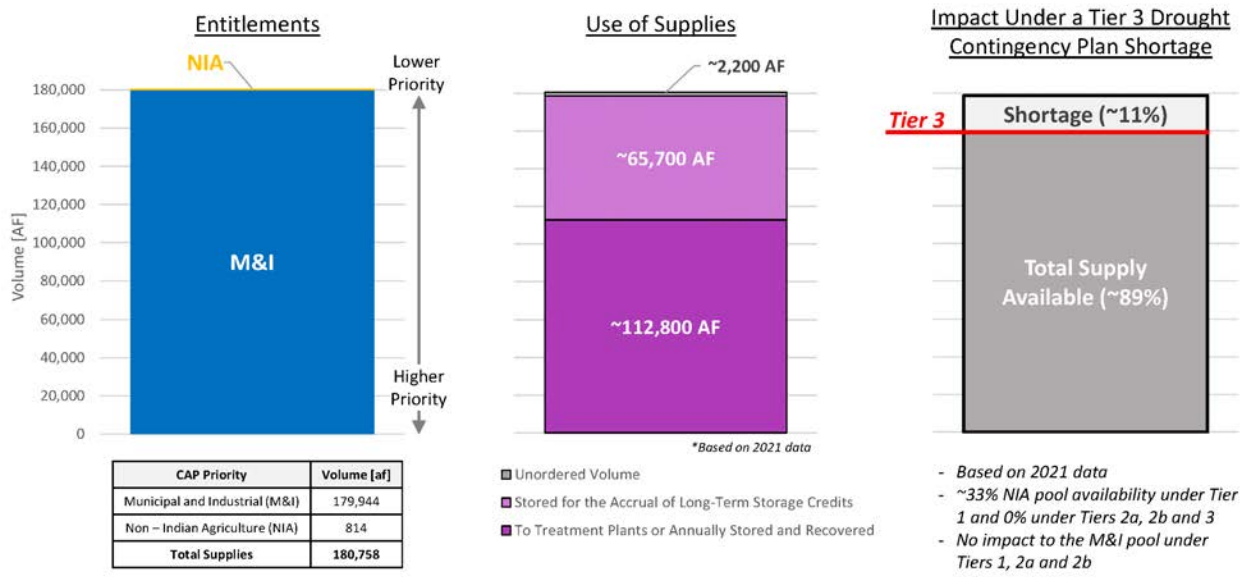


Figure 5-9 – Impact to the TAMA's municipal and industrial and non-Indian agriculture entitlements under a Tier 3 shortage as defined by the 2019 Drought Contingency Plan. (Source: CAP, personal communication, 2022)

5.2.4. Reclaimed water

Under Arizona law, reclaimed water is water that has been treated or processed by a wastewater reclamation facility. Reclaimed water is a valuable, locally generated, renewable resource and a key component of the LSCR Basin's water resources.

Reclaimed water has been used since it was first generated. Tucson's first sewers were constructed in the early 1900s, with the untreated wastewater used for agricultural irrigation. The first wastewater treatment plant was constructed in 1928 and reclaimed water continued to be used for agricultural irrigation until 1969. Since then, most of the reclaimed water from the region's two major water reclamation facilities has been discharged directly into the Santa Cruz River, where it recharges and supports a thriving riparian area.

In 1984, the City of Tucson began operating a reclaimed water distribution system that supplies turf facilities (parks, golf courses, and cemeteries) (Arizona Department of Water Resources, 2016a). Approximately 10,000 acre-feet of reclaimed water was delivered through this system in 2020 (Pima County Regional Wastewater Reclamation District, 2021).

The area's major wastewater treatment plants, the Agua Nueva and Tres Rios Water Reclamation Facilities (WRFs), are operated by Pima County Regional Wastewater Reclamation Department (Figure 5-10). The two plants generated 57,390 acre-feet of reclaimed water in 2020 (Pima County Regional Wastewater Reclamation District, 2021). Discharge to the SCR from the two WRFs totaled 37,791 acre-feet in 2020, significantly contributing to aquifer recharge and environmental restoration along the river. Of the 37,791 acre-feet discharged, 14,037 AF flowed past the Trico Road gage on the Santa Cruz River and exited the LSCR Basin.

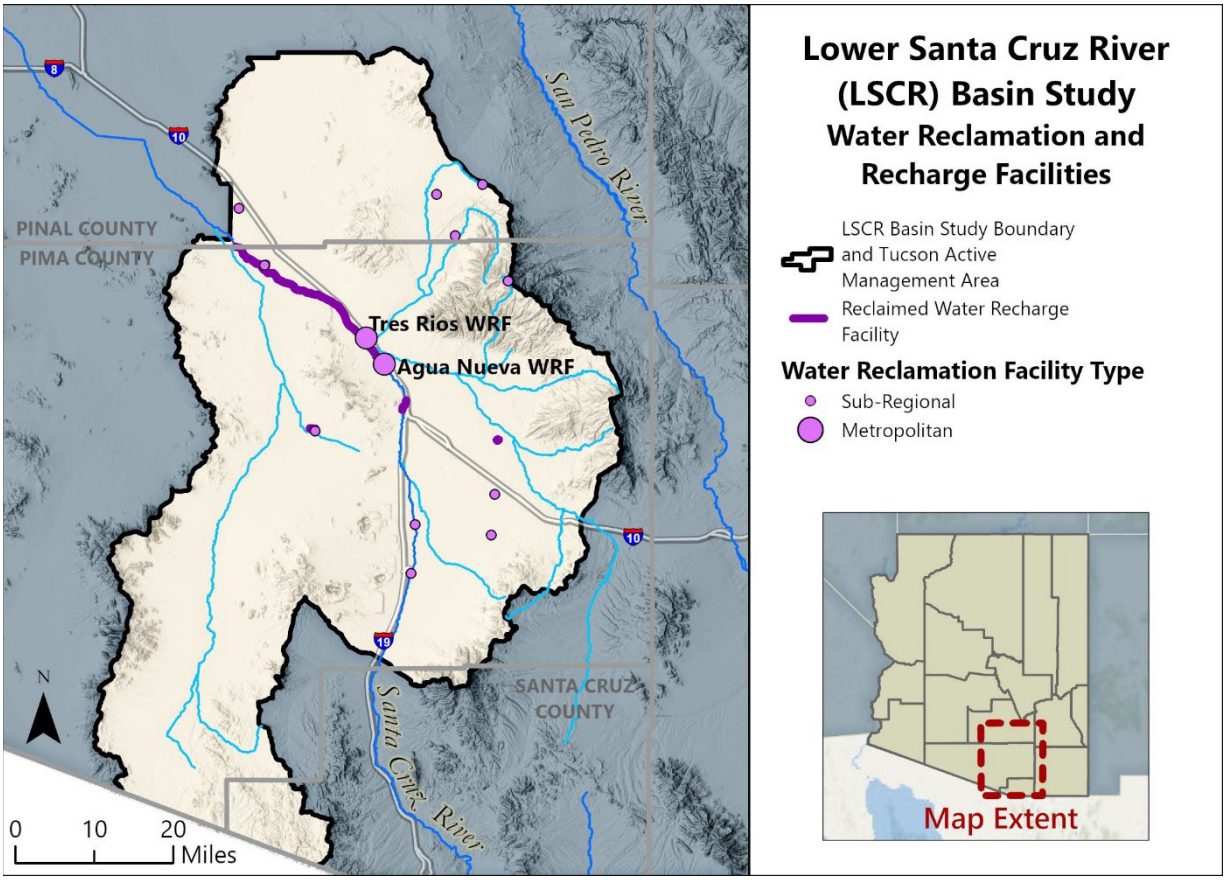


Figure 5-10 – Locations of water reclamation and reclaimed water recharge facilities within the LSCR Basin.

Smaller amounts of reclaimed water are treated at sub-regional facilities. In 2020, an additional 7,036 acre-feet of reclaimed water was generated in facilities other than Tres Rios and Agua Nueva. Most of this reclaimed water is recharged on the facility sites.

In terms of quantity, reclaimed water is considered to be an extremely reliable water source. Reclaimed water is the only type of water supply that is projected to increase over time within the LSCR Basin (Central Arizona Project, 2021b).

Chapter 6 Water Demands and their Legal and Regulatory Settings by Sector

This chapter provides a brief overview of the water demands in the LSCR Basin and the Arizona's legal and regulatory requirements. To provide a complete description, this section of the report includes material presented in previous chapters.

6.1 Water Demands in the LSCR Basin by Sector

In 2019, total municipal, industrial and agricultural demand in the Tucson Active Management Area was just over 300,000 acre-feet. Municipal demand was the largest component, accounting for just under half the total demand. Non-Indian agriculture uses, including the operation of Groundwater Savings Facilities, comprised about 28%, while Indian agriculture accounted for about 5% of total demand. Industrial uses, mostly mining, but also sand and gravel facilities, golf courses, and power generation facilities accounted for another 17% (Figure 6-1).

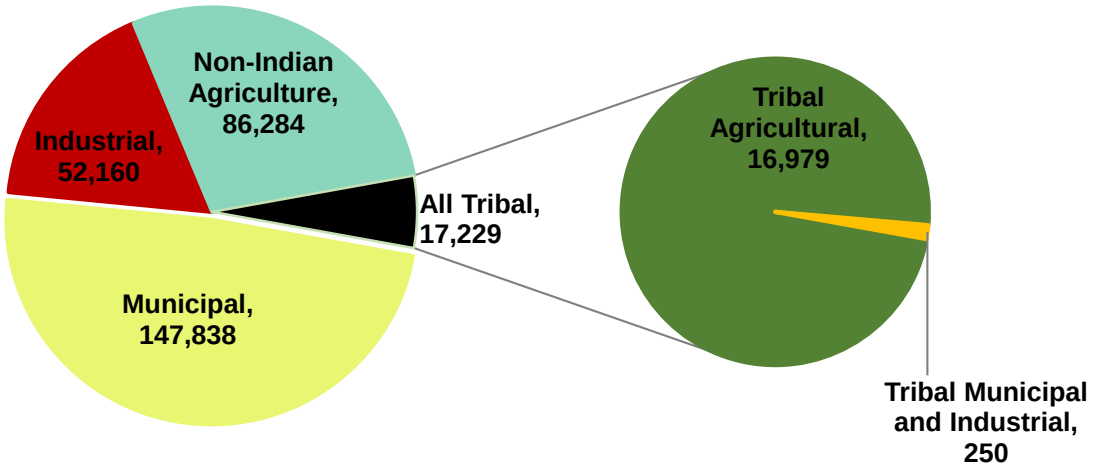


Figure 6-1 – Acre-feet of water use by sector in the LSCR Basin, 2019. Data Source: ADWR AMA Data Dashboard, downloaded 4/25/22. https://new.azwater.gov/ama/ama-data

6.2 Changes in Demand over Time

As illustrated in Figure 6-2, since 1985, the municipal sector has consumed the most water, followed by non-Indian agriculture and the industrial sectors. Tribal use has always been the smallest sector, although Indian agricultural use began to increase as CAP water became available around 2000 for the farms on the San Xavier and Schuk Toak Districts of the Tohono O'odham Nation.

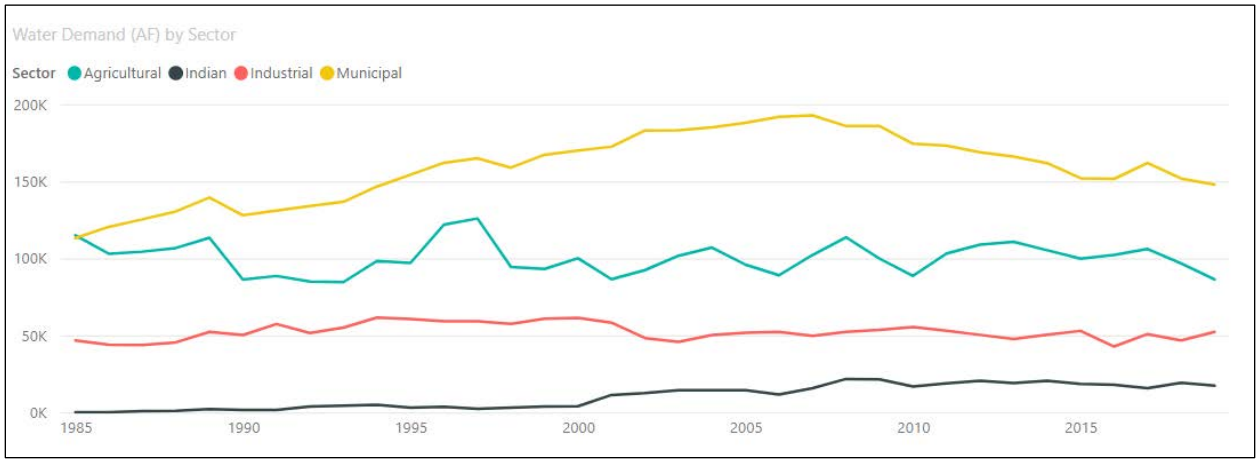


Figure 6-2 – Water use by sector in the Tucson Active Management Area, 1985 – 2019, accessed from AMA Data | Arizona Department of Water Resources (azwater.gov), March 28, 2022.

Municipal demand grew with population through 2007, but the economic downturn that began in 2008 hit the region hard. The population of Pima County grew at an average annual rate of 2% per year between 2000 and 2007. In 2008, it fell dramatically and remained below 1% until 2017. Since then, the highest population growth rate in Pima County was 1.1%, in 2018 (USA Facts, n.d.). At the same time, per-capita water use rates decreased significantly, following a nation-wide trend (City of Tucson Water Department and HDR Engineering, Inc., 2013). In 2019, total municipal use was still less than it was in 2007 (Arizona Department of Water Resources, 2022a).

In 2019, Colorado River water accounted for approximately 70% of the LSCR Basin's 104,700-acre-foot municipal supply (Figure 6-3). Groundwater accounted for about 20% of municipal demand, and reclaimed water made up the remaining 10% (Arizona Department of Water Resources, 2022a). However, much of the Colorado River water in this volume includes groundwater pumping replenished by the recharge of CAP water in Underground Storage Facilities or Groundwater Savings Facilities within the LSCR Basin, as explained in Sections 6.6 and 6.7.

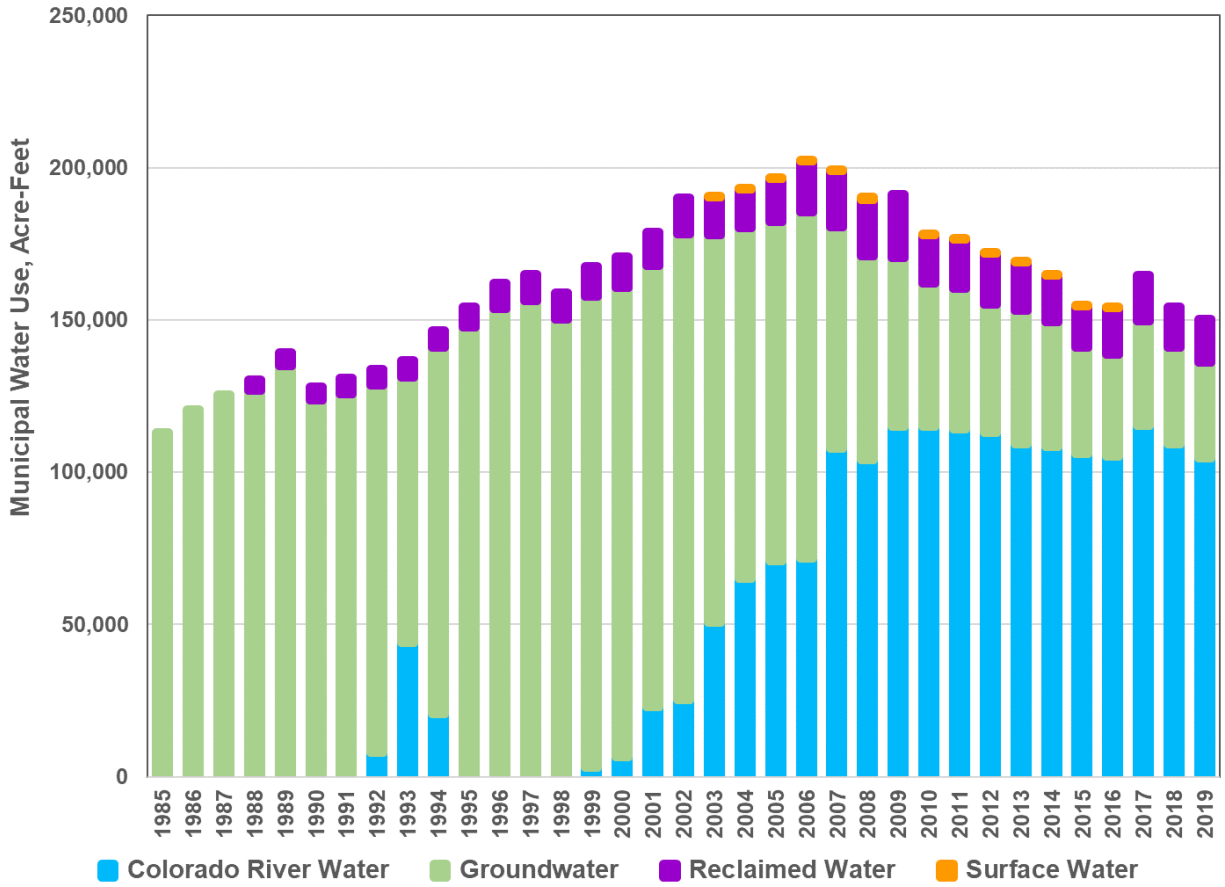


Figure 6-3 – TAMA municipal demand by source, 1985-2019. Source: ADWR AMA Data Dashboard, https://new.azwater.gov/ama/ama-data, downloaded 4/25/22.

Industrial uses include mining, turf-related facilities, sand and gravel operations, electric power generation, and dairies. Industrial water use has been relatively stable since 1985 except for periodic fluctuations caused by its largest subsector, metal mining, which has fluctuated between 25,000 and 43,000 AF per year (Arizona Department of Water Resources, 2022a).

The non-Indian agricultural sector is comprised of farms that were actively irrigated with groundwater from 1975 to 1980. (No new irrigated lands have been permitted in the Tucson Active Management Area since the passage of the Groundwater Code in 1980.) Agricultural demand for groundwater has decreased over time with a decrease in irrigation acres. Several large farms and irrigation districts function as Groundwater Savings Facilities, using either CAP water or reclaimed water "in lieu" of pumping groundwater.

The Pascua Yaqui tribal lands, part of the Schuk Toak District of the Tohono O'odham Nation (TON), and the entire San Xavier District of the TON are located within the LSCR Basin. Tribal demand is primarily agricultural and relies almost exclusively on CAP water with a small portion of municipal and industrial demand (Figure 6-1). Municipal tribal demand is estimated to have been about 250 AF in 2019 (Arizona Department of Water Resources, 2022a).

6.3 Legal and Regulatory Setting by Sector

In 1980, Arizona committed to the long-term management and conservation of its groundwater supplies through the passage of the Groundwater Code. The Code was enacted in response to serious water level declines in the aquifers in the central and southern parts of the state, including the Tucson area. A key goal of the Code was to eliminate severe groundwater overdraft in areas of the state where these supplies had been rapidly diminishing (Arizona Department of Water Resources, 1999).

The regulatory provisions of the Code are focused on areas of the state designated as Active Management Areas or AMAs. Within AMAs, the Code established a management goal and a new groundwater rights system that: (1) strictly limited groundwater withdrawals; (2) prohibited new irrigated farmland; (3) required new subdivisions to have long-term, dependable supplies; and (4) required measurement and reporting of groundwater withdrawals (Arizona Department of Water Resources, 1999).

6.4 Safe-yield

The management goal to be reached by the Tucson Active Management Area by year 2025 or earlier is “safe-yield”. Safe-yield is defined in statute as “a groundwater management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management area” (A.R.S. § 45- 561(2)) (Arizona Department of Water Resources, 1999).

Assessing safe-yield is complex, but simply stated, it means that the outflows from aquifers in the AMA are balanced in the long term by inflows, whether natural or artificial, and that balance is maintained going forward. Achieving the goal does not require this balance to be maintained every single year, but there should be a balance in the long term (Arizona Department of Water Resources, 2022b).

Safe-yield is achieved on an AMA-wide basis. Early on, it was recognized that as safe-yield conditions were attained on an AMA-wide basis, some areas could be depleted, some areas of active recharge could be in surplus, and other areas could achieve a localized balance between the amount of water recharged and pumped. It was also envisioned that additional tools might be required to develop a more resource-based, localized water management program (Arizona Department of Water Resources, 1999).

The Tucson AMA is at or around safe-yield as of 2019 (Figure 6-4). This is largely a result of imported Colorado River water supplies that offset groundwater pumping, combined with a total water demand that has remained flat or even slightly decreased. However, under Colorado River shortage conditions, it may be challenging for the TAMA to maintain a safe-yield condition (Arizona Department of Water Resources, 2022a).

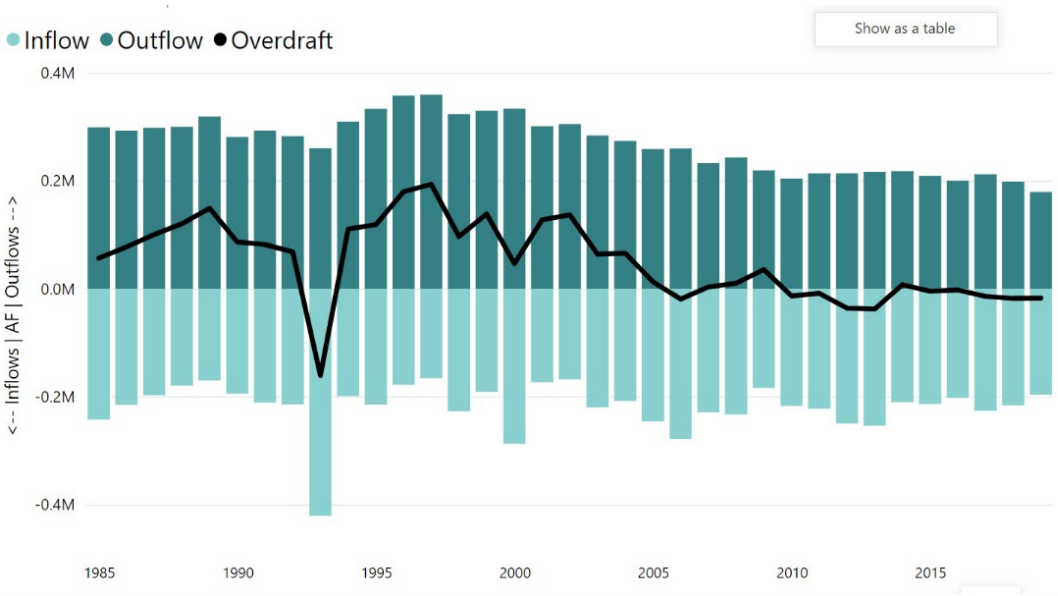


Figure 6-4 – Inflows and outflows in the Tucson Active Management Area 1985 – 2019.
Source: ADWR Overdraft Dashboard, https://new.azwater.gov/ama/ama-data, accessed 4/13/22.

Initially, a key concern of the Study Partners was the impact of future climate and municipal growth on the ability to maintain safe-yield in the Tucson Active Management Area. Achieving safe-yield is more difficult than balancing physical groundwater inflows and outflows over a defined period of time, since ADWR assumes that inflows of stored water will be recovered (pumped out) at some point in time. Therefore, water stored for future use in state-certified Underground Storage Facilities is not counted as an inflow in safe-yield calculations.

In addition, the calculation of safe-yield depends on ADWR's assumptions regarding groundwater inflows and outflows, mountain-front recharge, and streamflow recharge. This Study generated its own projection of streamflow infiltration based on climate change projections. These differences made it impractical to project whether the Tucson AMA would maintain safe-yield over the projection period. While this Study evaluates the groundwater inflows and outflows into the TAMA, it also focuses on spatial distribution of inflows and outflows and their impact on groundwater levels.

6.5 Assured Water Supply Program Rules

The Assured Water Supply Program rules, which were adopted in 1995, ensure that new municipal growth depends on renewable water sources rather than mined groundwater. New subdivisions within an AMA must demonstrate that they have a physically, legally, continuously available water supply of sufficient quality for a 100-year period. In addition, these plans must be consistent with the AMA's Management Goal, in this case, safe-yield. If the provider has physical access to renewable supplies (CAP or reclaimed water), they can supply these to their customers. Alternatively, municipal providers can pump groundwater to meet their demands, but

most of the groundwater that is pumped must be replenished in state-certified facilities within the same AMA. Under AWS Program rules, groundwater pumping may take place at a distance from the facility in which renewable supplies are recharged, as long as this replenishment takes place within the same Active Management Area.

For municipal water providers without sufficient renewable supplies to meet their demands, membership in the Central Arizona Groundwater Replenishment District (CAGRD) is a way to satisfy the renewable supply requirement of the AWS Program rules. The CAGRD is a special function of the Central Arizona Project; however, it is financially separate and is funded solely by its members. The CAGRD enrolls members and collects fees, dues, and assessments.

The CAGRD works closely with the water providers serving its members. The water providers report how much groundwater was used and how much must be replenished under the Assured Water Supply Program rules (Central Arizona Project, 2021). The CAGRD uses funds paid by the members to purchase renewable water supplies and replenish them on the members' behalf, by recharging in state-certified facilities. This process ensures that the CAGRD members' water use is consistent with the management goal of the AMA, but again, CAGRD member groundwater pumping may take place at a considerable distance from the location of CAGRD's recharge.

6.6 Underground Water Storage, Savings and Replenishment

Replenishing groundwater pumping with the recharge of renewable supplies (CAP or reclaimed water) has become an important tool for municipal providers and the CAGRD to comply with the AWS Program rules. Recharge must take place in either one of two types of permitted facilities: Underground Storage Facilities (USFs) and Groundwater Savings Facilities (GSFs) (see Figure 6-5, Figure 6-6, and Figure 6-7).

Most USFs that store CAP water are located close to the CAP in order to minimize pumping costs. The northernmost USFs in the Study Area are the Lower Santa Cruz Replenishment Project (LSCRP), operated by the Central Arizona Water Conservation District, and the Avra Valley Recharge Project (AVRP), operated by the Metropolitan Domestic Water Improvement District, with capacities of 50,000 and 11,000 acre-feet per year respectively.

Farther south are two large USFs: the Central Avra Valley Storage and Recovery Project (CAVSARP) and the Southern Avra Valley Storage and Recovery Project (SAVSARP), operated by Tucson Water, the City of Tucson's water utility. These facilities are permitted for 75,000 and 115,000 acre-feet per year, respectively. CAVSARP and SAVSARP are actively managed for recharge and recovery, allowing Colorado River water to mix with groundwater to produce a blended water supply that is served to Tucson Water customers (Wilson W. , 2009).

The Pima Mine Road Recharge Project (PMRRP), which connects to the CAP terminus at Pima Mine Road, is the furthest south and most upgradient of the large recharge projects within the

Study Area. It is also operated by the Central Arizona Water Conservation District and is permitted for 50,000 acre-feet of recharge per year. Another USF, Project Renews. is permitted for 3,000 acre-feet per year of recharge but is still awaiting the completion of the pipeline that will transport CAP water to the Green Valley area.

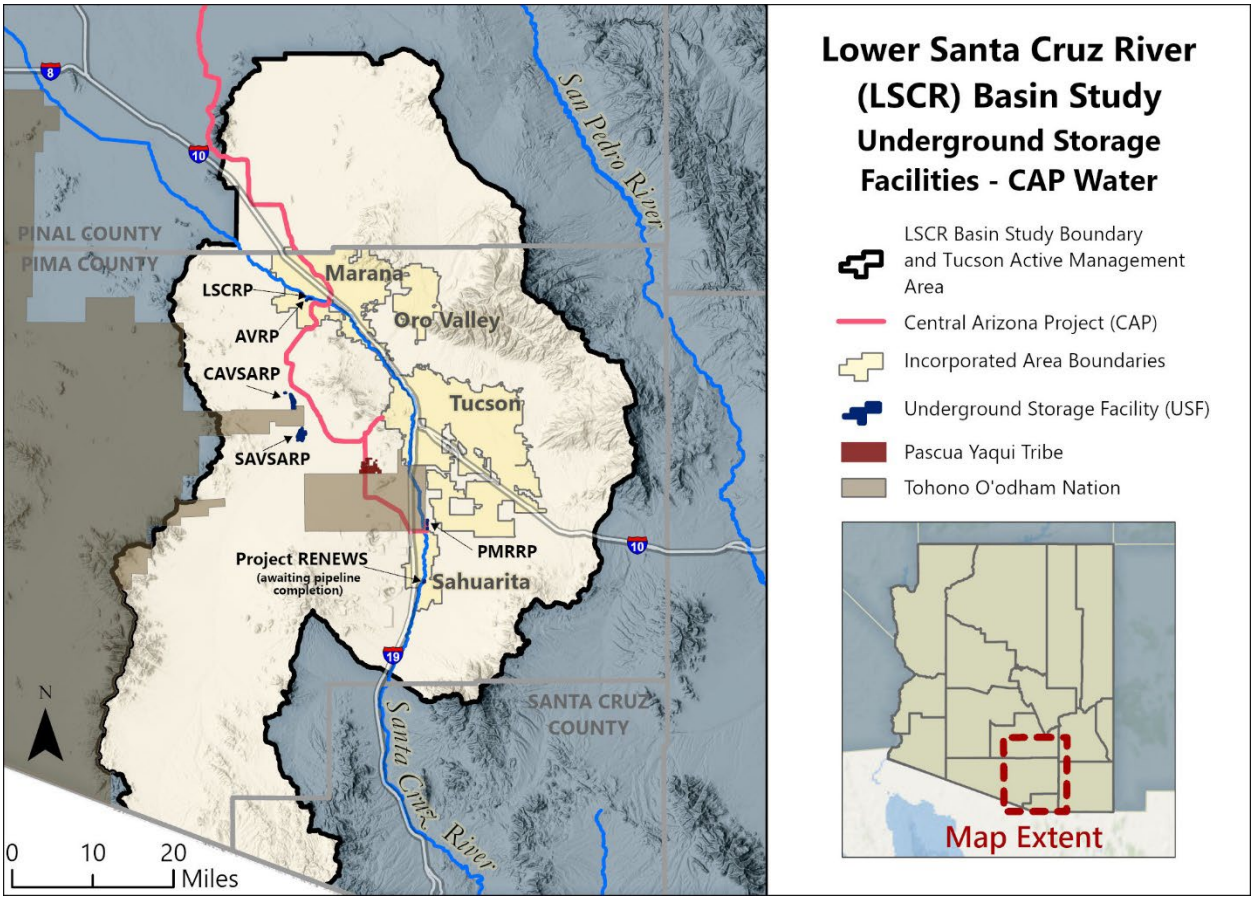


Figure 6-5 – Underground Storage Facilities storing CAP water in the LSCR Basin.

All of the previously described USFs operate under a "Constructed Underground Storage Facility Permit" issued by ADWR. This permit allows water to be stored in an aquifer using some type of constructed device, such as an injection well or percolation basin. Most of the Study Area's water reclamation plants also store reclaimed water using constructed facilities, with a few exceptions.

The Study Area's two metropolitan-scale Water Reclamation Facilities, Agua Nueva and Tres Rios, discharge into the adjacent Santa Cruz River. The stretch of the Santa Cruz River downstream of these WRFs is designated as a "Managed Underground Storage Facility", as shown in Figure 6-6. In this type of facility, water is discharged to a naturally transmissive area, such as a streambed, that allows the water to percolate into the aquifer without the assistance of a constructed device. A small portion of the SCR near downtown Tucson, called the "Santa Cruz River Heritage Project", recharges reclaimed water and also supports a riparian ecosystem.

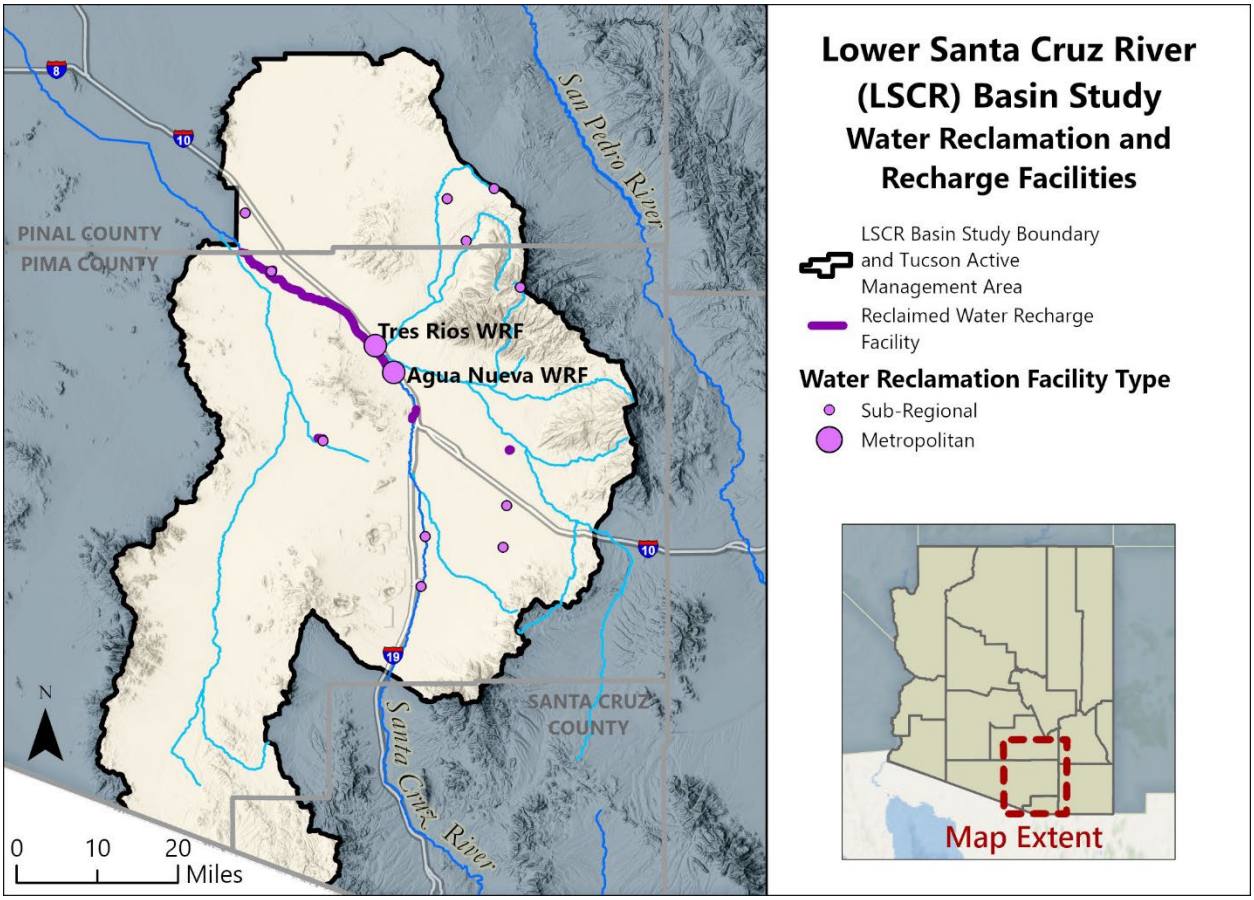


Figure 6-6 – Underground Storage Facilities storing reclaimed water in the LSCR Basin.

6.7 Groundwater Savings Facilities

Another way of "storing" renewable supplies is through a Groundwater Savings Facility, or GSF (Figure 6-7). Under this program, a user that may legally pump groundwater, such as a farm or an irrigation district, receives renewable supplies in lieu of groundwater. The GSF uses the renewable water supply on a gallon-for-gallon substitute basis, instead of the groundwater it would otherwise have pumped (Arizona Department of Water Resources, 1999). GSF permits have allowed CAP water to replace groundwater pumping for much of the agriculture within the LSCR Basin (Figure 6-8). The ASARCO mine is also designated as a GSF.

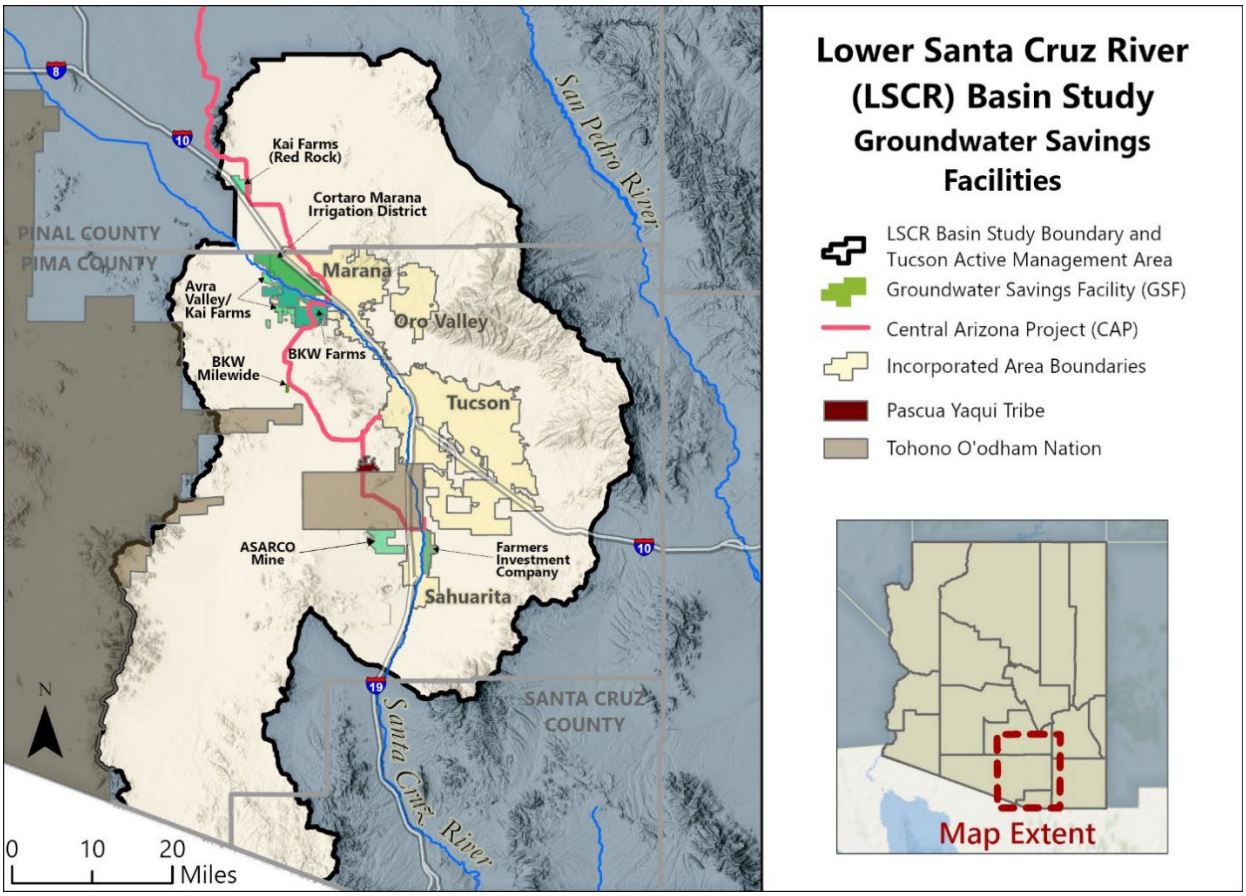


Figure 6-7 – Groundwater Savings Facilities in the LSCR Basin.

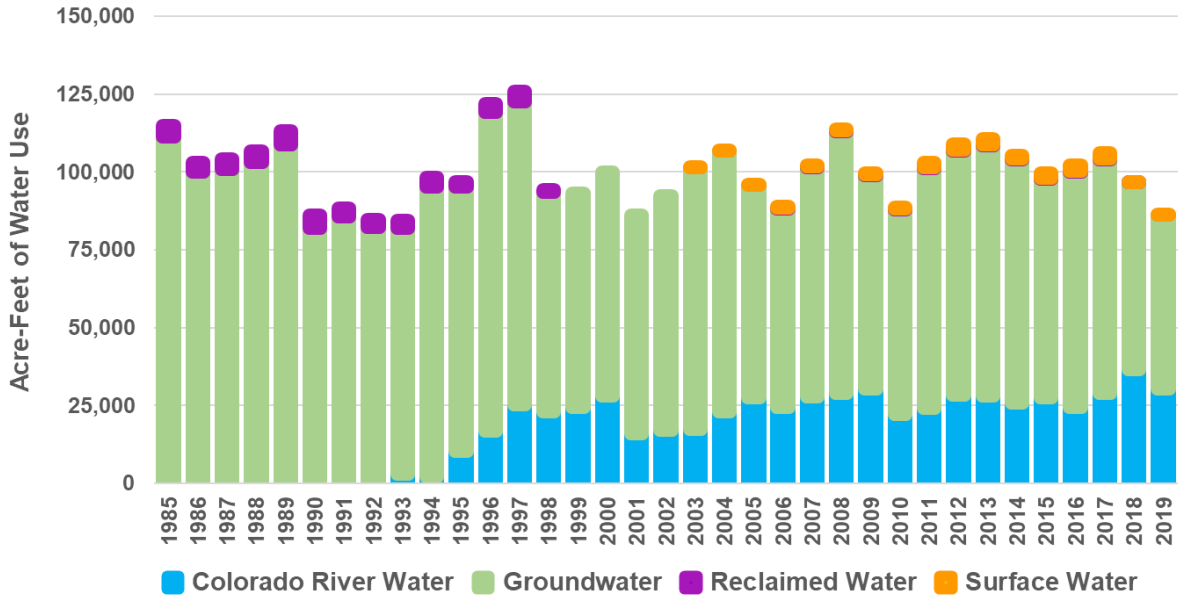


Figure 6-8 – Basin agricultural use by source, 1985 – 2019. Source: ADWR AMA Data Dashboard, https://new.azwater.gov/ama/ama-data, accessed 4/18/22.

As of 2019, the LSCR Basin had 25 recharge facilities with a total permitted storage capacity of 448,027 AF/year. Approximately 83 percent of the permitted capacity is at USFs (19 facilities) and the remaining 17 percent is at GSFs (six facilities) (Arizona Department of Water Resources, 2022a).

Most of the Groundwater Savings Facilities within the Study areas are agricultural operations that substitute CAP water for groundwater they are entitled to pump, in order to irrigate crops such as corn, cotton, alfalfa and wheat. These entities include the Cortaro-Marana Irrigation District, BKW Farms and Kai Farms. The FICO-Sahuarita Farm GSF uses CAP water instead of groundwater to irrigate many of its pecan orchards. The ASARCO GSF uses CAP water rather than groundwater to operate its mining facility.

6.8 Hydrologic Disconnect Between Location of Pumpage and Recharge

As discussed earlier, municipal water providers can replenish the amount of groundwater they have pumped in excess of the AWS rules by recharging renewable supplies in a USF or GSF. The location of recharge may be distant from pumping site, as long as it is within the same AMA. Additionally, entities with excess renewable supplies may store them in a USF or GSF in exchange for a Long-Term Storage Credit issued by ADWR (Arizona Department of Water Resources, n.d.). Long-Term Storage Credits may be “recovered” by pumping an equal volume of groundwater within the Active Management Area at a later date, potentially at a significant distance from the storage location.

While these regulations have incentivized the use of renewable supplies earlier and more extensively that might otherwise have occurred, they have also contributed to a phenomenon referred to as a “hydrologic disconnect” (Governor’s Water Augmentation, Innovation, and Conservation Council, Post-2025 AMAs Committee, 2020). This hydrologic disconnect is an important driver of the supply-demand imbalances within the Study Area.

Municipal water providers in the Study Area pump groundwater near population centers in the eastern parts of the LSCR Basin, many of which are at relatively high elevations and up-gradient in terms of the direction of groundwater flow (Figure 6-9). In contrast, the locations where water is replenished or stored tend to be at lower elevations, often close to the CAP canal and down-gradient relative in terms of the direction of groundwater flow. Thus, groundwater pumped up-gradient is replenished by renewable supplies in down-gradient locations, where it may eventually flow out of the Basin and become unavailable for use.

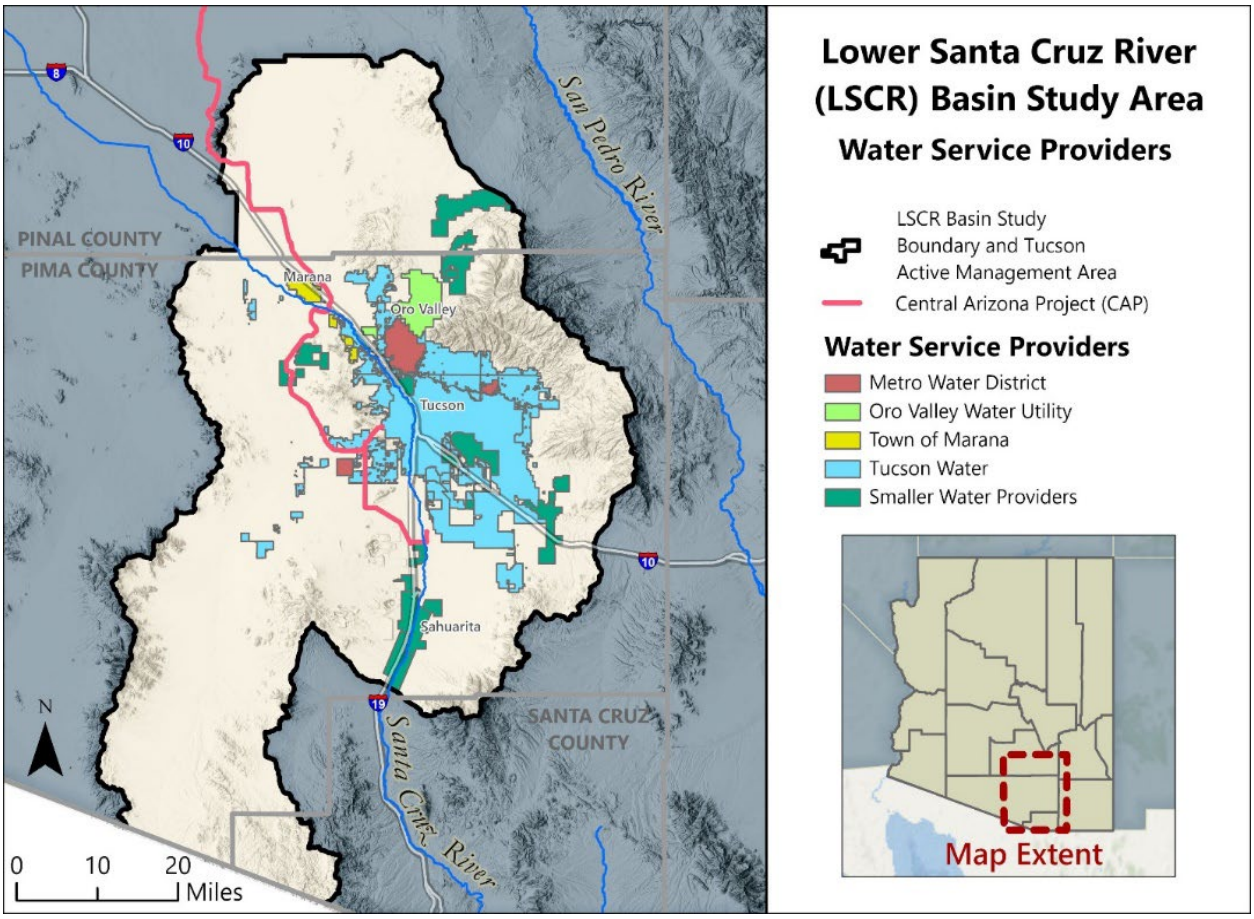


Figure 6-9 – Municipal water providers in the LSCR Basin.

Reclamation staff used the Tucson Active Management Area Regional Groundwater Model to develop maps of the changes in water levels between 1940 and 2004, the period when pumping greatly exceeded natural and artificial recharge, and between 2004 and 2020, when artificial and natural recharge exceeded pumping.

As Figure 6-10 shows, areas of supply-demand imbalance in Avra Valley (western portion of the LSCR Basin) have been eliminated, due to the construction and operation of CAVSARP and SAVSARP. In addition, much of the supply-demand imbalance in the central part of Tucson has been addressed due to a reduction in pumping in this area. However, areas of supply-demand imbalance associated with the hydrologic disconnect still exist in the: 1) northeastern Cañada del Oro area, 2) the Sabino Canyon and Tanque Verde area, 3) southeast Tucson and 4) the Green Valley/ Sahuarita areas. Groundwater modeling through 2060 projects further groundwater declines in each of these areas.

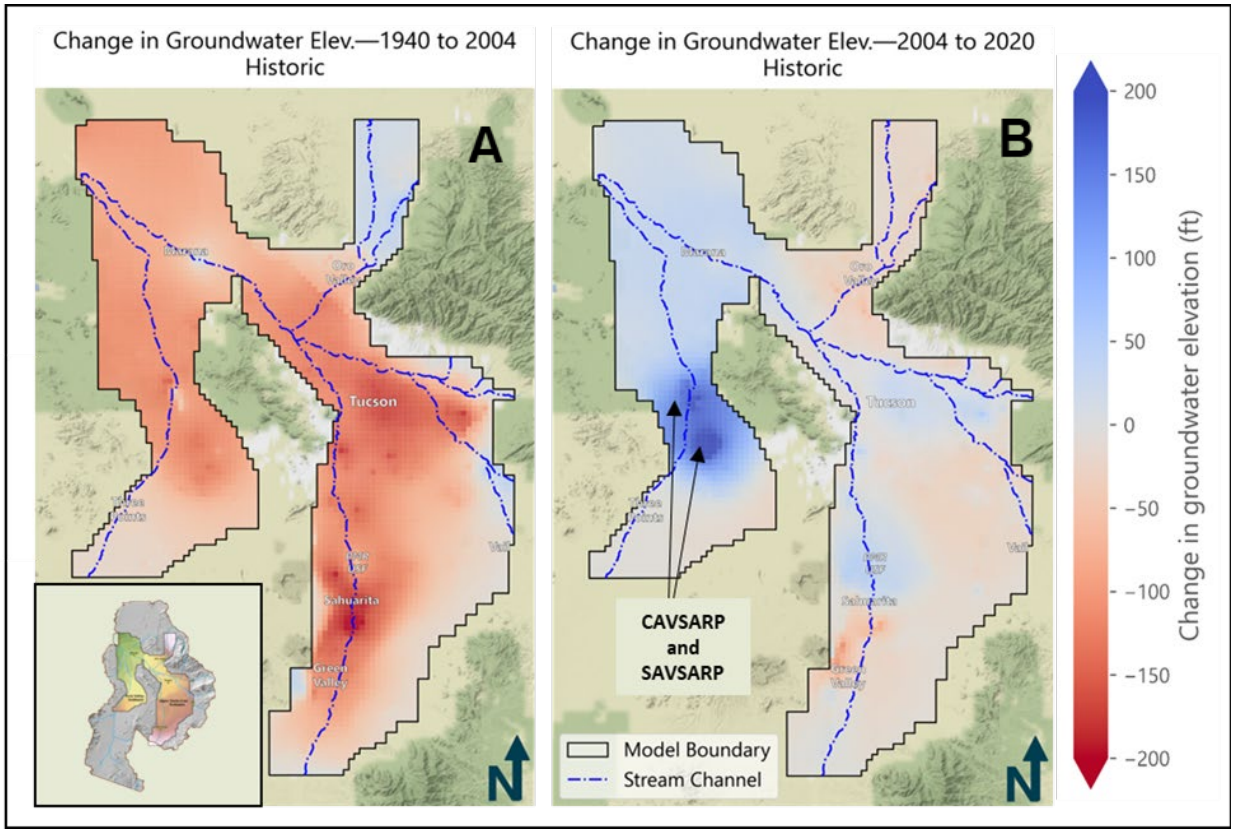


Figure 6-10 – Change in groundwater storage within the TAMA Groundwater Model Domain A: Change from 1940 – 2004, B: Change from 2004 to 2020.

Chapter 7 Climate and Surface Water Modeling (Hydroclimate Analysis)

7.1 Analysis Formulation

The Hydroclimate Analysis was created by linking the climate projections, a weather generator to simulate the seasonal climatic variability, and a surface water model to simulate the above-ground hydrologic processes typical in a semi-arid basin. A schematic of this process, with its connection to the Groundwater Modeling Analysis is shown in Figure 7-1.

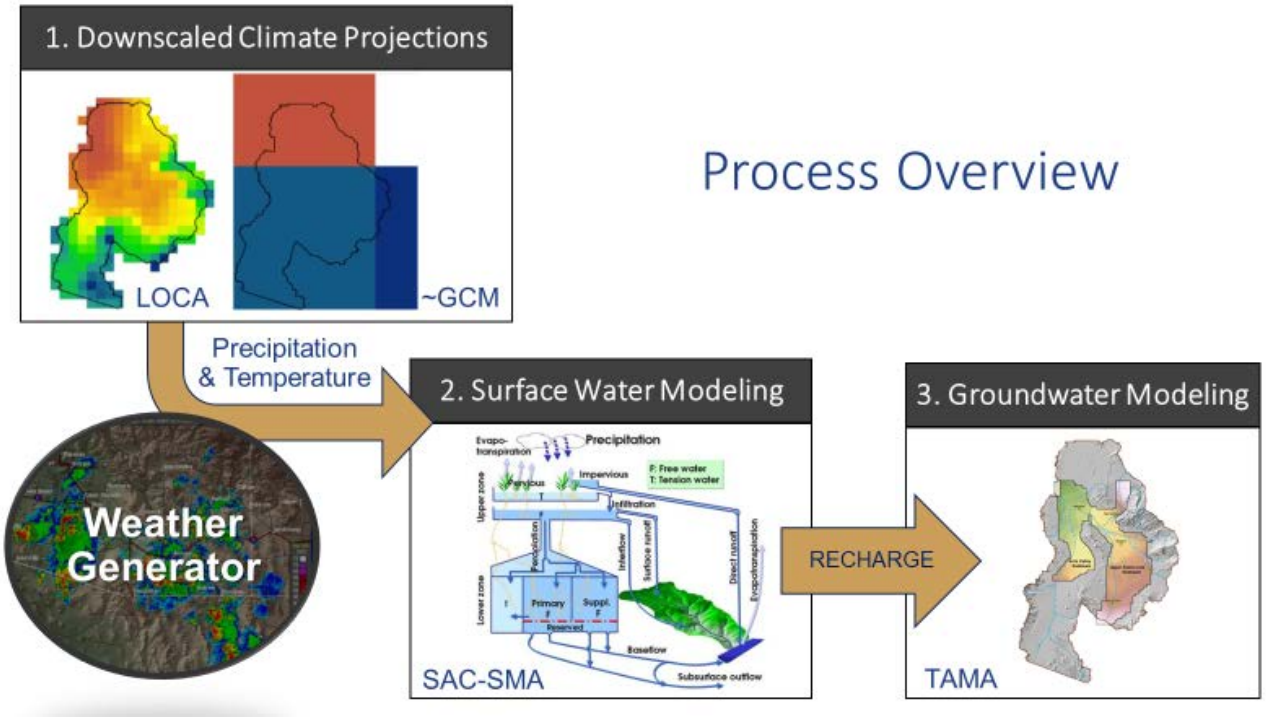


Figure 7-1 – Conceptual overview of basin-wide climate and surface water model inputs to the groundwater model.

As discussed in Chapter 2, the Study's Project Team made certain key decisions that shaped the climate and surface water modeling (Hydroclimate Analysis). The Project Team chose to concentrate on the range of risks to water users by concentrating on two climate scenarios. They requested a worse-case climate scenario, with a higher level of greenhouse gas emissions, where the impacts would represent the high end of the range. The use of the term worse-case (as opposed to worst-case) emphasizes that while this scenario would have greater impacts than the

best-case, it does not describe the most extreme possible outcomes of climate change. At the opposite end of the spectrum, the Project Team requested a best-case future climate, a scenario in which action is taken to reduce the rate of worldwide greenhouse gas emissions. This scenario represents conditions under which a lesser amount of adaptation would be necessary.

7.1.1. Climate analysis

The climate analysis evaluated projected changes in 30-year average temperature and precipitation, as well as several other analyses specific to the local climate and of importance to the Study Partners. As explained in Chapter 2, seasonality is a key feature of the LSCR Basin climate. There are essentially three distinct seasons: 1) monsoon season (approximately June – September), the winter wet season from approximately October through March, and 3) the dry foresummer, a dry period with low to no precipitation before the start of the next monsoon. Partners were interested in projected changes in the timing of seasonal onset and the length of each season.

Study Partners recognized the importance of intra-annual and inter-annual variability from a water management and environmental perspective and requested that this aspect of the climate be incorporated into the analysis. Also of concern, were changes in the magnitude and frequency of extreme events: heat waves, cold snaps, and flooding, all which have significant impacts on water delivery, public infrastructure, the environment, and human health. These concerns were formalized in the request for an analysis of specific climate metrics, listed below:

1) Changes in the intensity and frequency of temperature and precipitation.
2) Changes in the onset and demise of the monsoon season.
3) Changes in the onset of the dry period.

7.1.2. Climate scenario development

The formulation of climate scenarios began by developing assumptions about how the key drivers that impact the Earth's climate will vary in the future. While these sets of assumptions contain information besides levels of greenhouse gas emissions, they are commonly referred to as emissions scenarios. The Intergovernmental Panel on Climate Change (IPCC) sponsored the development of standardized emissions scenarios called Representative Concentration Pathways (RCPs). This Study used two RCPs from the IPCC 5th Assessment Report (AR5) to define future climate outcomes: RCP 4.5, which the Study used for the best-case scenario and RCP 8.5, used for the worse-case scenario, depicted in Figure 7-2.

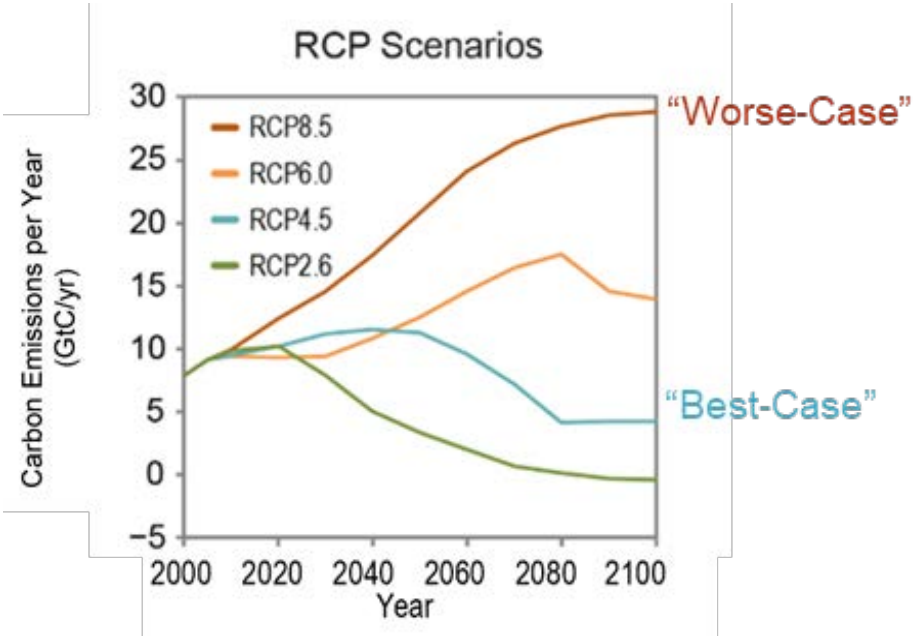


Figure 7-2 – Annual carbon emissions (gigatons of carbon per year) by RCP. Adapted from Hayhoe, K., J. et al., 2017: Climate models, scenarios, and projections. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I.

Global Climate Models (GCMs) use RCPs as input to simulate the Earth's response to changes in incoming and outgoing radiation. This Study uses long-term GCM simulation outputs driven by RCPs from the IPCC's standardized climate experiments known as the Coupled Model Intercomparison Project phase 5 (CMIP5). GCM outputs represent large-scale atmospheric and oceanic processes, with coarse model grid resolutions, typically on the order of 100 km laterally. More information on the details of the RCPs is provided in Section 3.1 of this report and Section 2.2 of the Study's Hydroclimate Memo.

7.1.3. Projection downscaling

The output of GCMs is too coarse (too large in scale) to use in an analysis of basin-scale hydrology. Therefore, the second step in climate scenario formulation was a "downscaling" process applied to the GCM output to infer additional spatial detail (Figure 7-3). Methods to generate these types of climate projections include statistical and dynamical downscaling.

Statistical downscaling is a widely used technique that is computationally straightforward and does not require intensive computing resources. A set of 32 GCM projections, statistically downscaled with the LOCA, or Locally Constructed Analogs method, run under RCP 4.5 and 8.5, is readily available to researchers. To date, all Reclamation Basin Studies have employed statistically downscaled climate projections.

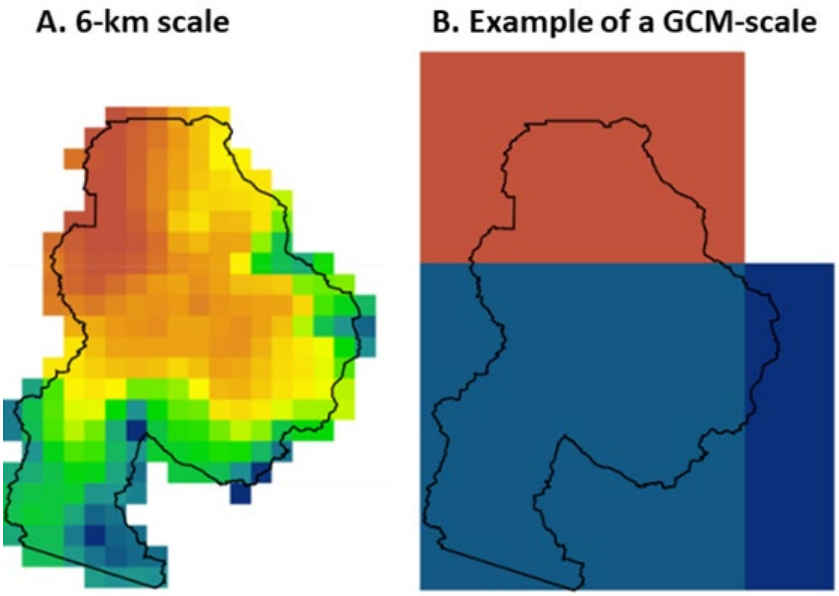


Figure 7-3 – Example of resolutions from a downscaled projection (left) and a Global Climate Model projection (right). These use the same Global Climate Model data.

While statistically downscaled climate projections are readily available and widely used, they are constrained by their reliance on historical observations to project the future. In other words, this technique assumes that the range and distribution of hydrologic events that have occurred in the past will be maintained in the future. In fact, climate scientists have observed that the future variability of hydrologic processes may be fundamentally different from the past (Milly, et al., 2008).

To account for this risk, the Project Team requested the inclusion of a climate projection that used a physically based method of downscaling, called dynamical downscaling. Dynamical downscaling uses the GCM output as the input to a Regional Climate Model (RCM) that simulates atmospheric processes that take place at a finer scale (in this case, 25 kilometers). Using a Regional Climate Model improves the simulation of local topography, which is poorly represented in Global Climate Models (Feser, Rockel, Von Storch, Winterfeldt, & Zahn, 2011). The numerical simulation of actual atmospheric processes allows dynamic downscaling to project conditions outside of the historical climate record.

Despite these advantages, the large amount of computing resources required by dynamical downscaling limits the number of GCMs projections available, as well as the number of emissions scenarios for each GCM and the spatial resolution of projection. These constraints explain the preference for statistically downscaled climate projections, despite their limitations. For this Study, the selected dynamically downscaled GCM projection was only available under the RCP 8.5 emissions scenario.

7.1.4. Selection of downscaled climate projections

From a local water resource manager's perspective, the onset date of the monsoon is a critical consideration. A review of available dynamically downscaled GCMs showed that the most accurate simulation of monsoon timing in the Study Area was from the low resolution (LR) Max-Planck-Institute Earth System Model run (MPI-ESM-LR) (Giorgetta et al., 2013), downscaled using the Weather Research and Forecasting Model (WRF). This downscaled simulation is referred to as "WRF-MPI" throughout this report. Only the higher emissions scenario was available for this GCM/RCM combination.

Without a WRF-MPI simulation available for the best-case climate scenario, the Study used a statistically downscaled MPI-ESM medium resolution GCM output. Statistical downscaling was performed using the Localized Constructed Analogs, or LOCA method (Pierce, Cayan, & Thrasher, 2014). This GCM was the same model used for the worse-case scenario, but using the run identified as mid resolution (MR). This projection predicts a future that is wetter and cooler than the worse-case scenario.

Due to the natural variability of the climate, it was necessary to compare time periods, rather than individual years, to detect changes in precipitation and temperature. The National Weather Service uses a period of thirty years to calculate a "climate normal." Figure 7-4 depicts the 30-year time periods used for the Hydroclimate Analysis. The analysis compared simulations of a base historical period (1970-1999), to a near future period of 2020-2049, also referred to as the "2030s", and a far future period of 2050-2079, or "2060s". While the groundwater modeling in the Study extends to 2060 to align with the Partners' requests, the Hydroclimate Analysis was not restricted by assumptions on Colorado River operations and thus could be examined for two thirty-year periods.

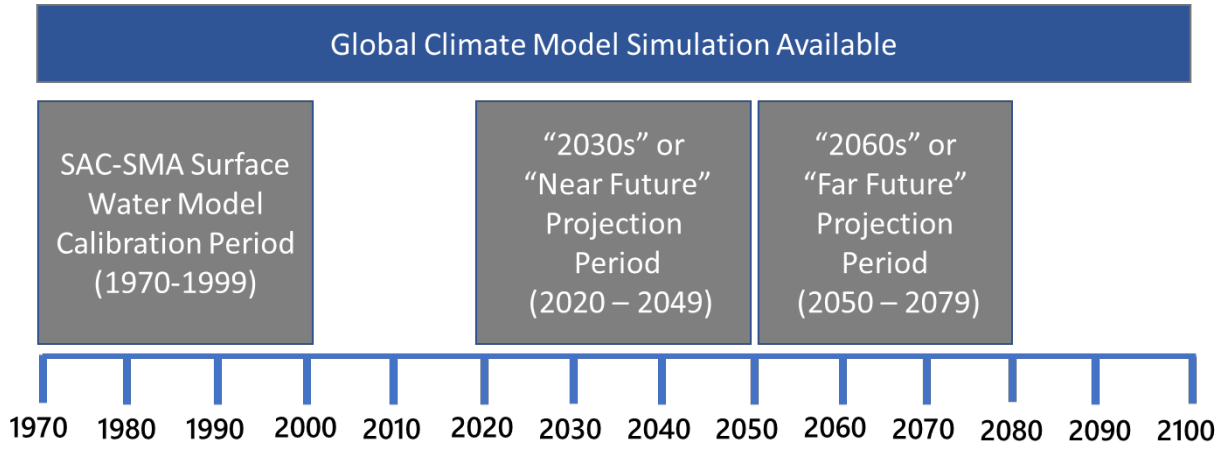


Figure 7-4 – Diagram of Hydroclimate Analysis time periods.

7.1.5. Weather generator

The southern Arizona climate is characterized by a high degree of variability (Sheppard, Comrie, Packin, Angersbach, & Hughes, 2002), and the Study Partners requested that Reclamation incorporate this variability into the analysis of climate impacts. To this end Reclamation staff developed a customized computer program called a probabilistic "weather generator" (Figure 7-5). A weather generator is a statistical model used to create many sequences of weather variables, such as precipitation and temperature, while maintaining selected statistical characteristics of an original data set. In this case, the weather generator was designed to reproduce the transition probabilities between wet and dry days for each of three seasons. The weather generator was used to produce a group, or ensemble, of 100 temperature and precipitation time series for each 30-year period. Together, the ensemble of 100 time series represents a plausible range of rainfall and temperature values, daily patterns, and seasonality at a time scale appropriate for driving the surface water model. Samples of the weather-generated results for changes in streamflow by season are shown in Figure 4-5.

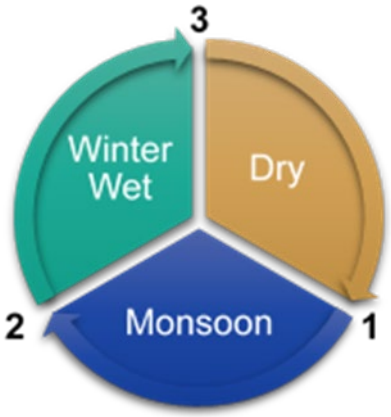


Figure 7 5 – Conceptual diagram of the seasonal weather generator.

7.1.6. Surface water modeling

Development of the projected temperature and precipitation time-series ensembles provided the necessary input for the next stage of the Hydroclimate Analysis, surface water modeling. Because initial hydrologic modeling using the Variable Infiltration Capacity (VIC) model did not produce acceptable results, further efforts were required to identify a surface water model that properly simulated the hydrologic properties of a semi-arid basin.

An alternative surface water model, the Sacramento Soil-Moisture Accounting Model (SAC-SMA), was selected for its performance in semi-arid areas, as well as for its calibration for the LSCR Basin and contributing watersheds by the National Weather Service's Colorado Basin River Forecast Center (CBRFC). The SAC-SMA model simulates mechanisms that drive water movement through the soil column (surface runoff, infiltration, interflow, percolation, storage, evapotranspiration, and baseflow) while preserving the water balance (Figure 7-6). The SNOW-17 model was also included in elevation zones where snowfall was important.

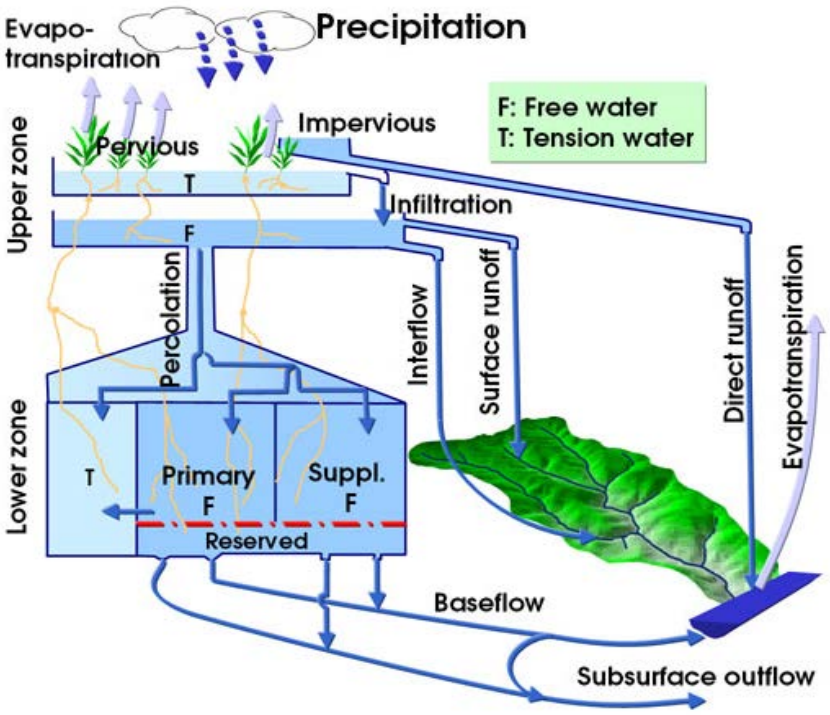


Figure 7-5 – Schematic Diagram of the Sacramento Soil Moisture Accounting Model (SAC-SMA) (University of California, Irvine. http://chrs.web.uci.edu/research/hydrologic_predictions/activities07.html)

The SAC-SMA model is part of the CBRFC's operational streamflow modeling system and focuses on simulating the antecedent soil conditions that drive the runoff response. It calculates the wetness of the soil just before the storm event, so the resulting amount of runoff varies according to the moisture content of the soil. The model version available at the time of this Study was calibrated from 1970-1999.

7.1.7. Spatial domain of analysis

In order to reflect the impact of climate on all the inflows to the LSCR Basin, results were developed for an area that contained the major upstream drainage basins. The northwest portion of the LSCR Basin was excluded from the Hydroclimate Analysis, as it drains out of the LSCR Basin further north into Pinal County. The outline of the surface water modeling area relative to the LSCR Basin boundaries is shown in Figure 7-7.

Results showed that all models and climate scenarios consistently identified increases in temperature through time. Increases were larger under the worse-case climate, which represents higher future greenhouse gas emissions. Precipitation changes were less consistent than temperature changes. The best-case climate scenario showed relatively minimal change in seasonal precipitation; in the worse-case climate scenario, total precipitation decreased in the monsoon and winter wet seasons.

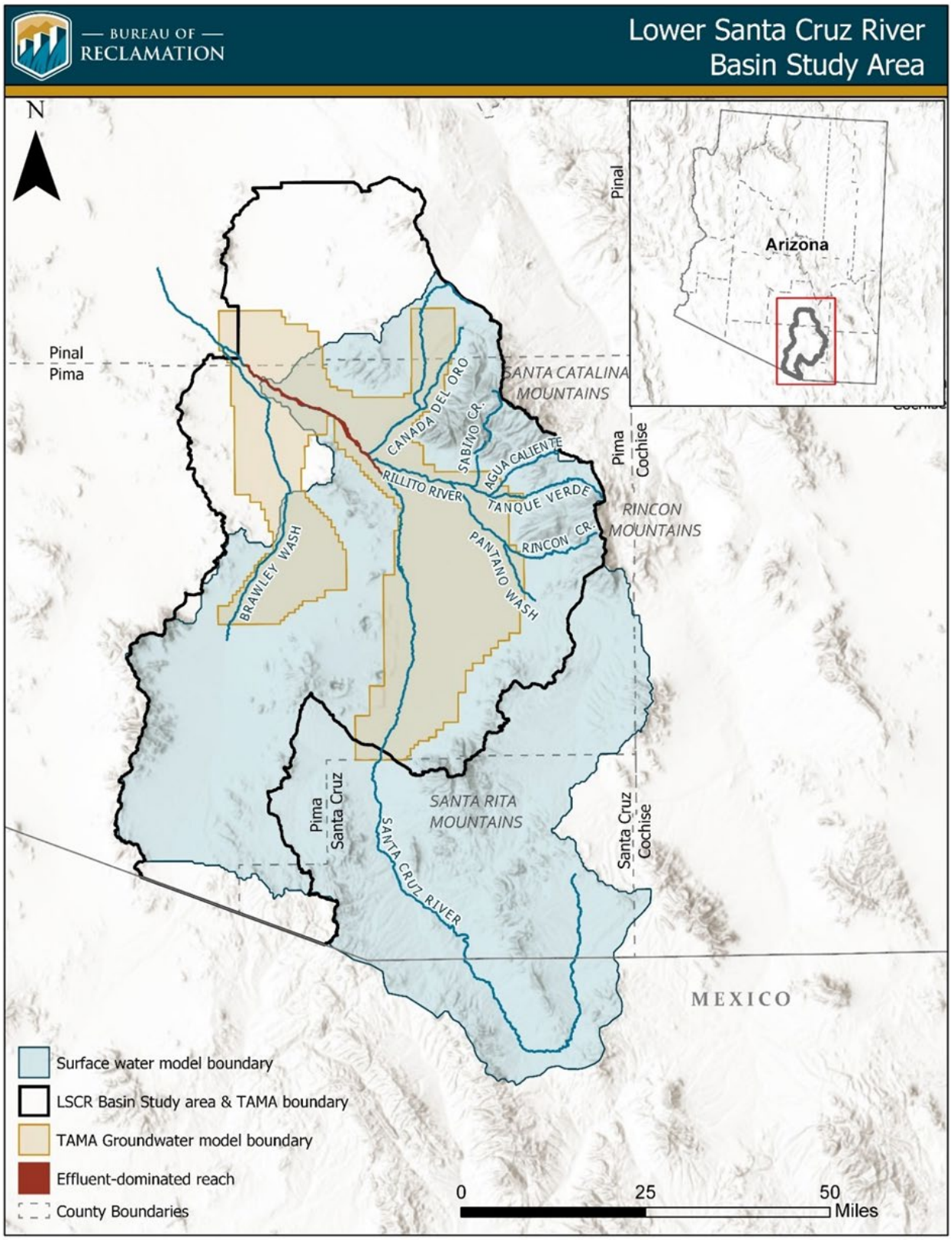


Figure 7-6 – Extent of surface water modeling using SAC-SMA model (green polygon) in comparison to the Tucson Active Management Area.

7.2 Climate Analysis Results

7.2.1. Average temperature and precipitation

The time-series from each of the best and worse case climate projections were input into the weather generator to create two ensembles of 100 plausible realizations of temperature and precipitation. These ensembles simulated the future variability of the climate within the SAC-SMA model domain under the Study's two climate projections. Projected changes from the model calibration period of 1970-1999 are presented in Table 7-1.

Table 7-1 – Hydroclimate Results Summary

Statistic	Best-Case 2020-2049	Best-Case 2050-2079	Worse-Case 2020-2049	Worse-Case 2050-2079
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″
Change in Average Dry Season Precipitation	-0.27″	-0.55″	0.28″	0.05″
Precipitation RSD* compared to 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

Changes in average temperature and precipitation from calibration period 1970 – 1999 under the best and worse climate cases, for the periods 2020 – 2049 (2030s) and 2050 – 2079 (2060s).

7.2.2. Extreme temperature and precipitation

Extreme temperatures increased in both scenarios. Extreme temperatures increased consistently in future periods in every season, with the largest increases occurring in the dry and monsoon seasons (Figure 7-8), which are the spring and summer months when extreme temperatures pose the largest public health and environmental risk. See the Hydroclimate Technical Analysis for more detailed information on changes in temperature and precipitation extremes.

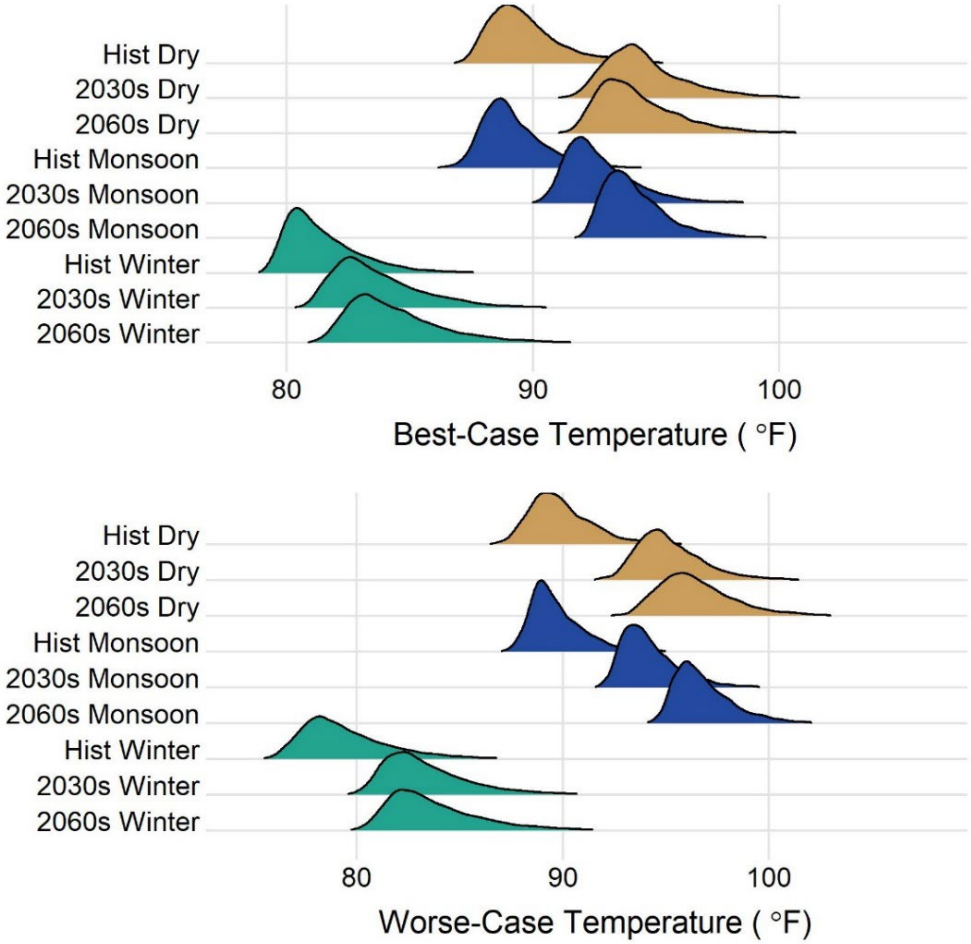


Figure 7-7 – Projected changes in extreme (top 10% of distribution) for temperature (compared to 1970 -1999 historic period).

Detection of changes in extreme precipitation events from daily, gridded modeled outputs was challenging because monsoon events are often short but intense, occur over small areas, and are highly variable in time and space. Despite these limitations, both the weather generated best- and worse-case scenarios included changes in extreme precipitation events (Figure 7-9). Here, extreme precipitation was defined as daily rainy-day precipitation that exceeds the 90th percentile in that season, from all the years within a weather generated 30-year simulation.

Changes in the central tendency across the ensembles of extreme precipitation were not consistent, although increases in extreme winter precipitation were suggested by both the mean and the median statistics. The more severe ensemble extremes (the 95th percentile) consistently increased through time in both the monsoon and winter seasons. Maximum values represent less than 1% of extremes and can exceed 4 inches per hour in the worse-case scenario.

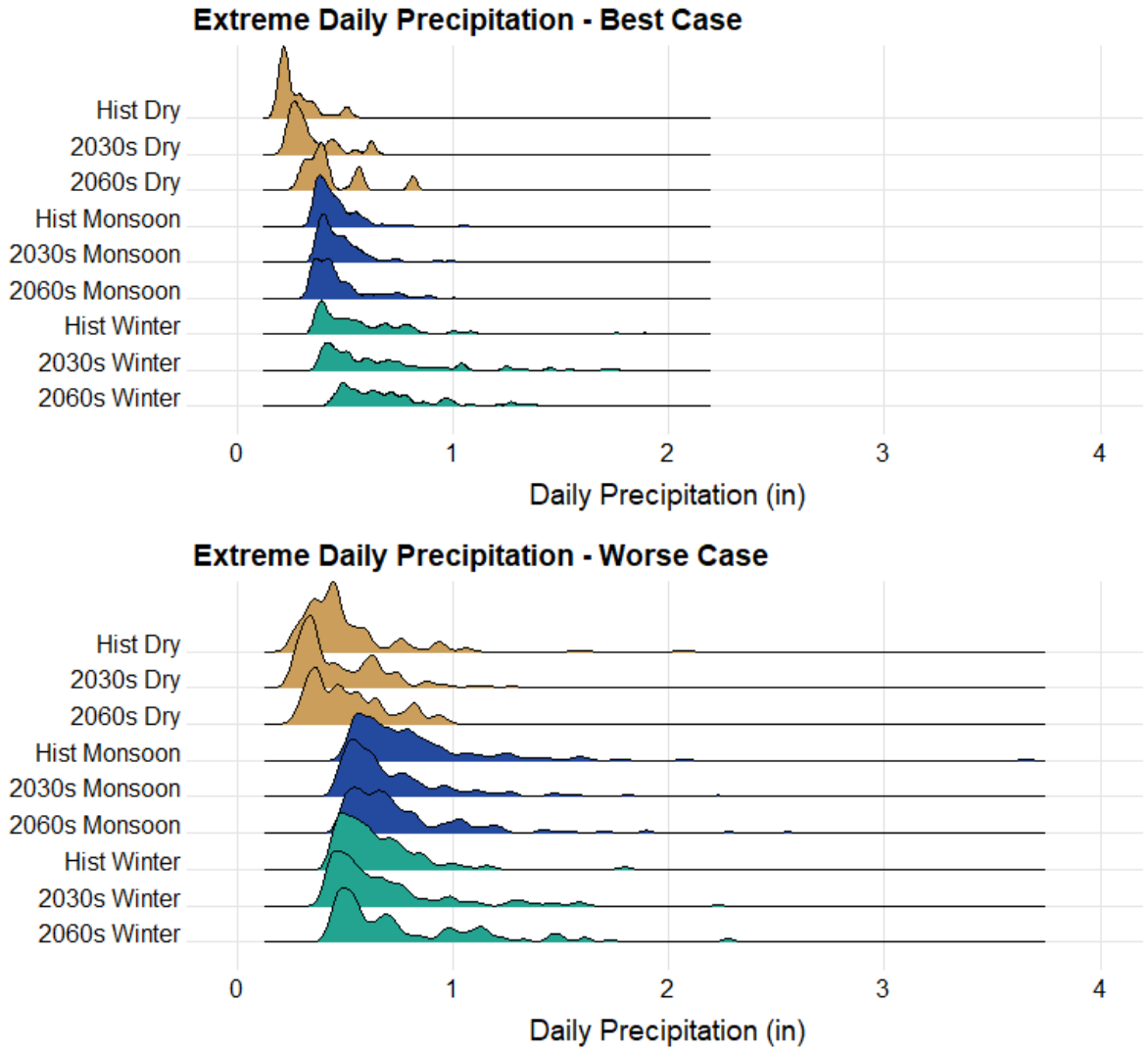


Figure 7-8 – Projected Changes in extreme (top 10% of distribution) for precipitation (compared to 1970 -1999 historic period).

Monsoon onset is an important climate feature both for vegetation health and for a reliably observed reduction in municipal water demand. For the best-case scenario, the median onset dates advance by two days for each future period, to July 3 for the near future and July 1 for the far future. Although small, the shift in the median date of monsoon onset and the tightening range of onset timing, drive an earlier start to the best-case monsoon season (Figure 7-10). The worse-case scenario did not show a trend in monsoon onset date for the future periods, with a later median onset date of June 29 in the near future and returning to a median date of June 22 in the far future. The worse-case climate scenario therefore did not provide earlier relief to the dry season, as projected in the best-case.

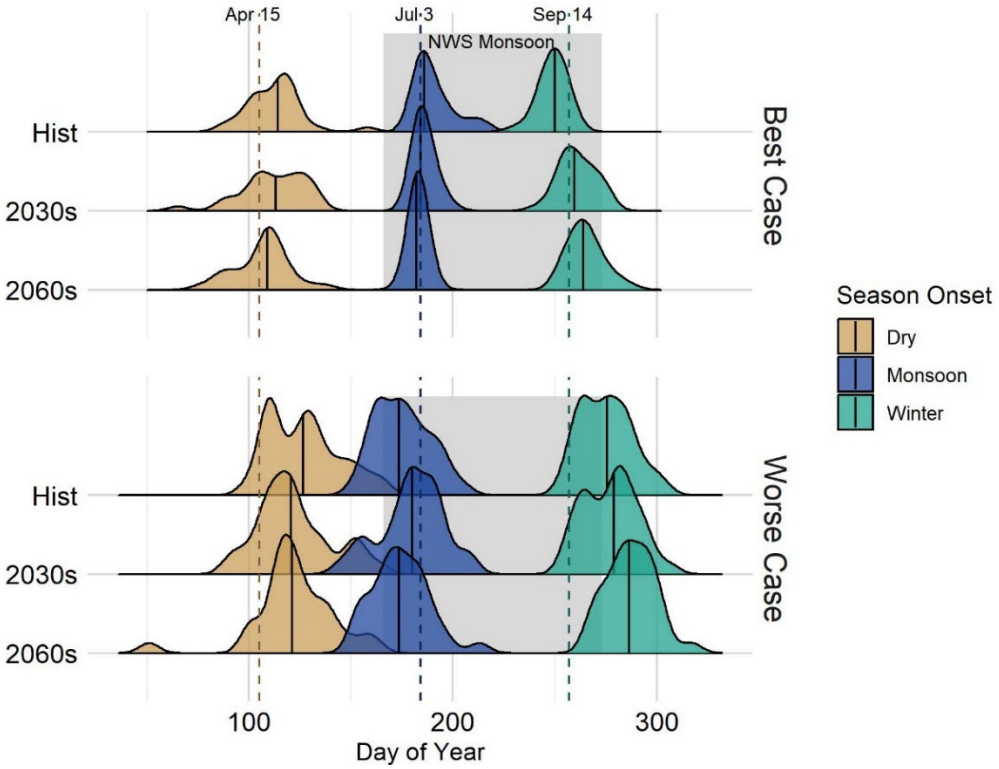
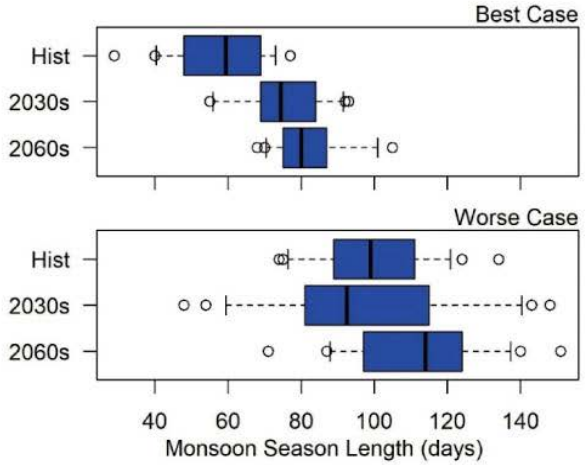


Figure 7-9 – Distribution of seasonal onset day of the year for the best-case (top) and worse-case (bottom) scenarios. Black solid lines represent median onset day for each distribution; dashed lines represent select literature values. Gray shading indicates the NWS monsoon period of June 15 through September 30.

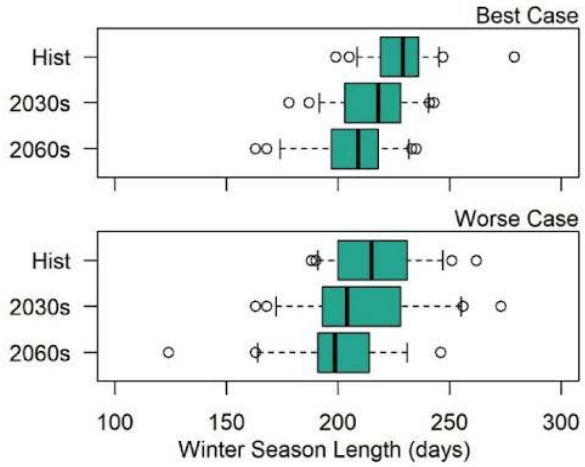
7.2.3. Length of seasons

The lengthening of the monsoon season and changes in the dry season onset resulted in a consistent shift toward shorter winter wet periods under both scenarios (Figure 7-11, middle panel). In both projected futures, the dry season begins slightly earlier in the year (Figure 7-11, bottom panel).



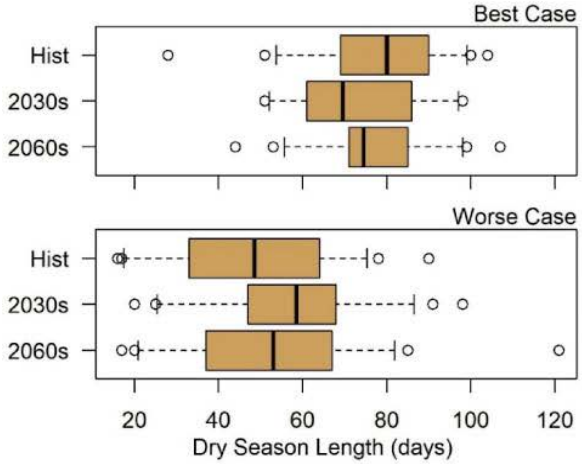
	5th perc.	Median	95th perc.
Hist.	40	60	73
2030s	56	75	92
2060s	70	80	101

	5th perc.	Median	95th perc.
Hist.	76	99	121
2030s	59	93	140
2060s	88	114	137



	5th perc.	Median	95th perc.
Hist.	209	229	245
2030s	192	218	241
2060s	174	209	232

	5th perc.	Median	95th perc.
Hist.	191	215	247
2030s	172	204	255
2060s	164	198	231



	5th perc.	Median	95th perc.
Hist.	54	80	99
2030s	52	70	97
2060s	56	75	98

Figure 7-10 – Distribution and statistics of season lengths (in days) by period for the best-case (top) and worse-case (bottom) climate scenarios. Monsoon is in blue, winter wet is in green, dry season is in brown. Whiskers represent 5th/95th percentile of data.

The combined changes in the starts of the dry and monsoon seasons resulted in offsetting effects on the length of the dry season over time (Figure 7-10). Generally, the best-case scenario exhibited a shorter dry season in the future than the modeled historical period and the worse-case scenario projected an increase in dry season length. More detail is provided in the Hydroclimate Analysis Technical Memorandum.

7.2.4. Climate analysis conclusions

The historical climate in the Lower Santa Cruz River Basin varies greatly from year to year. Future projections under the scenarios developed here consistently identify increases in annual temperature. Increases are larger in the worse-case scenario.

The best-case scenario suggests relatively minimal change in seasonal precipitation. The worse-case scenario indicates decreases in total annual and seasonal precipitation. Interannual variability in precipitation increases under both scenarios.

7.3 Surface Water Modeling Results

7.3.1. Change in seasonal streamflow

Changes in monsoon and winter wet streamflow, presented as a fraction of the simulated historical period flow, are presented in Figure 7-12 and Figure 7-13. Note that these figures have scales tailored to highlight the detail within each season’s range of values.

Changes in the total monsoon season streamflow result from a combination of changes in the length of the season, storm intensity, and frequency of storms. In the near future, the best-case scenario had a consistently longer monsoon season resulting in more total flow over this season. Streamflow decreased in some sub-basins in the far future, particularly in sub-basins that experience larger increases in no flow days.

Under the worse-case scenario, the near future appeared to be a transition time with generally shorter, but highly variable, monsoon season length. The changes in monsoon seasonality resulted in high variability in monsoonal rainfall totals from year to year, with an overall decreased median streamflow.

In the far future, the longer monsoon season resulted in an apparent recovery of streamflow. However, streamflow events were less frequent and likely more extreme, consistent with the increase in individual large precipitation events projected under this scenario.

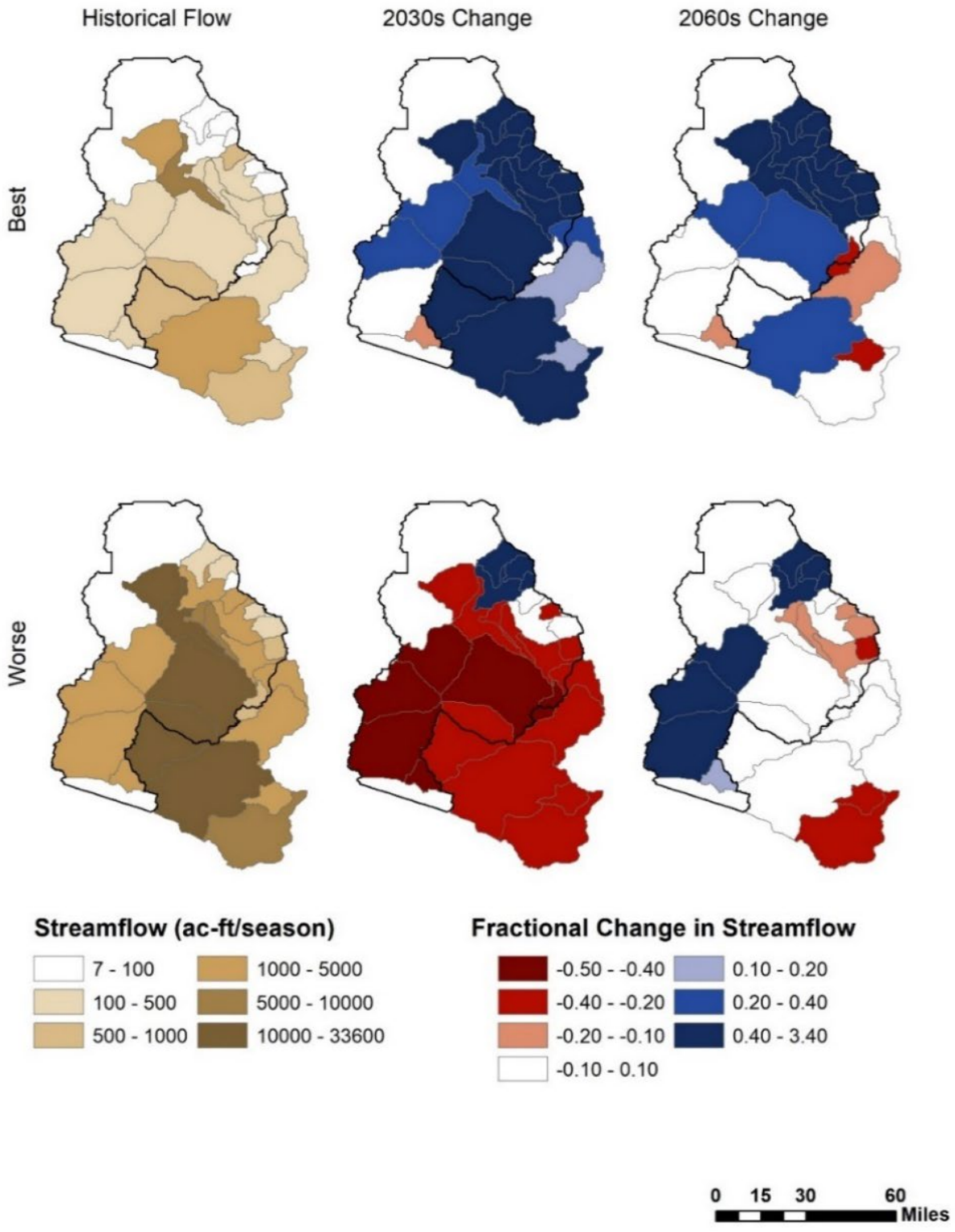


Figure 7-11 – Median of the ensemble 30-year average monsoon season total streamflow from the modeled historical period (tan) for each scenario, and projected change from historical (red for negative and blue for positive change respectively) in streamflow for the best- and worse-case climate scenarios. Note coverage is only over the areas identified as subbasins in Figure 7-14.

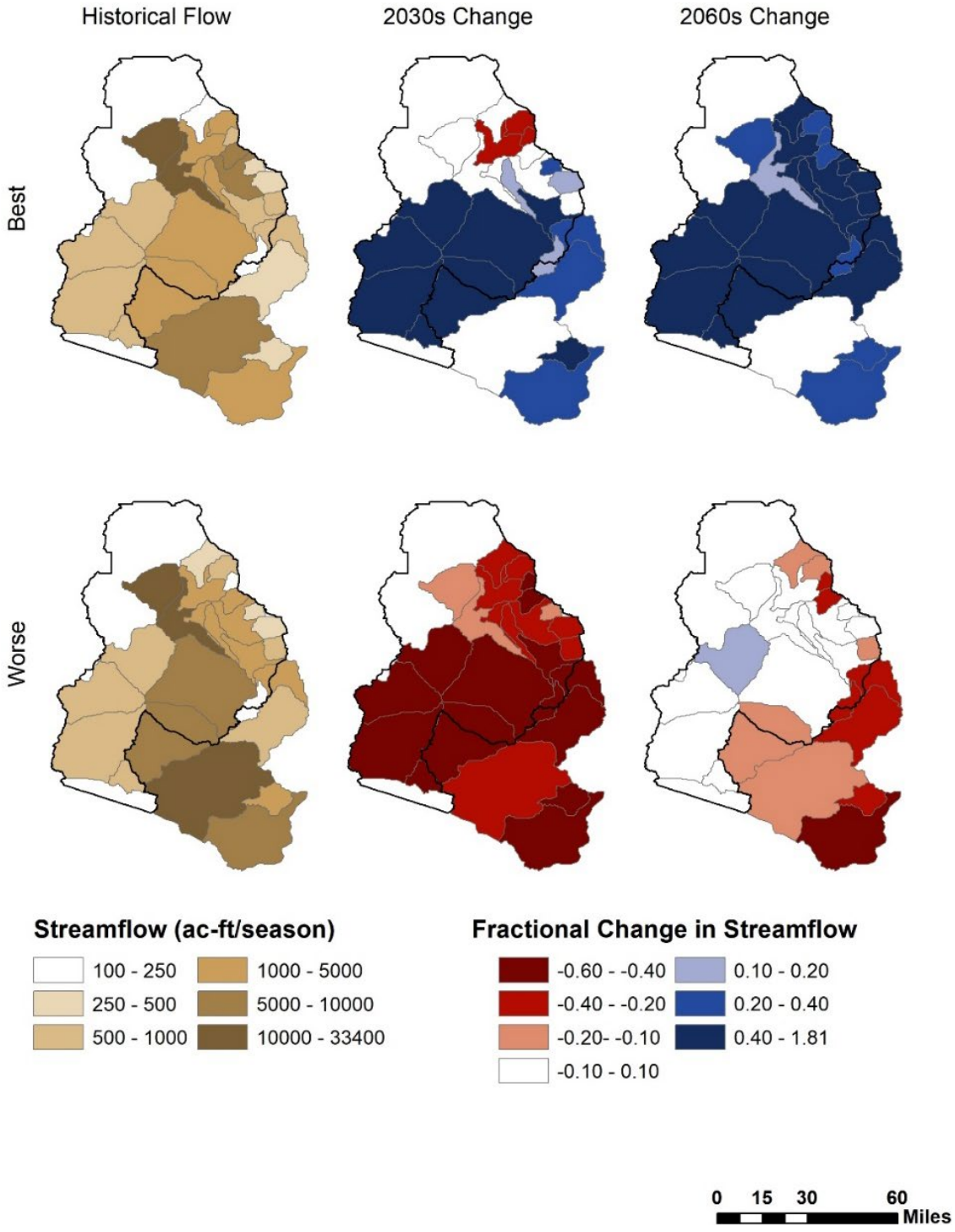


Figure 7-12 – Median of the ensemble 30-year average winter wet season total streamflow from the modeled historical period (tan) for each scenario, and projected change from historical (red for negative and blue for positive change respectively) in streamflow for the best- and worse-case climate scenarios.

The winter season was projected to shorten under both climate scenarios. In the best-case scenario, the large events got consistently larger into the future, compensating for the shortening of the winter season. In the worse-case scenario, total winter precipitation was lower in both future periods and translated to less overall streamflow. In the near future, there was a relatively larger fractional decrease in streamflow due to a shorter season and lack of large precipitation events to compensate for the shortened season. In the far future, more extreme precipitation likely results in some streamflow recovery.

7.3.2. Changes in dry days

Historically, the surface water systems in the surface water model boundary area are overwhelmingly ephemeral (flow only in response to rainfall) or intermittent, meaning that few locations in the area have streamflow all year long. A dry day is defined as any day with no flow modeled at the subbasin outlet.

Figure 7-14 illustrates the ephemeral nature of the area, displaying the number of dry days at gaged points along a channel, calculated as average of the ensemble median over the historic 30-year period, for the worse-case scenario. Thus, year-round flow, as seen for the Cienega Creek (CNEA3), highlighted in red, may be a very small amount of modeled flow. It is also important to note that locations downstream of the wastewater treatment plants (CSCA3 and SCTA3), highlighted in purple, receive continuous reclaimed water contributions, and thus also flow year-round (perennial).

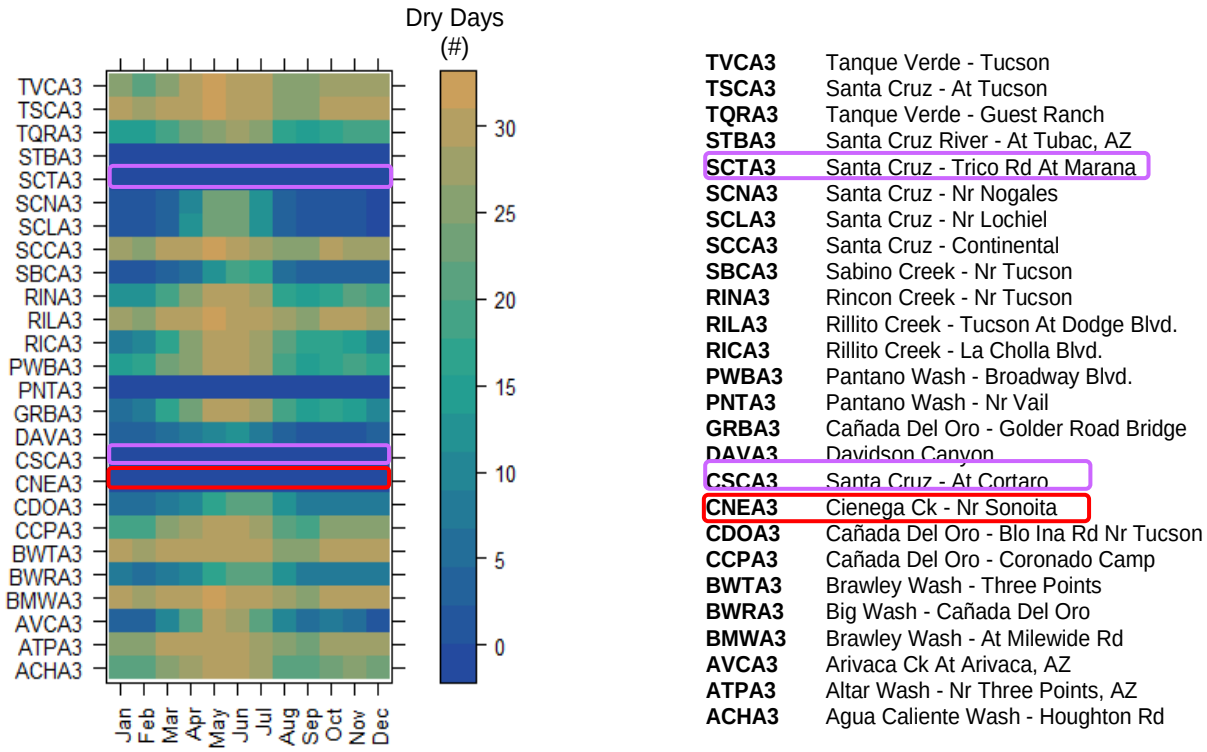
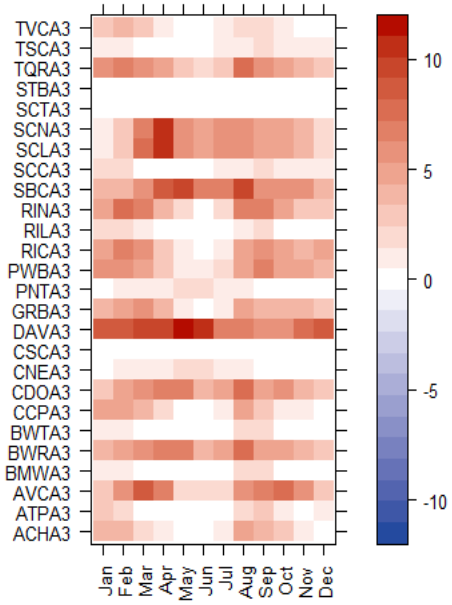


Figure 7-13 – The number of modeled historical dry days per month under the worse-case scenario for each SAC-SMA subbasin, as defined. Tan colors indicate months when the stream is dry the entire month, while the dark blue represents streams that flow the whole month.

The change in the number of streamflow dry days between the historical period and modeled future periods under the worse-case scenario is presented in Figure 7-15 for the near future, and Figure 7-16 for the far future. The largest increases in no-flow days consistently occurred in headwaters subbasins, such as the Sabino Creek and the Santa Cruz near Nogales. These no-flow day increases tended to be largest where the modeled subbasins are not fully perennial streams but have at least some flowing days every month.

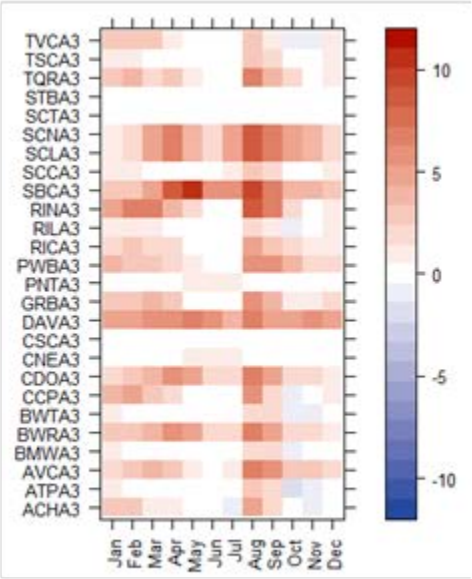
This change suggests that these transitional basins may experience longer no-flow periods in the future. Larger increases in no-flow days consistently occur in the spring during the transition to the dry season, but also occur in August during the monsoon season. The later onset of the monsoon season in the near future relative to the far future is likely the reason why there are more dry days in these transition months in the earlier period. Analyses of changes in dry days for the best-case scenario are available in the Hydroclimate Analysis, Appendix B.



2030s - Top 5 increases in dry days

month	# days
Davidson Canyon (DAVA3)	May	12
Davidson Canyon (DAVA3)	June	11
Santa Cruz near Nogales (SCNA3)	April	10
Santa Cruz near Lochiel (SCLA3)	April	10
Sabino Creek (SBCA3)	May	10

Figure 7-14 – Change in the number of dry days per month in the near future for each subbasin under the worse-case climate scenario. The table to the right provides details on the subbasins and months with the top five increases in dry days under near-future conditions.



2060s - Top 5 increases in dry days

month	# days
Sabino Creek (SBCA3)	May	10
Sabino Creek (SBCA3)	August	10
Sabino Creek (SBCA3)	April	9
Santa Cruz near Lochiel (SCLA3)	August	9
Santa Cruz near Nogales (SCNA3)	August	9

Figure 7-15 – Change in the number of dry days per month in the far future for each subbasin under the worse-case scenario. The table to the right provides details on the subbasins and months with the top five increases in dry days under far-future conditions.

7.3.3. Soil moisture

In addition to its role in streamflow generation, soil moisture supports upland vegetation communities and determines the amount of additional water needed for irrigation. SAC-SMA calculates sub-daily soil moisture for each elevation zone. Calculations include two soil layers: a fast-responding upper layer (about 8 inches) and a deeper (lower) layer that can extend to 60 inches, depending on the soil depth.

Each layer is broken into tension and free water. Free water is controlled by gravity and can percolate to deeper soil layers. From the soil, it can return to the stream either as interflow from shallow layers or as baseflow from deeper layers. Tension water is held tightly in the soil by tension processes and can only be removed through evapotranspiration or diffusion. Changes in soil moisture generally mirror changes in precipitation under future climate scenarios.

For the best-case scenario, soil moisture generally increased in the fall and winter, particularly in the far future, and decreased in the far future monsoon season months of July and August (see Appendix C and Figure C2 of the Hydroclimate Analysis).

The worse-case scenario was drier, with nearly all soil water zones indicating decreases in soil moisture in both the near and far future. The exceptions were the transitions to the dry season in May and the fall months in the far future, which suggest wetter soils during these periods. These soil moisture increases tended to occur in the lower-elevation, drier, portions of the area where a large percentage change may represent small increases in moisture (Figure 7-17).

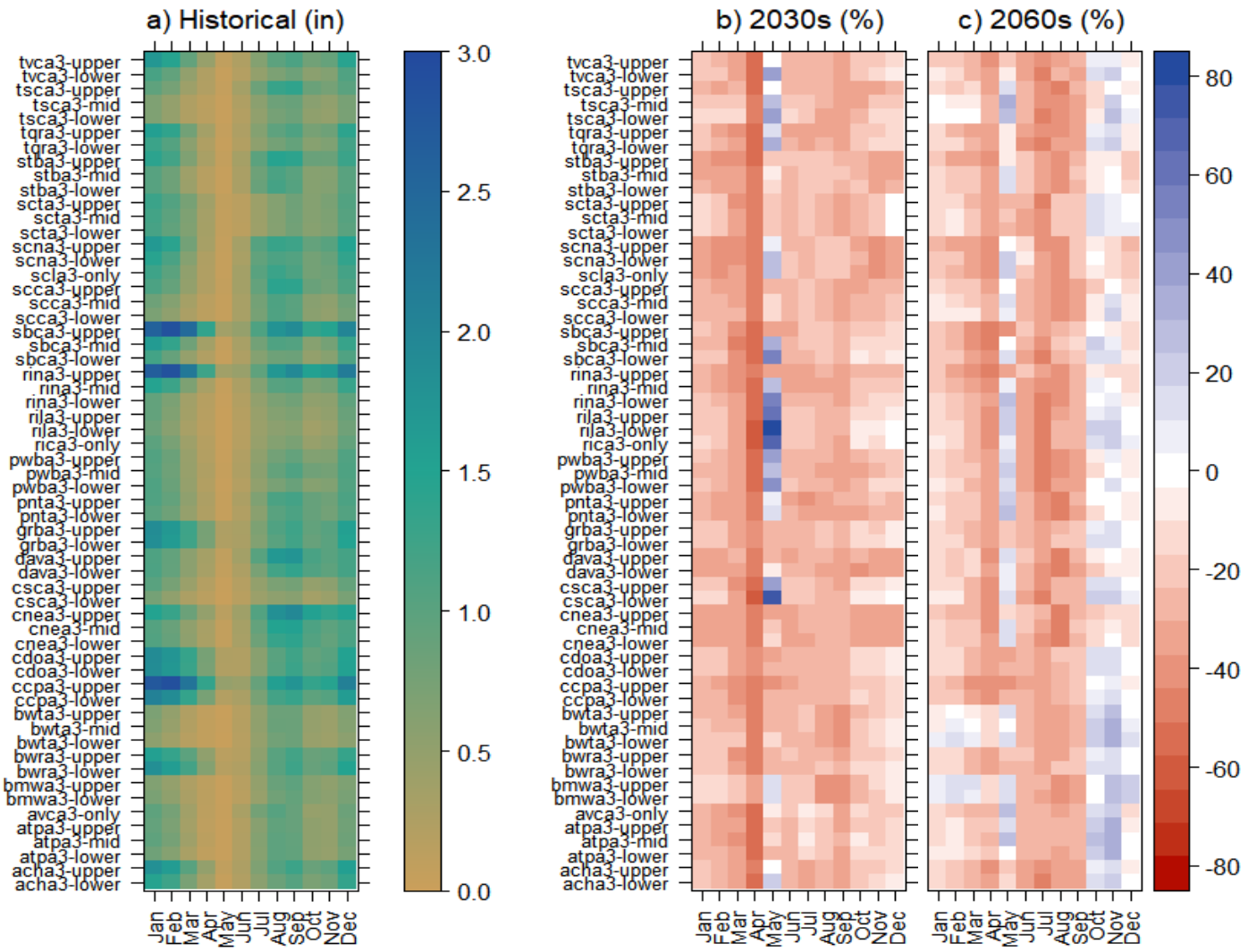


Figure 7-16 – Ensemble median, monthly average of the total tension water (sum of upper and lower soil zones) under the worse-case climate scenario for: a) modeled historical tension water in inches, b) near future change, and c) far future change as a percent relative to the historical period. For soil moisture change, blue indicates an increase and red indicates a decrease. Results are presented for each elevation zone.

The higher elevation and wetter subbasins in the Santa Catalina and Rincon Mountains still decreased in soil moisture throughout the year. While these high elevation subbasins are not located within the TAMA, they contribute recharge to the basin through the lateral transfer of water through the mountain block to the basin boundaries, or via local return flow to streams. The changes in these mountain recharge processes warrant additional consideration.

7.3.4. Surface water modeling conclusions

Surface water modeling for the best-case between 2020 – 2049 projected more monsoon streamflow due to a longer season. For the 2050 – 2079 period, monsoon flows were projected to decrease in some basins. Under the worse-case scenario, the 2020 – 2049 monsoon season was projected to be shorter but highly variable, resulting in decreased median streamflow. Results for the 2050 – 2079 period project increased monsoon variability and an apparent recovery of total streamflow volume due to a small number of extremely high flow events.

The winter wet season was projected to shorten under the best-case and worse-case climate scenarios. In the best-case scenario, the large events got consistently larger into the future, compensating for the shortening of the winter season. In the worse-case scenario, total winter precipitation was lower in both future periods, translating to less overall streamflow.

Chapter 8 Supply and Demand Assessment using the Central Arizona Project Service Area Model

8.1 Overview

The Central Arizona Water Conservation District (CAWCD) operates the Central Arizona Project (CAP), the 336-mile canal system that brings Colorado River water to Maricopa, Pinal, and Pima counties (Figure 8-1). The CAWCD's long-term contract obligations for Colorado River water total 1.415 million acre-feet (Central Arizona Project, 2022a). CAWCD is a non-federal cost-share partner of the Study and conducted the Supply and Demand Assessment in conjunction with Study participants.

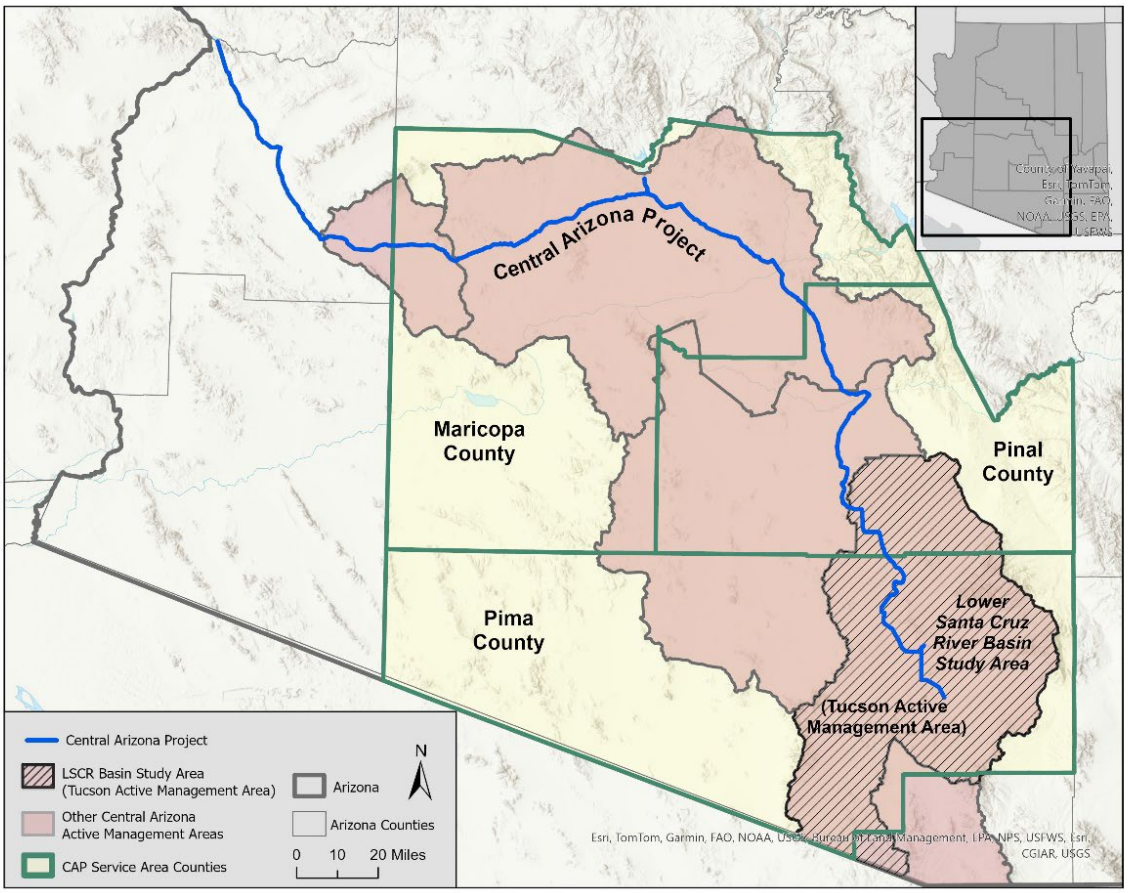


Figure 8-1 – CAWCD's three-county service area is outlined in yellow; the Central Arizona Project is represented by the blue line.

CAWCD's Resource Planning and Analysis department has developed unique modeling capabilities to evaluate future supply and demand conditions. This capability includes the CAP Service Area Model (CAP:SAM), a computer model designed to simulate over 135 water users (Tribes, municipal providers, irrigation districts, institutional users) and 16 supply types within the CAP's three-county service area. The model takes into account the laws and regulations governing water management within Active Management Areas, as described in Chapter 6.

CAP:SAM is not a hydrologic model: its purpose is to estimate water supplies and demands through time under a range of assumptions regarding climatic, socio-economic, and behavioral factors. It evaluates a wide range of future conditions, including Central Arizona Project water availability, the rate and pattern of municipal growth, use of reclaimed water, trends in agricultural use, etc.

Supply and demand projections were developed for CAWCD's entire three-county service area (Maricopa, Pinal, and Pima Counties). It was necessary to model the entire service area because the regional interdependency of both supply and demand produces sub-regional effects. CAP:SAM projects supply and demand at the level of the water provider. LSCR Basin municipal water providers' service areas are shown in Figure 8-2.

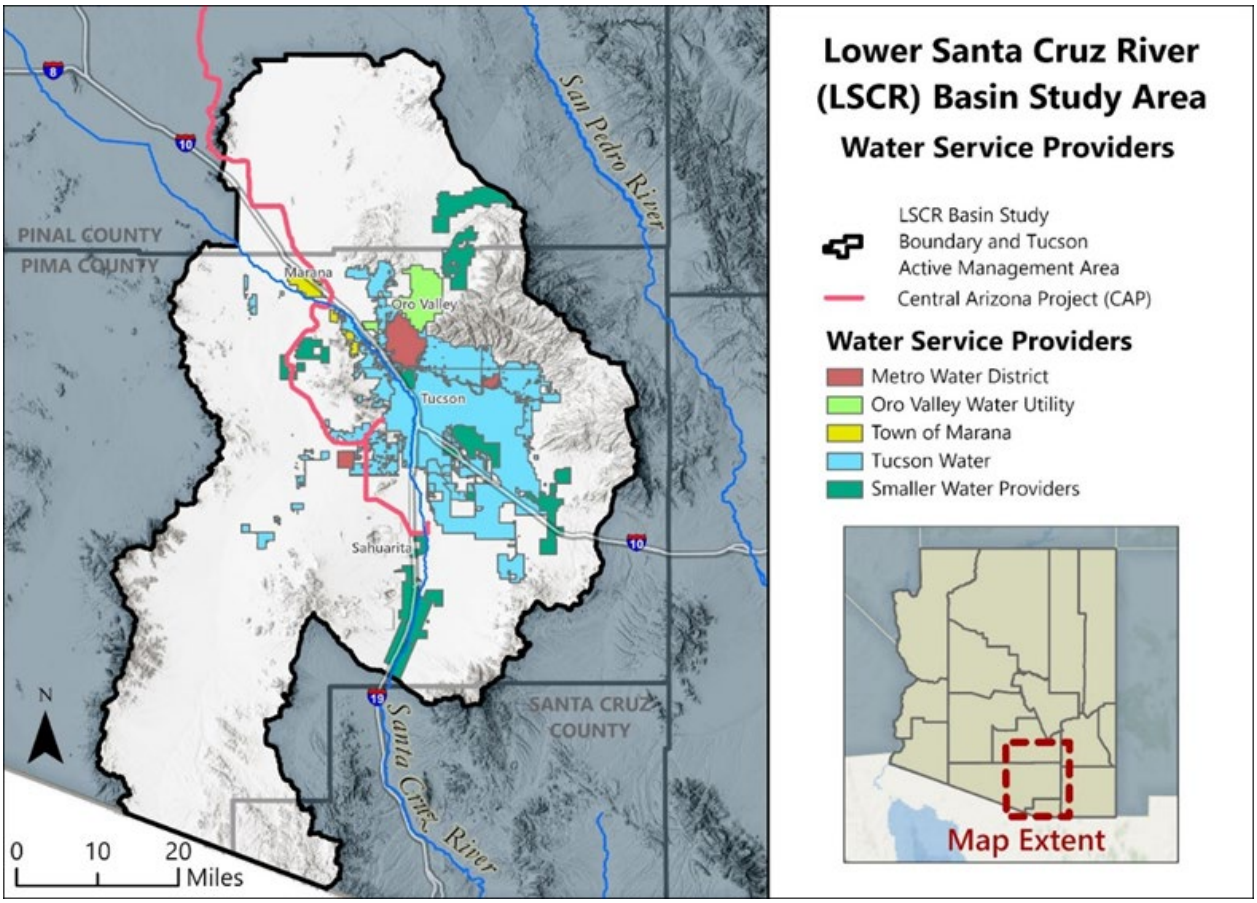


Figure 8-2 – LSCR Basin municipal water providers.

8.2 CAP:SAM Scenarios

CAP:SAM scenarios are comprised of assumptions regarding climatic, socio-economic, and behavioral factors that influence specific water supplies and demands through time. More detail on these factors is provided below. Using the parameters provided under each scenario, CAP:SAM projects municipal, agricultural (Indian and non-Indian) and industrial demands. It also incorporates the effects of shortages to CAP water on individual water providers.

8.2.1. Climate assumptions

Within CAP:SAM, the influence of climate is integrated into municipal conservation rates, crop evapotranspiration and the availability of CAP water in the context of shortages on the Colorado River. In this Study, availability of CAP water is by far the most important of these three factors. However, the availability of CAP water is highly dependent on the future operating rules of the Colorado River, which have not yet been established past 2026. Recognizing the high levels of uncertainty regarding future Colorado River operations, Partners decided that it was reasonable to make CAP:SAM projections only through the year 2060.

Expert CAWCD staff developed three representative sequences or "traces" of CAP shortages for the period of 2020 to 2060, designed to align with the Study's three climate scenarios: current, best-case and worse-case. The current climate trace is based on modeling of Colorado River operations under observed hydrology, the 2007 Colorado River Interim Guidelines and the 2019 Drought Contingency Plan. The best-case and worse-case shortage traces reflect degrees of impacts for which there is general agreement among Global Climate Models: reduced average runoff and greater variability of precipitation (Seasholes, 2023).

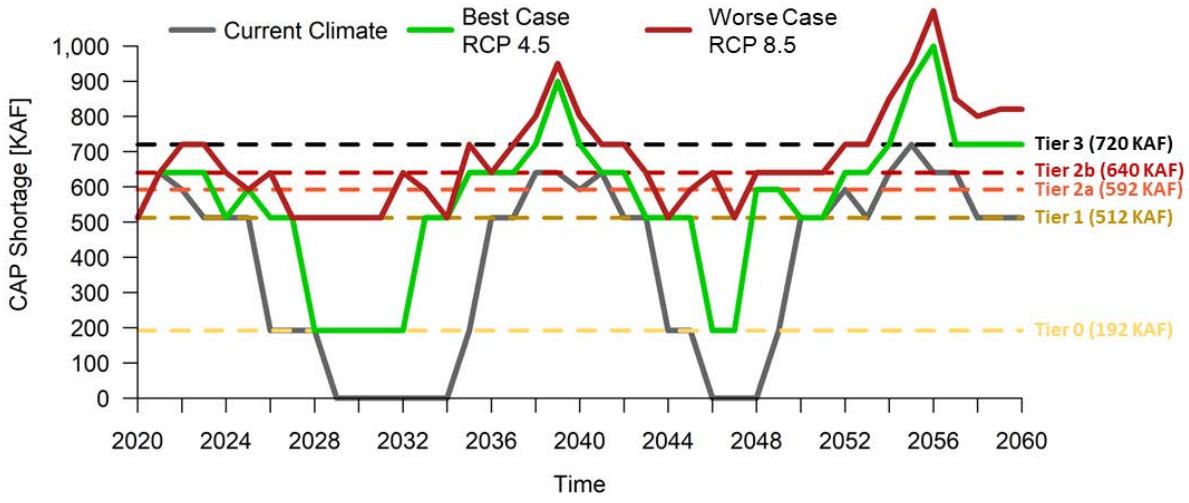


Figure 8-3 – Representative CAP shortage sequences or traces modeled using CAP:SAM, with reference levels of shortages under the 2019 Drought Contingency Plan. Note that shortage volumes apply to the entire CAP system, not just the LSCR Basin Study Area.

Figure 8-3 shows the three traces of the CAP shortages under the climate assumptions and how these correspond to the shortage tiers in the 2019 Drought Contingency Plan. Larger values on the Y-axis signify greater shortages, which occur more frequently under the worse-case climate.

8.2.2. Population

The CAP:SAM modeling used the Arizona Office of Economic Opportunity (AOEO) official county and statewide population projections. The AOEO projections consist of three series: low, medium, and high (Figure 8-4) and are typically updated every three years.

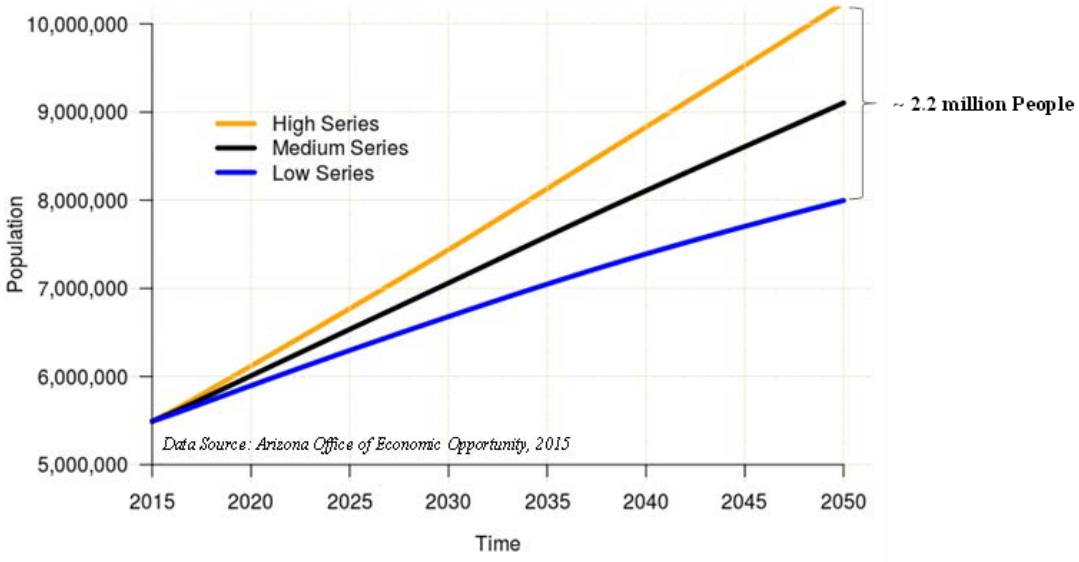


Figure 8-4 – Arizona Office of Economic Opportunity's low, medium, and high series population projections for the three-county CAP service area (Maricopa, Pinal, and Pima counties.)

The housing unit (HU) is the fundamental unit for modeling population growth in CAP:SAM, and therefore growth in municipal demand. Annual projections of new housing units are generated using a growth curve. For this Study, rate of population growth was divided into three categories: slow, medium, and rapid, which correspond to AOEO's low, medium, and high population series, respectively.

8.2.3. Spatial pattern

Once the magnitude of housing unit growth is determined, CAP:SAM distributes this growth based on geographic projections of housing units by municipal water provider through time. These projections are based on many factors, including demographic data, construction data, planned developments, land uses, employment patterns and transportation infrastructure.

CAP:SAM can incorporate alternative growth patterns. Some of the factors in these patterns include the relative proximity of transportation infrastructure and existing development, how quickly planned development takes place, residents' relative willingness to commute to employment centers, and land use capacity factors.

Three growth patterns were used in this Study: "Official", "Outward Growth" and "Compact" (Figure 8-5). The Official projection mirrors the officially adopted growth pattern generated by each county's Associations of Governments. Outward Growth places a greater proportion of housing units in suburban and exurban areas. For the LSCR Basin Study Area, this translates to fewer housing units projected in the centrally located Tucson Water service area and more housing units projected for water providers that serve the periphery of the Basin (Figure 8-2). The Compact growth projection places more housing units in the existing urban areas, focusing municipal growth in Tucson Water's service area.

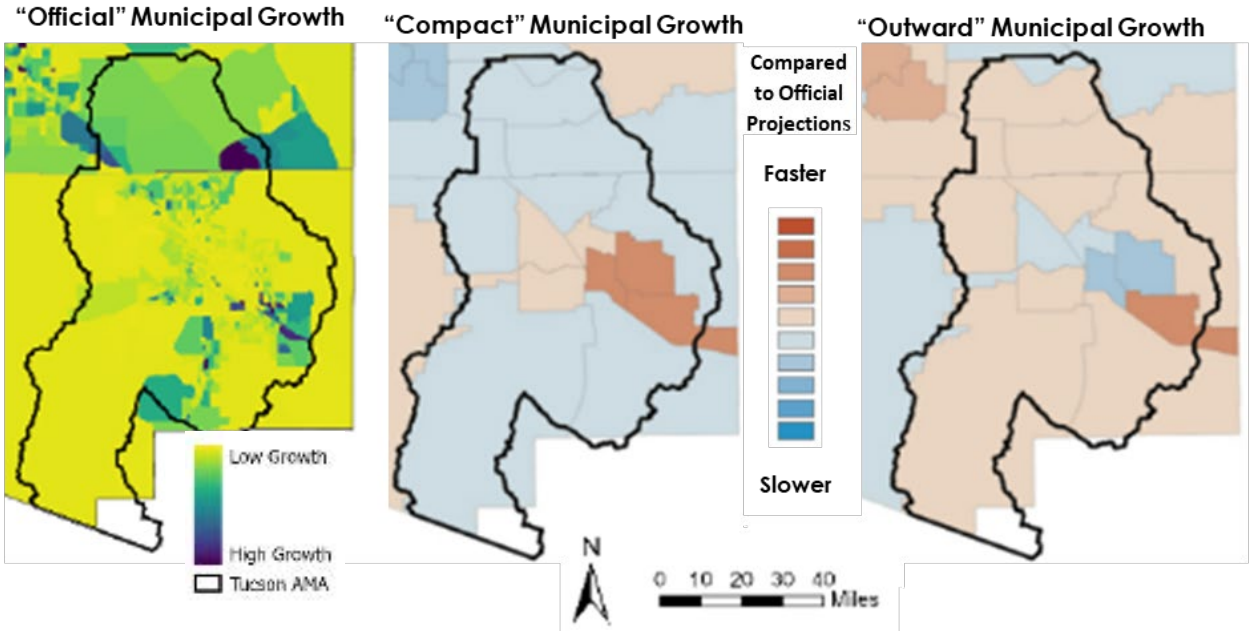


Figure 8-5 – Official Housing Unit spatial pattern developed by the counties' Associations of Governments. Compact and Outward Growth alternative spatial patterns developed by Applied Economics. Study Area is outlined in black.

8.3 CAP:SAM Scenario Matrix

Six CAP:SAM scenarios were developed as part of the Supply and Demand Assessment, each representing a plausible future condition for the region (Figure 8-6). While the matrix depicted could generate nine pairings of climate and growth conditions, Partners suggested a total of six scenarios to simplify the analysis while enabling useful pairwise comparisons.

Scenario A was considered as the baseline condition, as it used the official growth projections developed by the Pima Association of Governments with no adjustments for climate change. Assuming official projections of growth, a comparison of Scenario A with Scenario E would reveal impacts due solely to climate. Comparisons of Scenarios B vs. C, as well D vs. F would isolate the impacts of growth under constant climate conditions. The differences between Scenarios B and D and C vs. F could be attributed solely to the future level of climate change.

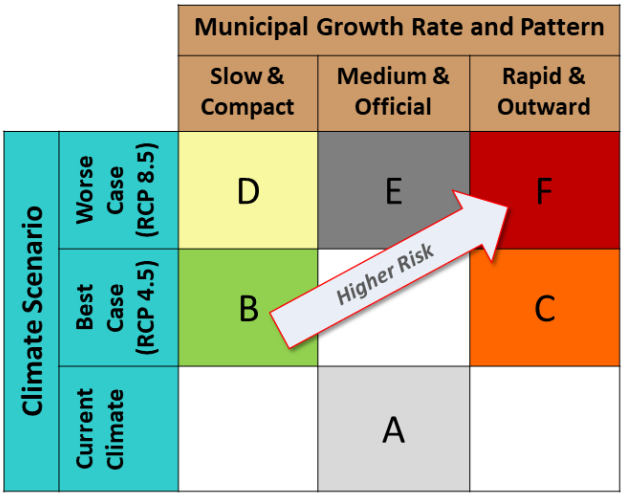


Figure 8-6 - Climate and Municipal Growth Scenarios for Supply and Demand Assessment

8.4 Methodology

To begin the Supply and Demand analysis, data from ADWR and other Study participants were compiled to determine the availability of CAP and reclaimed water supplies. Demands for these supplies were quantified by sector (i.e., municipal, industrial, agricultural, etc.). This provided a snapshot of current conditions in the LSCR Basin and served as a starting point for generating the CAP:SAM supply and demand scenarios.

8.5 CAP:SAM Modeling Results

8.5.1. Municipal demand

Municipal demand grows year-over-year under all six modeling scenarios. The extent of this growth was determined by the population growth rate as well as the spatial pattern defined for each scenario. The impact of these assumptions was evident when comparing scenarios with slow and compact growth (Scenarios B and D) to those with rapid outward growth (Scenarios F and C). Demand in 2060 ranged from a minimum of about 158,300 AF in Scenario B to a maximum of about 271,500 AF in Scenario F.

8.5.2. Agricultural demand

Despite urbanization, recent agricultural demands have remained relatively constant in the LSCR Basin Study Area. Between 2000 to 2018, agricultural demand averaged just over 100,600 AF. The full range of agricultural demand projections for the Study Area falls within this historical variation (Figure 8-7).

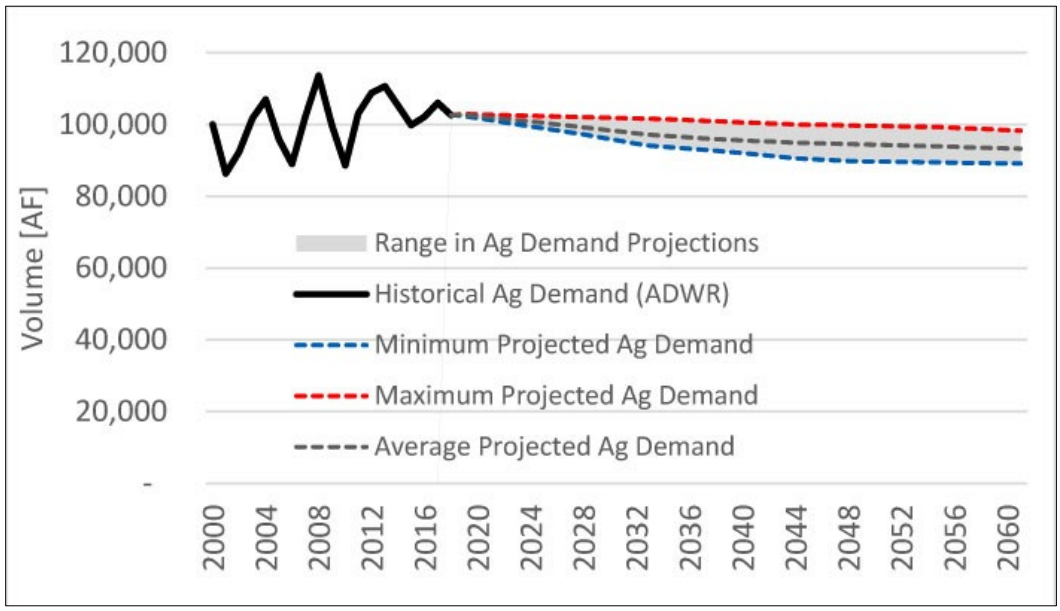


Figure 8-7 – Projected volume of agricultural water demand in used in CAP:SAM scenarios.

In general, all projections decreased slightly due to the assumption that the conversion of agricultural land to urban land will continue. Agricultural demand decreased more rapidly for scenarios that assume a larger increase in irrigation efficiency. Increases in crop consumptive use due to a hotter and drier climate balanced this decline. The percent decrease in projected demand by the year 2060 ranged from a minimum of 4% to a maximum of 13%.

8.5.3. Tribal demand

Tribal demand in the TAMA is predominately agricultural with a small proportion of municipal and industrial demand. Tribal demand represented a small component of the total projected demand for the Study Area. Projected tribal demand across all sectors ranged from 17,600 AF to 19,200 AF in 2060.

8.5.4. Industrial demand

For this Study, projections of industrial demand were generated outside of CAP:SAM as part of the Groundwater Modeling Analysis. These projections assumed a constant demand of ~45,000 AF per year, of which over 70% is associated with mining activity. Industrial demand

projections for Scenarios C and F also assumed an increase in mining activity beyond current levels. Industries are required to follow best management practices and recycle as much water as possible; however, there are no mechanisms to limit industrial demand in the same ways as municipal and agricultural demand. Unlike the municipal sector, there is no legal obligation for industrial users to replenish pumped groundwater with renewable supplies.

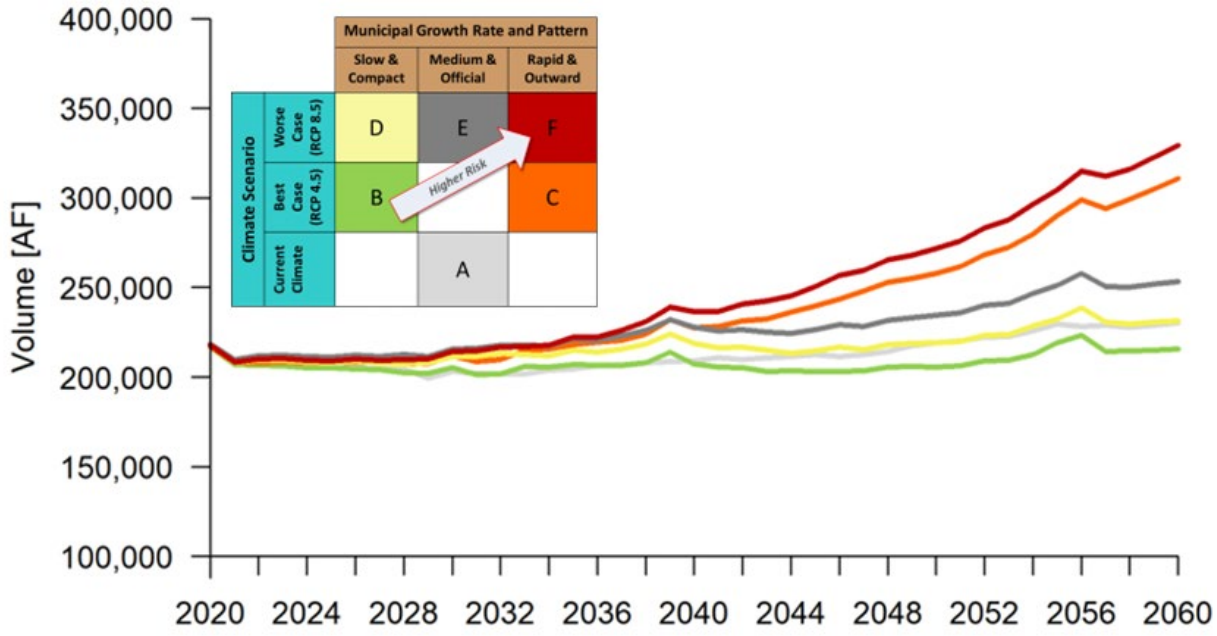


Figure 8-8 – Total TAMA groundwater pumping by CAP:SAM scenario.

8.5.5. Trends in Groundwater Pumping

Figure 8-8 shows the projected groundwater pumping within the LSCR Basin for each scenario. Groundwater pumping is projected to increase across all scenarios over the projection period, with the exception of Scenario B. Pumping volumes in 2060 represent a net increase from historical levels that ranges from 6% (Scenario A) to over 50% (Scenario F). The grouping of the scenarios in Figure 8-8 demonstrates that the rate and pattern of municipal growth is the primary driver of future groundwater pumping. The abrupt spikes in pumping simulated in 2039 and 2056 are associated with extreme reductions to the CAP supply.

8.5.6. Total demand and supply

Total projected demand in 2060 ranged from a 5% decrease under Scenario B to a 37% increase under Scenario F, compared to current levels (Figure 8-9). Scenarios C and F had the greatest increase in demand, primarily as a result of rapid, outward population growth. Scenarios B and

D, which assume slow and compact growth, resulted in the smallest increase in demand. In addition to slower, more urban-centric growth, Scenario B included additional assumptions regarding agricultural efficiency and municipal conservation that reduce the 2060 demand from its historic levels. Scenarios A and E both result in moderate increases in demand of 2% and 8%, respectively.

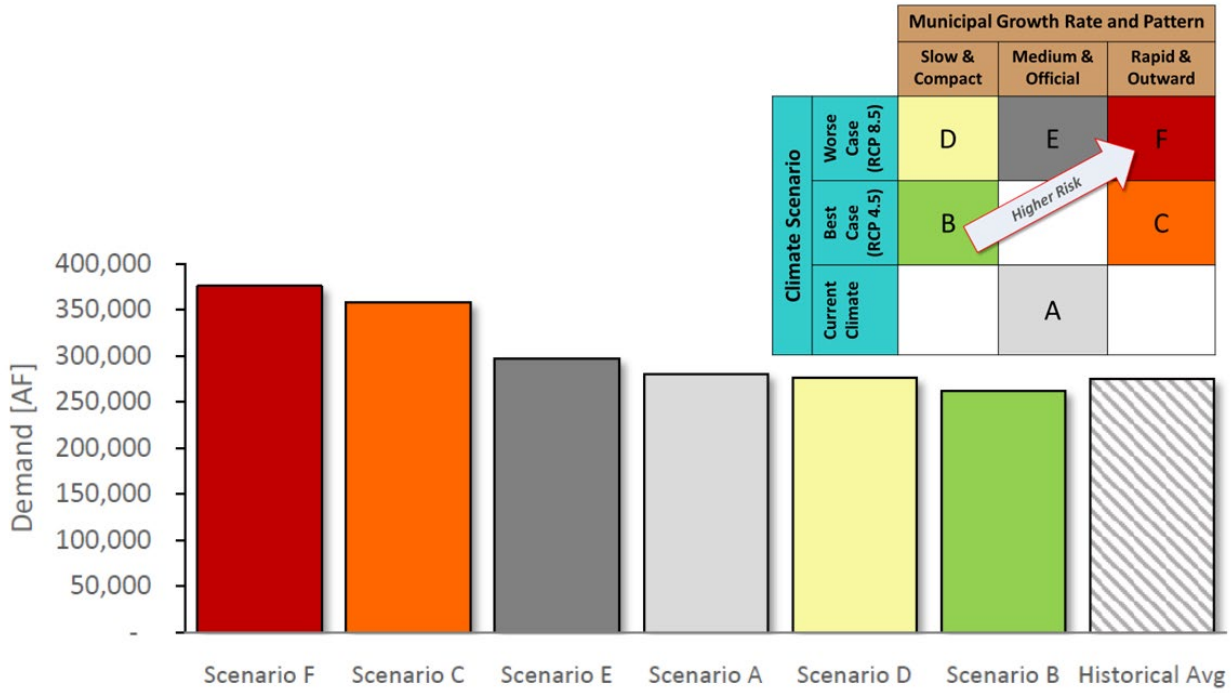


Figure 8-7 – Total projected demand in 2060 for the LSCR Basin by CAP:SAM Scenario. Historical average determined using ADWR's AMA Historic Template and Summary.

The composition of the water supplies that would be used to meet the sum of municipal, agricultural, tribal demands in 2060 in the LSCR Basin are shown in Figure 8-10. Reclaimed use was projected to increase in proportion with increases in municipal demand. On average, reclaimed water represented approximately 6% of the total supply across scenarios in 2060. CAP supply utilization was also projected to increase across all scenarios, as use of the supply shifts from earning Long-Term Storage Credits to meeting growing annual demands.

In the rapid growth scenarios (C and F), municipal demand grew and recovery of stored CAP LTSCs increased substantially. There was also a higher reliance on groundwater to meet this demand, since the outward growth assumptions resulted in more growth occurring in communities with smaller and less diverse renewable supply portfolios. As noted earlier, much of this groundwater reliance would generate a requirement for replenishment under the Assured Water Supply rules, either by the Central Arizona Groundwater Replenishment District or the water provider themselves.

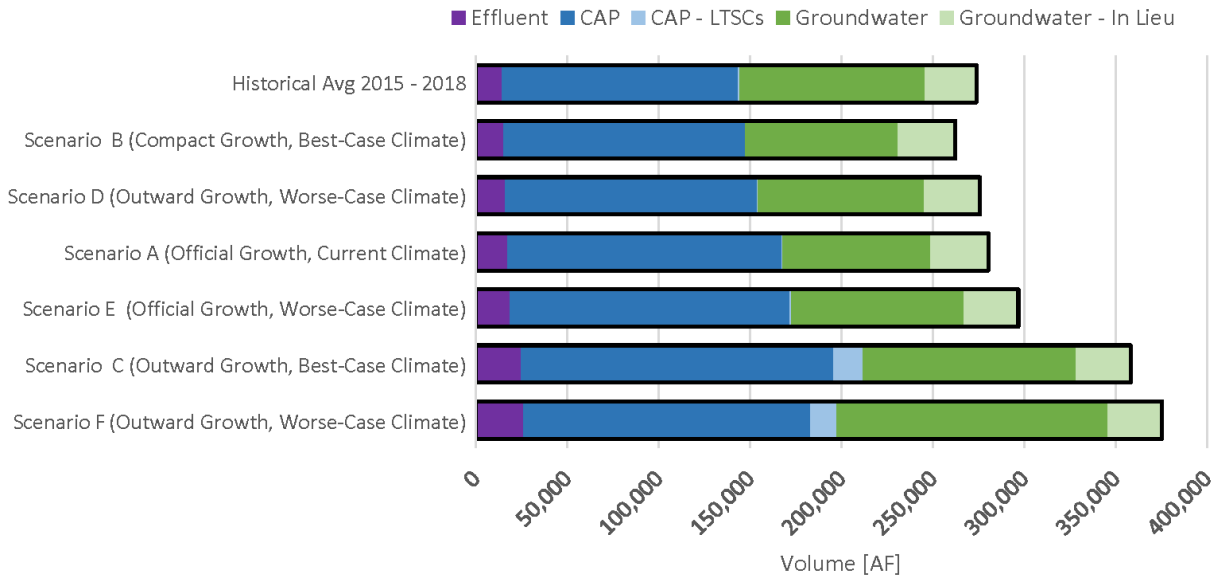
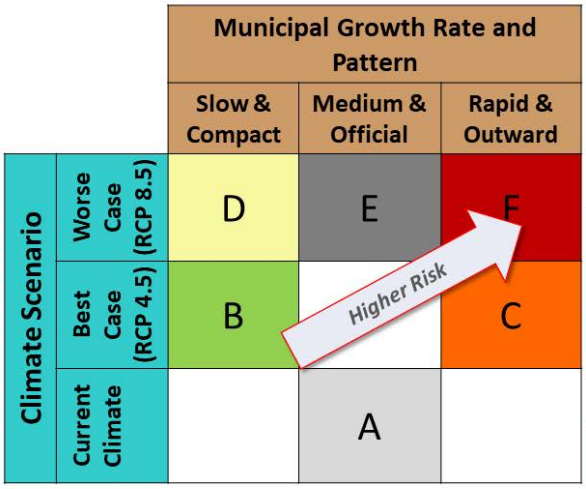


Figure 8-8 – Projected supply utilization to meet municipal, agricultural, and tribal demand in 2060. Historical average determined using ADWR's AMA Historic Template and Summary.

8.6 Groundwater Pumping Subject to AWS Rules, Without an Identified Source of Replenishment

Total groundwater pumping is not constrained in CAP:SAM. If the projected demand for a provider exceeds their availability of renewable supplies, exempt groundwater, and Long-Term Storage Credits, the corresponding volume incurs a replenishment obligation under the AWS rules. The rate of groundwater use that is subject to replenishment varied substantially across scenarios. Total volume for the simulation period ranged from a maximum of 570,000 AF in Scenario F to a minimum of 231,000 AF in Scenario B (Table 8-1).

Table 8-1 – Projected annual volume of groundwater subject to replenishment under the AWS rules in 2060



CAP:SAM Scenario	Volume Subject to AWS Rules in 2060 (AF)	Volume Subject to AWS Rules From 2020 to 2060 (AF)
A	12,700	330,100
B	8,800	231,000
C	34,400	517,400
D	9,500	250,600
E	14,300	368,400
F	38,100	570,000

The full analysis, including CAP:SAM output for each water provider under each of the six scenarios is provided in Appendix C, Supply and Demand Assessment. Some providers would be able to meet projected demands with their existing resources. Others would need to recover previously stored supplies to meet their projected demands through 2060. For certain providers, projected demands would exceed existing resources, including their stored water, creating a need to acquire additional renewable supplies. As shown in Table 8-1. the need for renewable supplies was greatest under the “rapid, outward growth” scenarios.

Chapter 9 Groundwater Modeling Analysis

9.1 Background and Scenario Definition

This chapter summarizes the groundwater modeling performed for the LSCR Basin Study. A full description of this effort is available in Technical Memorandum ENV-2021-64, Lower Santa Cruz River Basin Study Groundwater Analysis (Bureau of Reclamation, 2021a).

ADWR maintains the "Regional Groundwater Flow Model of the Tucson Active Management Area, Arizona" (TAMA Model) to support water resource planning and management in the Tucson AMA, and to "evaluate relative changes within the regional system (Mason & Hipke, 2013). Reclamation Technical Service Center staff used this model to evaluate impacts of six groundwater modeling scenarios (Figure 9-1) on groundwater resources in the Study Area from 2020 to 2060. The TAMA Model uses version 1.0.7 of the U.S. Geological Survey's (USGS) groundwater modeling code MODFLOW-NWT (Niswonger, Panday, & Motomu, 2011). The extent of the groundwater model domain with respect to the LSCR Basin (Tucson AMA) is shown in Figure 9-3.

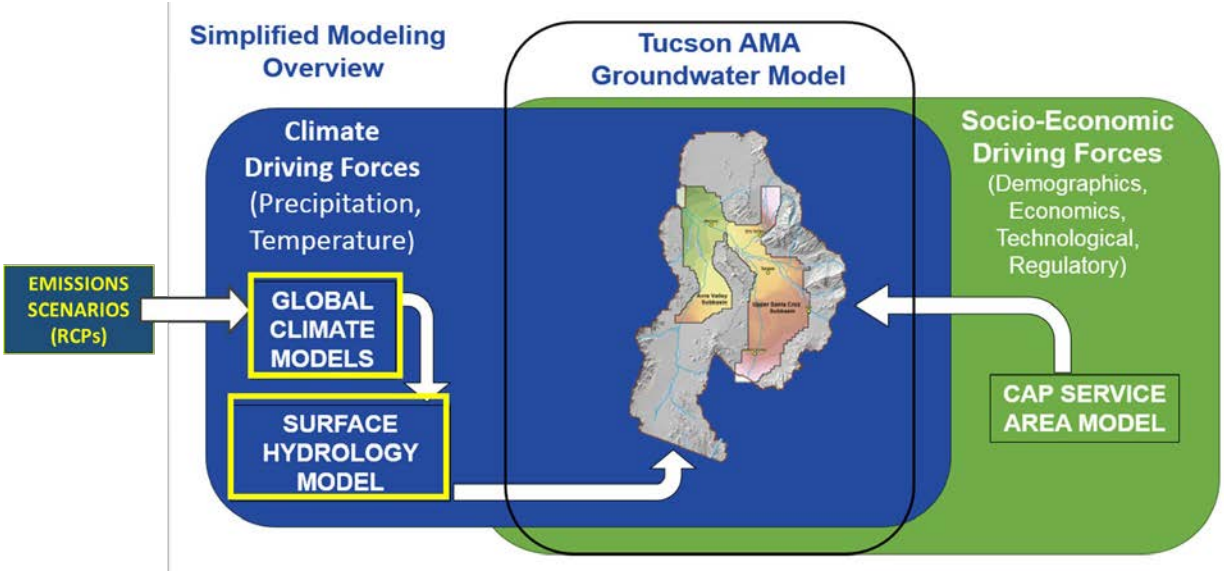


Figure 9-1 – A simplified diagram of modeling for the Groundwater Analysis.

The groundwater modeling scenarios were developed by combining CAP:SAM's projections of water demand and available CAP water with streamflow infiltration and evapotranspiration rates projected by the Hydroclimate Analysis (Figure 9-1). As discussed in Chapter 8, since CAP:SAM projections rely heavily on the rules of operation for the Colorado River, the period modeled in the Groundwater Analysis was set to 2020 to 2060.

Re-estimating parameters for mountain-front recharge and underflow in and out of the LSCR Basin was beyond the scope of the Study. The groundwater modeling used the values developed in the ADWR TAMA Groundwater Model for all six scenarios. Next, Project Team members with expert knowledge of water resource management within the LSCR Basin translated the artificial recharge and pumping projections into a location-specific groundwater model input file for each scenario.

Similar to the CAP:SAM scenarios, Scenario B combined the best-case climate with slow, compact municipal growth and represents the lowest risk to water resources overall (Figure 9-2). Scenario F combined the worse-case climate with rapid, outward municipal growth. It also included a 30% increase in pumping for the mining sector over the period from 2025 and 2060, thereby representing the highest risk to water resources. The range of risk to water resources was assessed by comparing the outcomes of Scenario B with those of Scenario F.

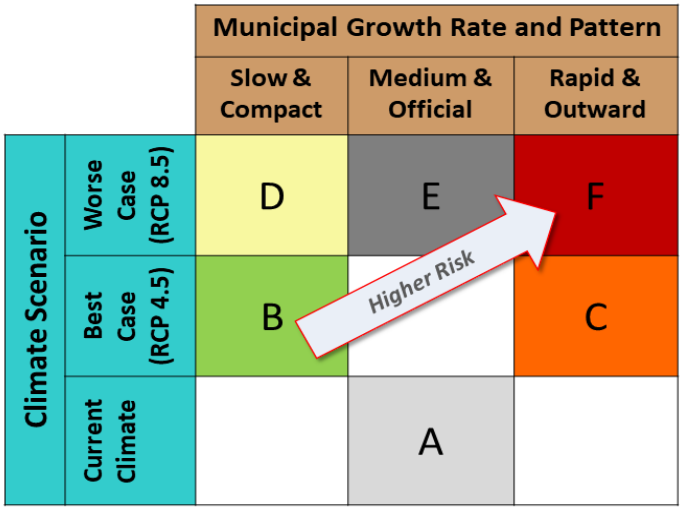


Figure 9-2 – Climate and Municipal Growth Scenarios used for the Groundwater Modeling Analysis

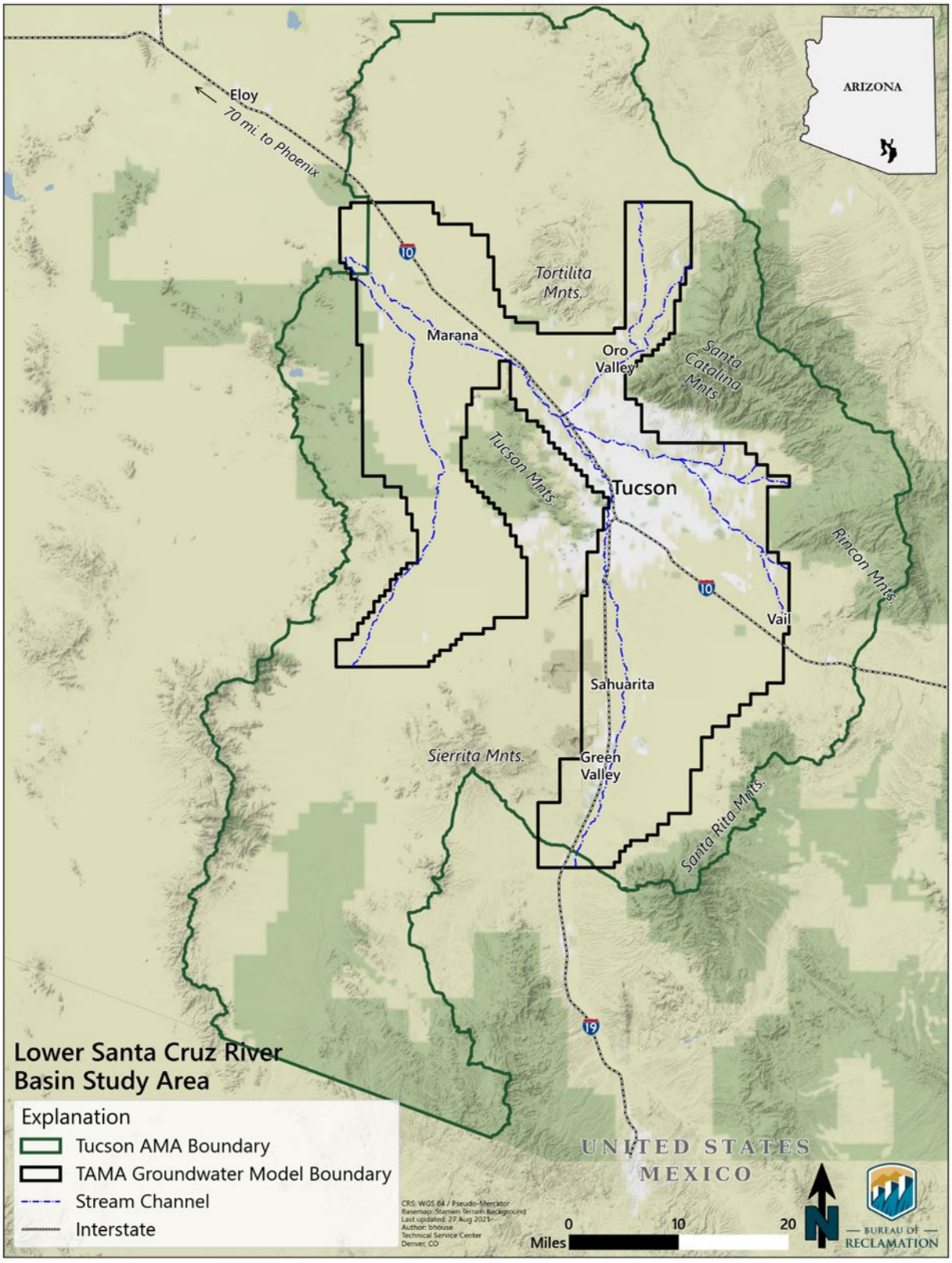


Figure 9-3 – Lower Santa Cruz River Basin Study Area (Tucson Active Management Area) and TAMA Model boundaries.

Figure 9-4, Table 9-1, and Table 9-2 provide an overview of the simulated inflows and outflows of the TAMA Model and their sources. Results show that under most scenarios considered in this Study, total groundwater storage would increase through 2060. The exceptions were Scenarios C and F – both of which feature rapid, outward municipal growth. Under scenarios C and F, it would be necessary to recover approximately 20,000 acre-feet per year of stored water to satisfy demands in 2060 per CAP's Supply and Demand Assessment (Figure 8-9).

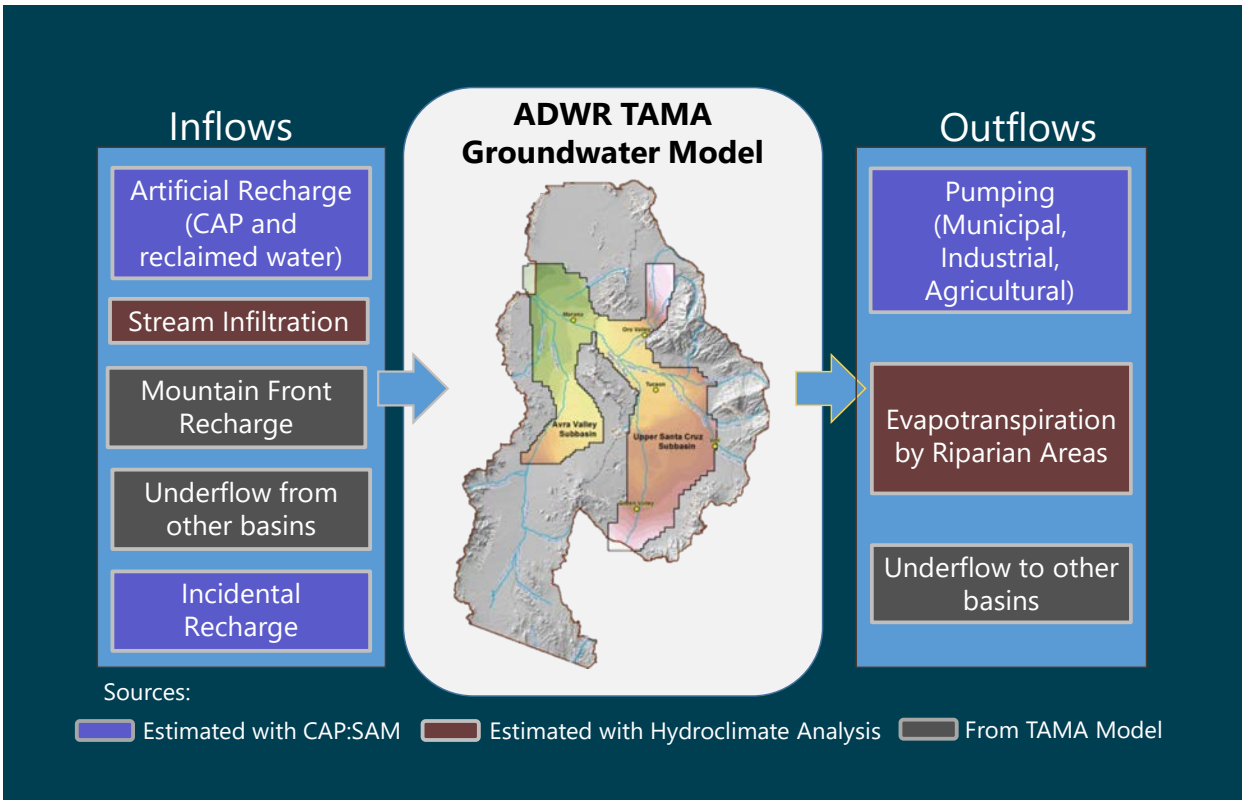


Figure 9-4 – Diagram of inflows and outflows used with the TAMA Model for the LSCR Basin Study Groundwater Analysis.

9.2 Projections of Simulated Inflows

Table 9-1 summarizes the inflows to the groundwater model over the projection period, including the range of values in thousands of acre-feet per year (TAF/yr) across all groundwater modeling scenarios, as well as the MODFLOW package used to simulate the inflow.

Table 9-1 – Summary of TAMA Model Inflows over the Projection Period and across All Groundwater Modeling Scenarios

Description	Rate (TAF/yr)			MODFLOW Package	Data Source(s)
	Min	Mean	Max		
Mountain Front Recharge*	-	28	-	RCH	Mason & Hipke (2013)
Underflow	27	28	29	WEL, CHD	Mason & Hipke (2013)
Mine Tailings Pond Seepage*	-	8	-	RCH	Mason & Hipke (2013)
Stream Channel Infiltration	54	121	382	RCH	Reclamation (2021a), Mason & Hipke (2013), CAP (2021b), Study Partners
Artificial Recharge Facilities	93	177	223	RCH	CAP (2021b), Study Partners
Agricultural Deep Percolation	18	20	20	RCH	CAP (2021b), Study Partners

*Inflow is constant over the projection period and across all groundwater modeling scenarios

9.3 Projections of Streamflow Infiltration

Like the TAMA Model, the LSCR Basin Study Groundwater Analysis used the method developed by (Burkham, 1970), to estimate streamflow infiltration. This method uses a power-law relationship between mean monthly streamflow discharge at a gage and mean monthly infiltration, as shown below:

Infiltration Rate = C x *Mean Monthly Discharge* $^{0.8}$, where C is reach-specific fitting parameter.

Reaches for which Burkham (1970) did not calculate the $C_{per\ mile}$ were estimated as part of this Study. The Burkham (1970) reaches and $C_{per\ mile}$ parameters are presented in Figure 8 of the Groundwater Analysis Technical Memorandum.

ADWR provided the values used for modeling historical streamflow infiltration in the TAMA Groundwater Model to Reclamation. The TAMA Fourth Management Plan identifies the period from 1999 to 2013 as "…generally representative of 'normal' (streamflow) conditions" (Arizona Department of Water Resources, 2016b). Therefore, this period was used to represent streamflow infiltration rates for the current climate (Scenario A). Streamflow infiltration rates for the projection period under the current climate case were defined by repeating rates for the period 1999-2013 in sequence.

Streamflow infiltration rates for the best-case and worse-case future climates were developed from the projections of mean monthly streamflow generated in the Hydroclimate Analysis (Figure 9-5 and Figure 9-6). As discussed in Section 7.1.5, the variability associated with future surface water flows was simulated by using a weather generator to create an ensemble of 100 possible temperature and precipitation time series for the SAC-SMA surface water modeling

domain. Each of the 100 ensemble members was run through the surface water model, generating an ensemble of 100 values for each output parameter. One hundred realizations of surface infiltration were produced for each of two climate cases, and each climate case was projected over two 30-year periods (2020 – 2049 and 2050 – 2079).

To align with the method used by the Central Arizona Project to model CAP shortages, a single realization was selected for each climate case. In other words, a single representative time series or trace was chosen that reflected the median value of the 100 realizations of streamflow infiltration for each climate scenario. The selected best-case and worse-case traces from the 2020 – 2049 projection period were supplemented by two addition median-value traces (one best-case, one worse-case) from the 2050 – 2079 period. The traces were merged to represent the period from 2020 – 2060. These streamflow realizations were inspected to ensure they exhibited reasonable temporal sequencing compared to the historical period.

Figure 9-7 shows the location and average volume of recharge from constructed facilities for all scenarios over the 2020-2060 modeling period. The amount of recharge from each of the facilities ranged from less than 1,000 AF/yr to over 100,000 AF/yr. This represents a significant portion of the LSCR basin water budget. Figure 9-8 similarly shows locations and average volumes instream recharge over all scenarios.

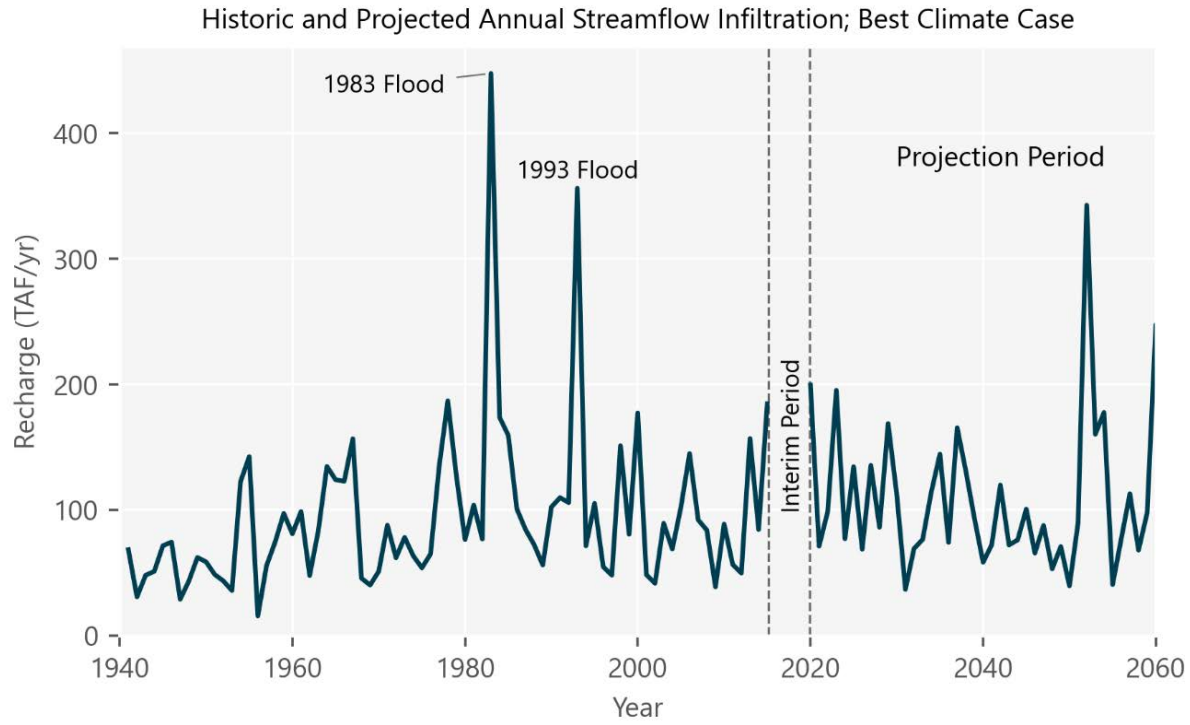


Figure 9-5 – Historical and best-case climate projected annual streamflow infiltration simulated in the TAMA Model.

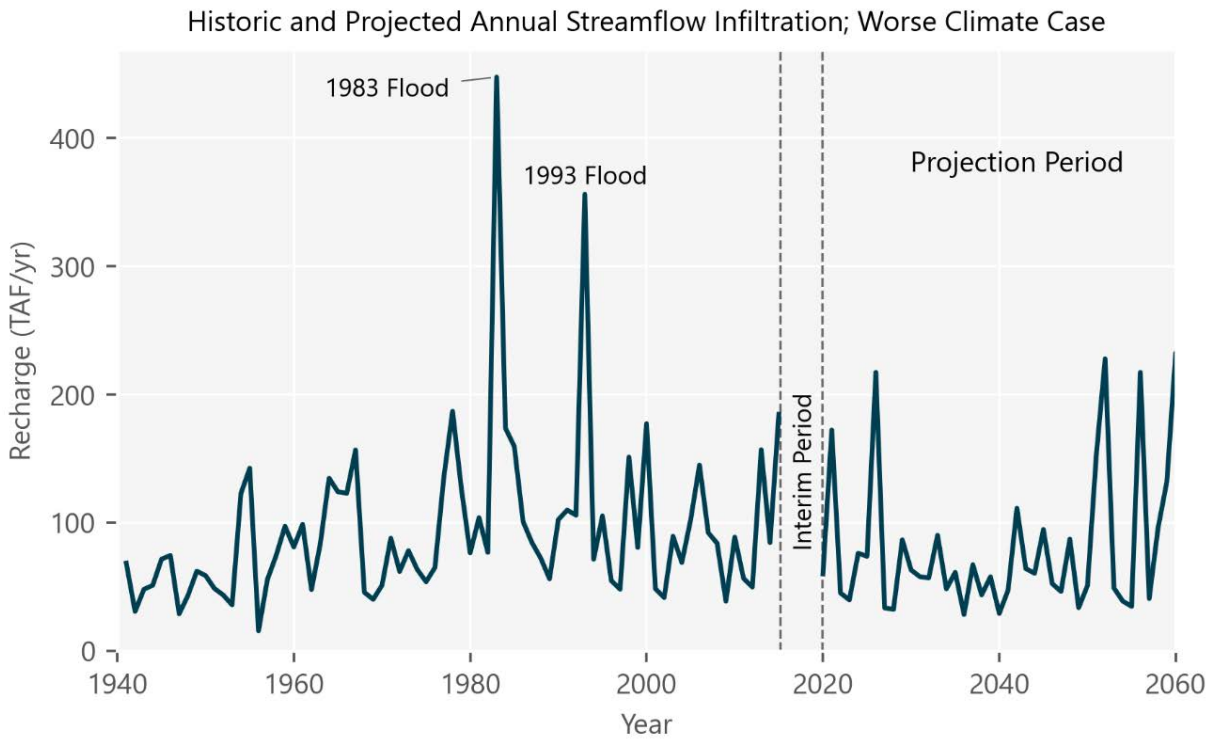


Figure 9-6 – Historical and worse-case climate projected annual streamflow infiltration simulated in the TAMA Model.

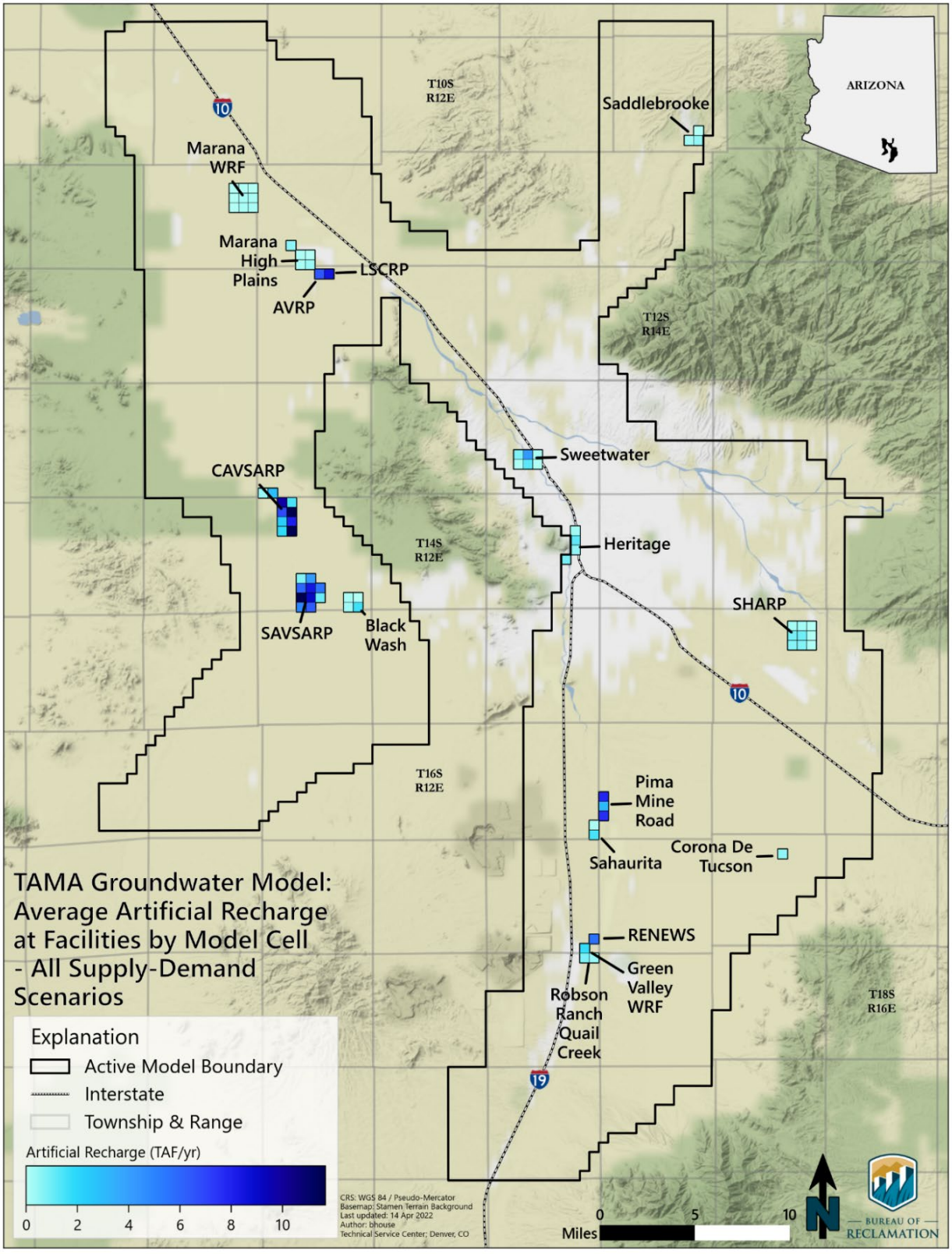


Figure 9-7 – Map of average groundwater recharge from facilities over the projection period (2020-2060) and all groundwater modeling scenarios.

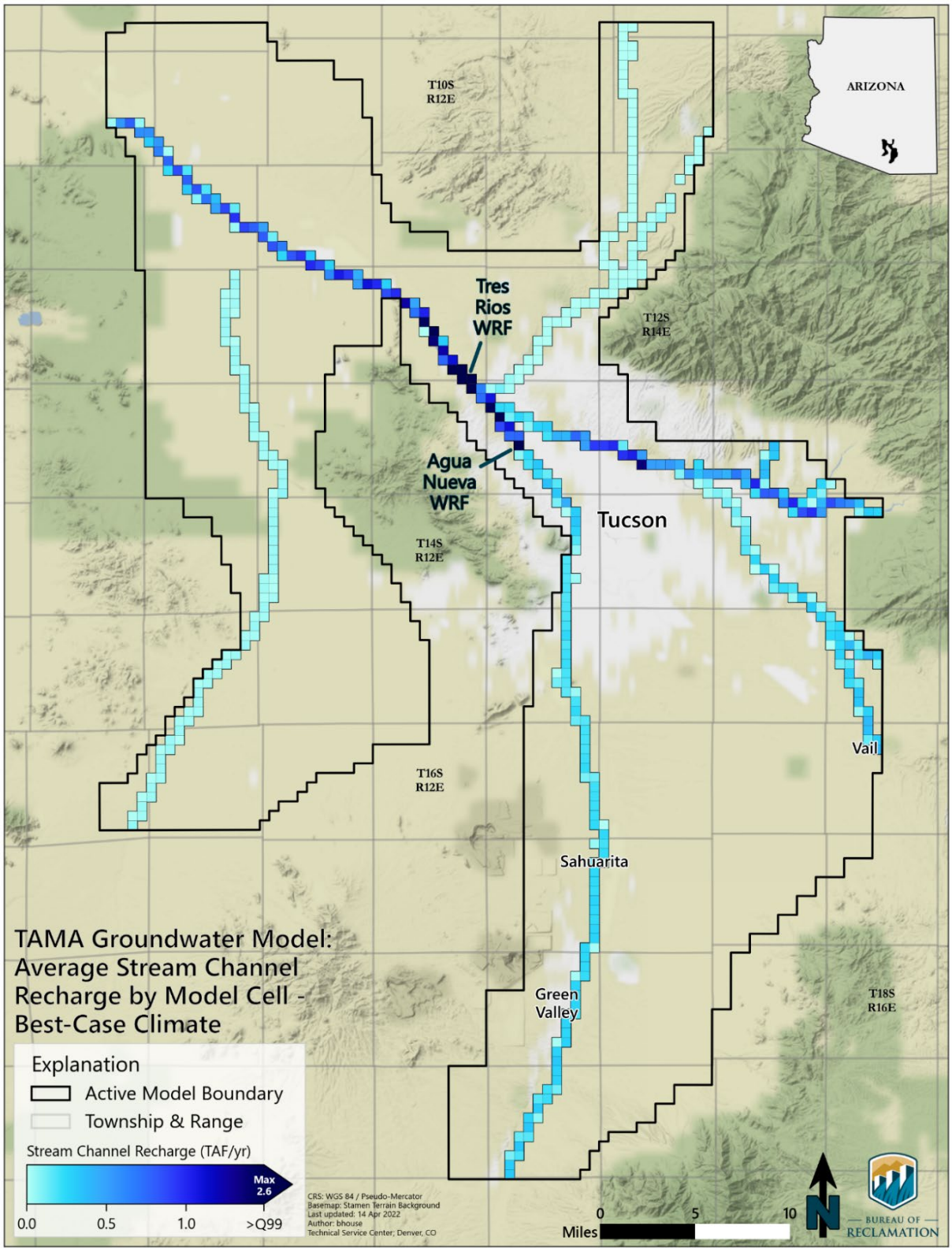


Figure 9-8 – Average annual groundwater recharge from streamflow (both natural and reclaimed water) for the best-case climate groundwater modeling scenarios (B and C) over the projection period. For clarity, the maximum value on the color scale was set to the 99th quantile.

Figure 9-9 displays the cumulative volume of inflows under each groundwater modeling scenario from 2020 to 2060. The groupings of the scenarios in Figure 9-9 demonstrate the influence of climate on inflows. Cumulative inflows under scenarios A, B, and C (current and best-case climates) were about 1.6 million acre-feet (MAF) greater over the projection period than under scenarios D, E, and F (worse-case climate). Averaged over the projection period, the current and best-case climate scenarios projected about 40,000 AF/yr more recharge than the worse-case.

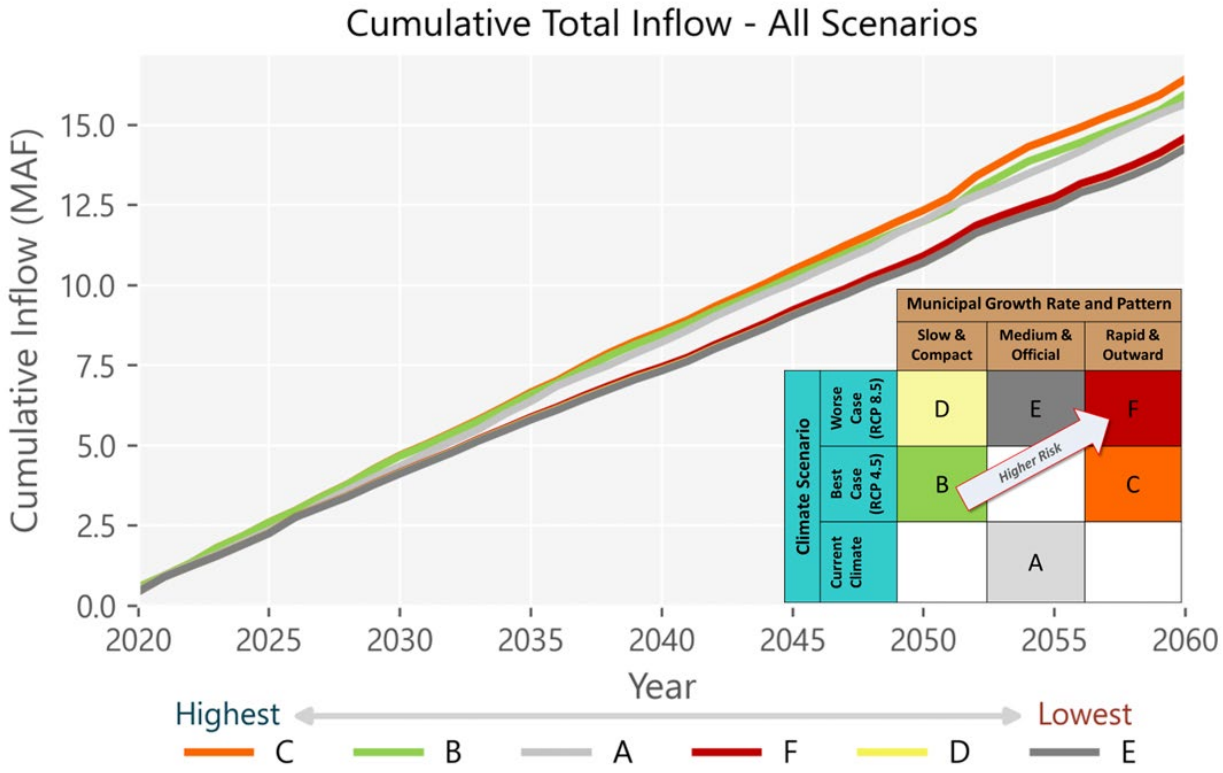


Figure 9-9 – Cumulative sum of simulated inflows from 2020 to 2060 in the TAMA Model by groundwater modeling scenario.

Figure 9-10 and Figure 9-11 display the inflow projections by source for groundwater modeling scenarios B and F. Inflows from recharge facilities (violet area) and natural and reclaimed water streamflow infiltration (brown area) accounted for the majority of total recharge. Annual variability in streamflow infiltration (brown area) accounted for most of the annual variability in total recharge under both scenarios. Figure 9-12 displays the average annual groundwater pumping over all scenarios over the projection period.

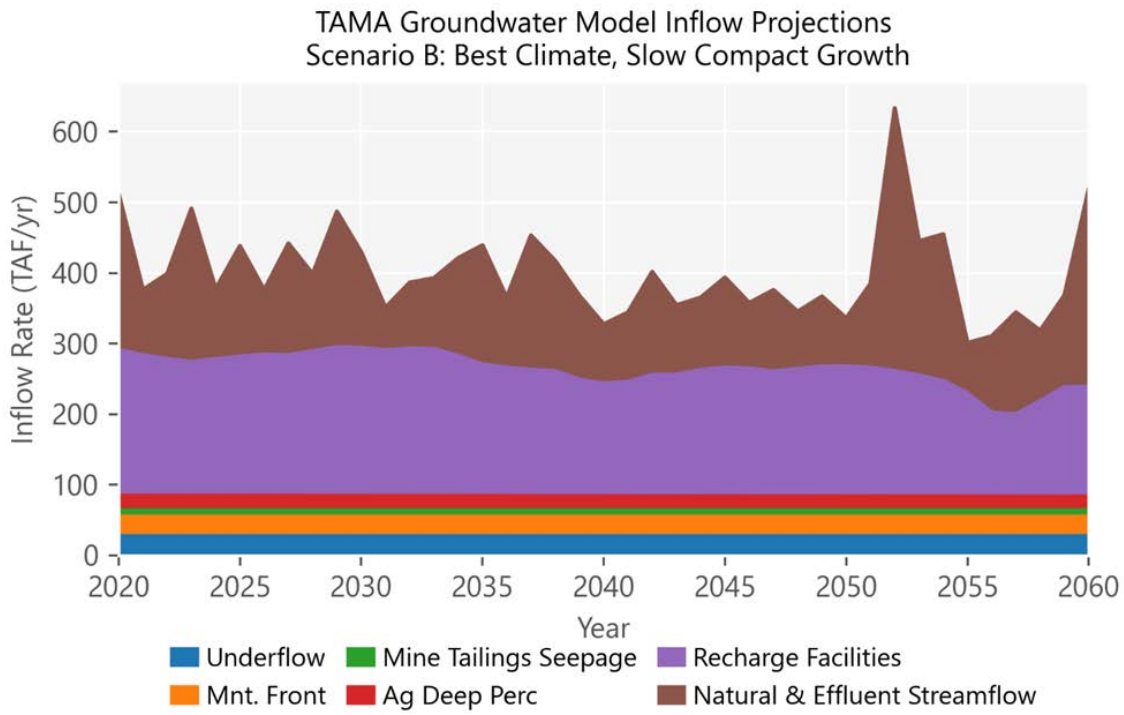


Figure 9-10 – Inflow (recharge) projections by type for the lowest risk groundwater modeling scenario (B).

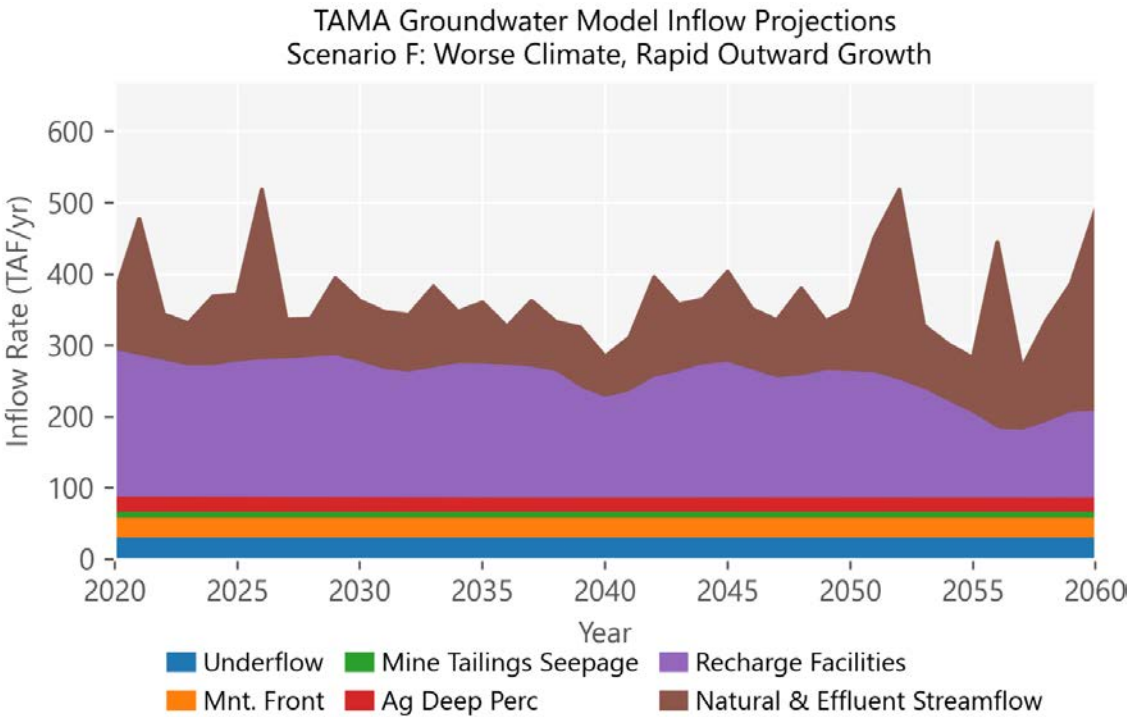


Figure 9-11 – Inflow (recharge) projections by type for the highest risk groundwater modeling scenario (F).

9.4 Projections of Simulated Outflows

Table 9-2 summarizes the outflows from the groundwater model over the projection period, including the range of rates for each outflow across all groundwater modeling scenarios and the MODFLOW package used to simulate the outflow. Groundwater pumping accounted for an average of 92% of total outflows simulated over the projection period and across all groundwater modeling scenarios.

Table 9-2 – Summary of TAMA Model Outflows over the Projection Period and across All Groundwater Modeling Scenarios

Description	Rate (TAF/yr)			MODFLOW Package	Data Source(s)
	Min	Mean	Max		
Evapotranspiration	0.4	4	16	EVT	Mason & Hipke (2013)
Underflow	17	20	26	CHD	Mason & Hipke (2013)
Pumping – Municipal	145	166	268	WEL	Mason & Hipke (2013), CAP (2021b), Study Partners
Pumping – Ag	47	57	70	WEL	Mason & Hipke (2013), CAP (2021b)
Pumping – Mining	29	34	46	WEL	Mason & Hipke (2013), Study Partners
Pumping – Industrial (Non-Mining)*	-	13	-	WEL	Mason & Hipke (2013)

*Outflow is constant over the projection period and across all groundwater modeling scenarios

All scenarios simulated the operation of infrastructure that currently exists, or is under construction, that transports renewable supplies to areas of historic groundwater pumping. This includes the operations of Tucson Water's Clearwater Program with its CAVSARP and SAVSARP facilities, as well as the partially constructed Northwest Recharge Recovery and Delivery System (NWRRDS). NWRRDS is a multi-jurisdictional project sponsored by Metro Water District, the Town of Marana, and the Town of Oro Valley that will transport renewable supplies to customers of the sponsors' municipal water utilities when it obtains sufficient funding to complete construction.

Figure 9-13 shows the simulated historical pumping for context, followed by the total projected groundwater pumping by scenario. The rapid, outward municipal growth projections (scenarios C and F) showed significant increases in pumping over the projection period and, by 2060, reached rates similar to the peak pumping period of the mid-1970s. All other scenarios suggested only modest rises in pumping demands compared to the historical 1940-1960 period, with Scenario B staying approximately constant. However, none of the projections suggested a decline in groundwater pumping.

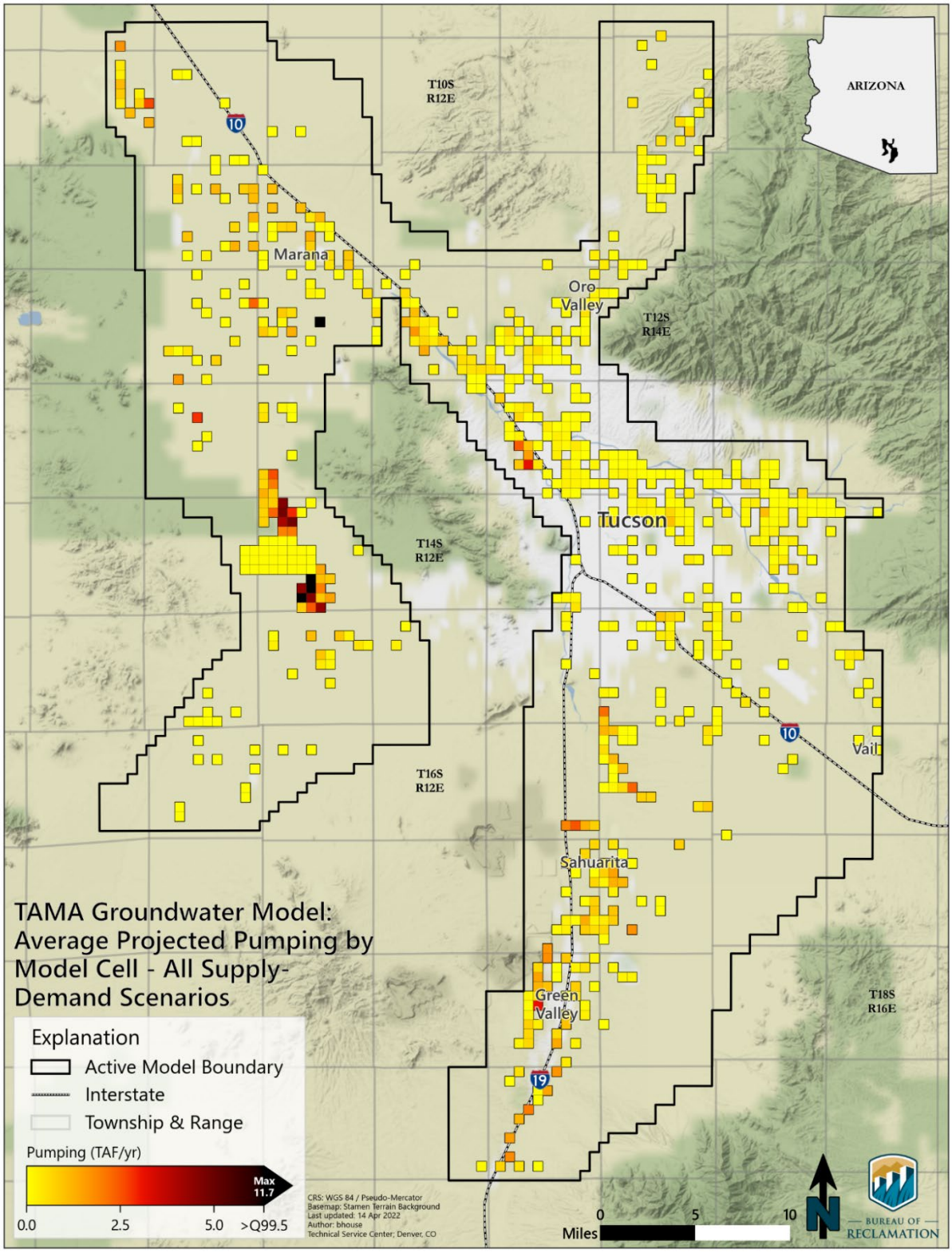


Figure 9-12 – Average groundwater pumping by model cell over the projection period. Simulated pumping has been summed over the model layers. For clarity, the maximum value on the color bar was set to the 99.5th quantile.

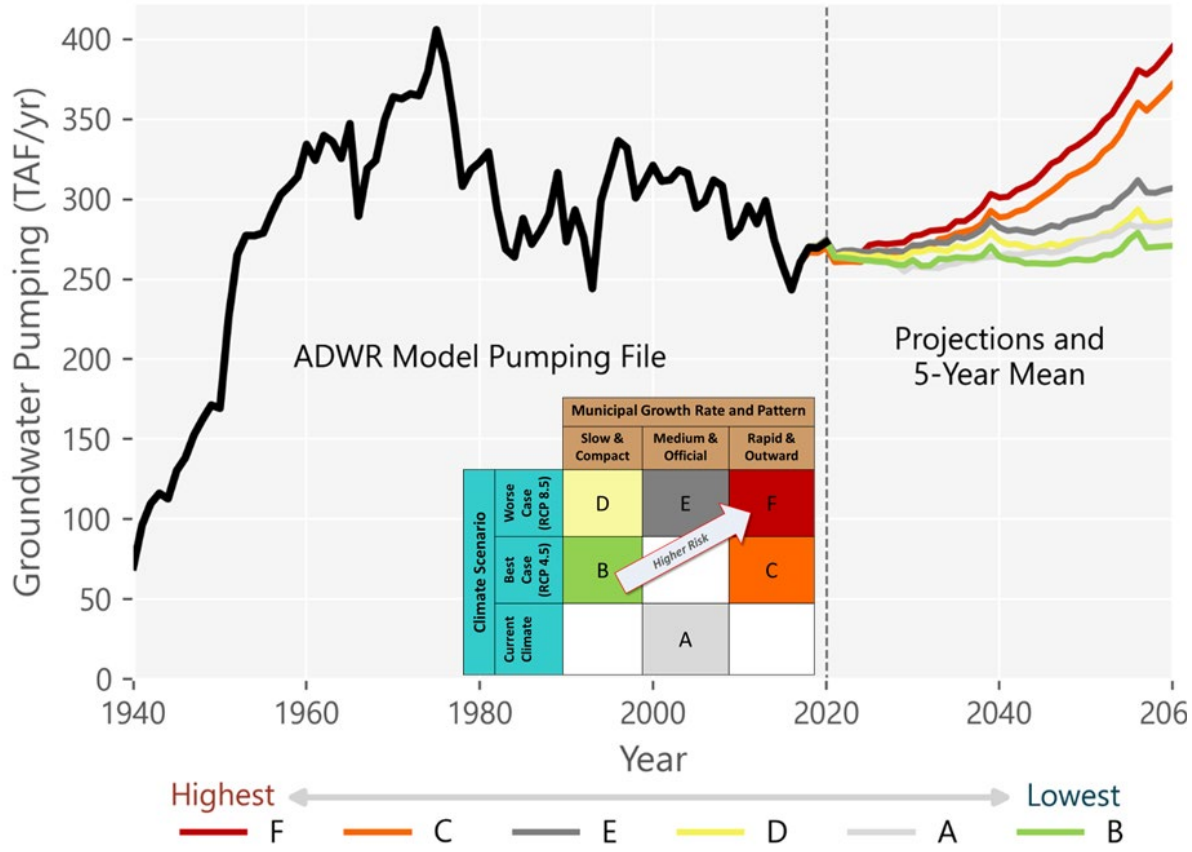


Figure 9-13 – Historical and projected annual groundwater pumping simulated in the TAMA Model.

Pumping projections by sector for the two groundwater modeling scenarios B and F are shown in Figure 9-14 and Figure 9-15, respectively. Scenario B (Figure 9-14) maintained an almost constant pumping rate over the projection period, both overall and within each sector. Scenario F showed a significant (approximately 50%) increase in pumping. Much of this increase in projected pumping under scenario F was from the municipal sector (green area in Figure 9-15) but the scenario included a 30% increase in mining demand that would take place over the period from 2025 and 2060 (dark brown area).

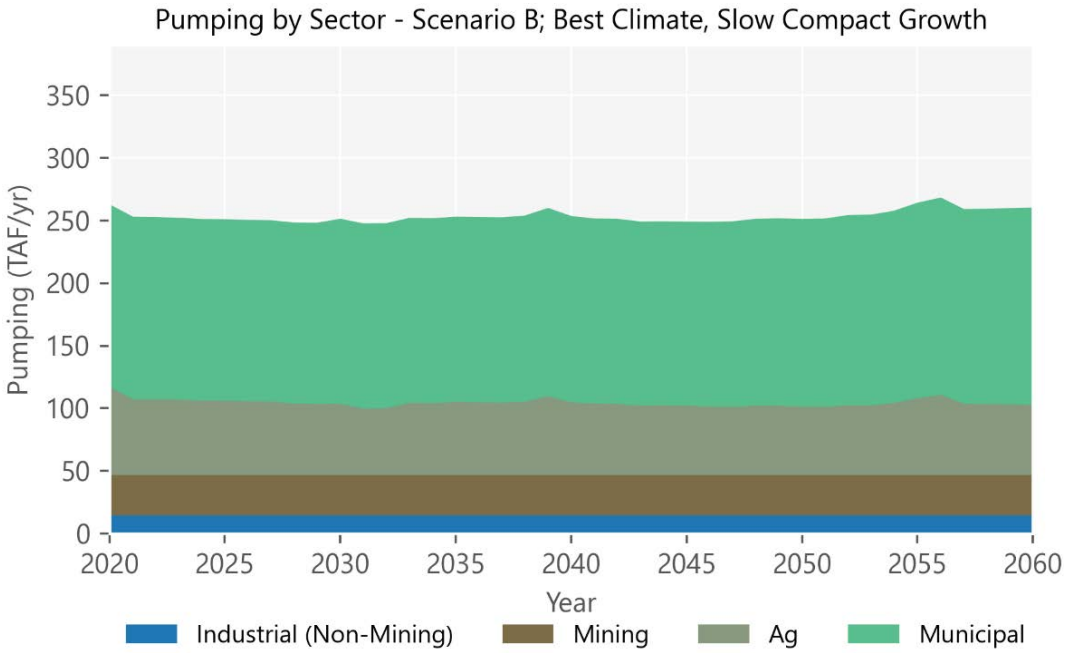


Figure 9-14 – Pumping projections by water use sector for the lowest risk groundwater modeling scenario (B).

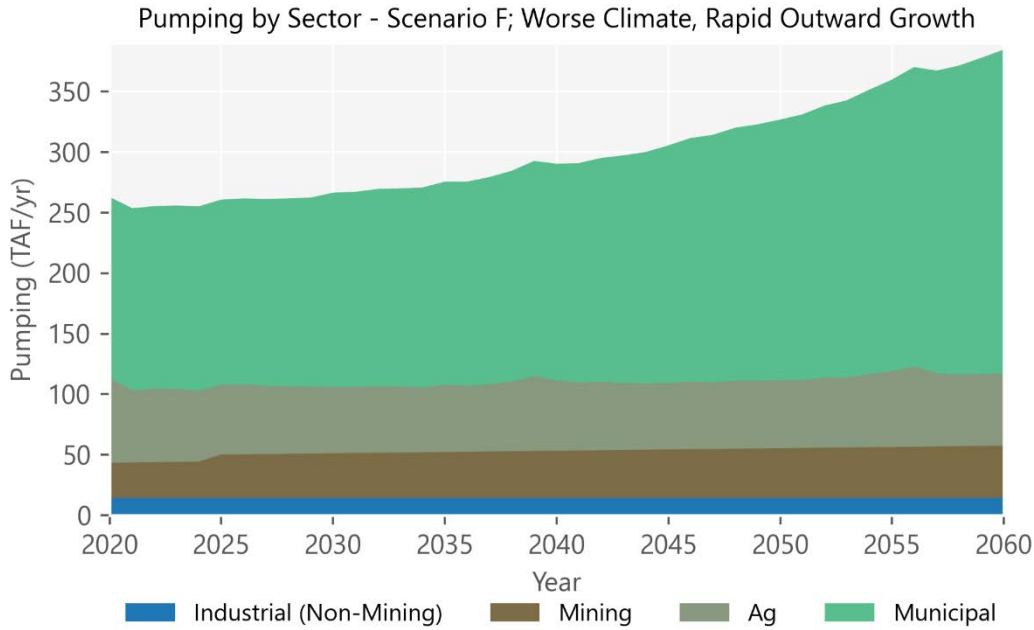


Figure 9-15 – Pumping projections by water use sector for the highest risk groundwater modeling scenario (F); includes a 30% increase in groundwater pumping for mining over the period from 2025 and 2060.

9.5 Trends in Groundwater Storage

The right-hand portion of Figure 9-16 depicts the simulated changes in groundwater storage over the projection period and exhibits grouping by climate scenario. Groundwater storage increased for all scenarios through approximately 2040. However, scenarios A, B and C (current and best-case climates) resulted in far more storage by 2060 than scenarios D, E and F (worse-case climate). Separation between scenarios D, E, and F suggests that differences in municipal growth will have an impact beginning around 2050.

The slope of the red line (Scenario F) in Figure 9-16 declines over the final 10 years of the projection period, indicating the point at which groundwater withdrawals begin to exceed natural and artificial recharge. These conditions were due to reduced streamflow infiltration and reduced artificial recharge of CAP water, as well as recovery of stored water to meet demand. The combination of these factors led to decreasing groundwater storage starting around 2050.

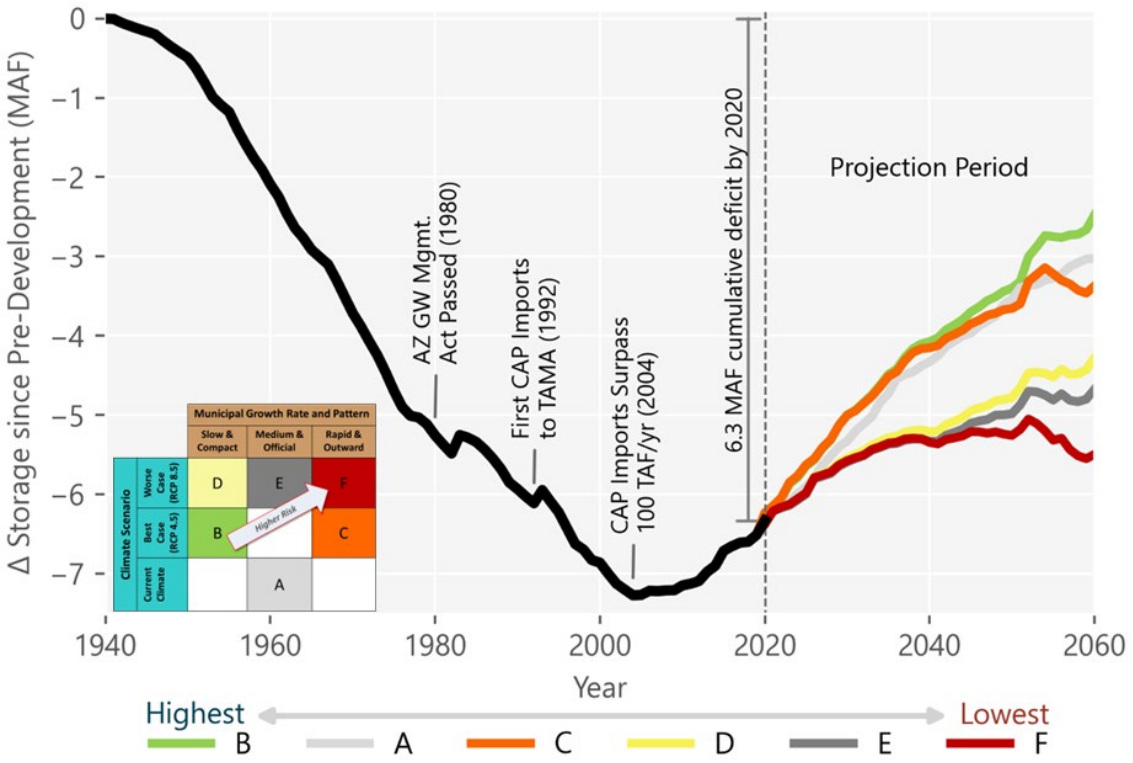


Figure 9-16 – Simulated cumulative change in groundwater storage within the TAMA since pre-development (1940). Historical period is in black with results from scenarios branching out at the start of the projection period (2020).

Under the other scenarios, total groundwater storage continues to increase through the end of the projection period. However, this does not mean that groundwater storage increases in all areas of the Tucson AMA; some areas will exhibit declines in groundwater storage while others will experience increases.

Figure 9-17 contrasts simplified groundwater budgets and the annual change in groundwater storage for scenarios B and F. For simplicity, only major sources of recharge (all except underflow) and pumping (as on average it represents 92% of the total outflow from the model) are included in these figures. The yellow lines in the first and third panels show annual recharge (inflow) to the TAMA Model domain, and the blue lines show annual groundwater pumping (outflow). When inflows exceeded outflows, there was a surplus and water was added to groundwater storage (blue shaded area in second and fourth panels). When outflows exceeded inflows, there was an overdraft and water was removed from groundwater storage (red shaded area of second and fourth panels).

For scenario B, pumping (blue line) was consistently less than recharge (yellow line) over the projection period, resulting in a consistent surplus. Under this scenario, overdraft only occurred in two years (2055-2056) when both streamflow infiltration and artificial recharge declined simultaneously (Figure 9-10).

Under scenario F, the steady increase in demand over the projection period resulted in pumping exceeding recharge by the last third of the projection period. Pumping in excess of recharge resulted in multiple years of overdraft, particularly towards the end of the projection period. However, during high streamflow years under the worse-case climate (2056, 2060), natural recharge exceeded these increased demands and resulted in surplus.

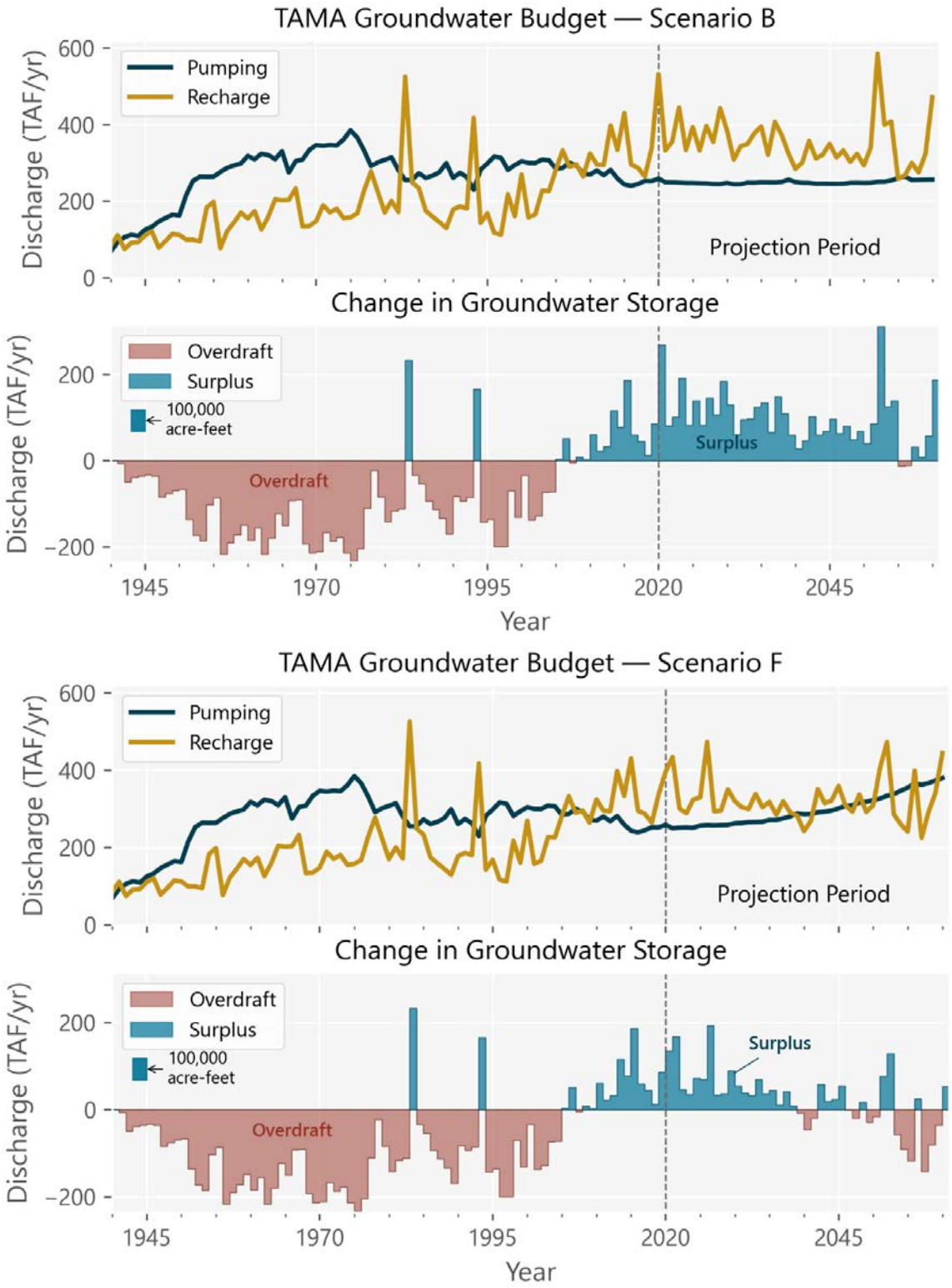


Figure 9-17 – Simplified groundwater budget and change in storage for scenarios B (lower risk) and F (higher risk). Shaded areas (blue and red) are proportional to the volume of groundwater storage change (the area for 100,000 acre-feet is noted by the legend in blue.)

These results highlight the uncertainty in the range of plausible futures resulting from the Study scenarios. Even under the highest risk groundwater modeling scenario, projected annual overdraft was consistently less than historic overdraft, except for a few years during the last portion of the projection period.

9.6 Comparison of Results by Groundwater Modeling Scenario

Maps of simulated change in groundwater levels over the projection period – i.e., the differences in water table elevation between 2060 and 2020 under each scenario – are shown in Figure 9-18. The color scale is the same across all panels, with blue areas indicating an increase in groundwater levels and red areas indicating a decrease. Comparing the results across scenarios provides insight into the spatial distribution of projected changes in groundwater heads and storage. For this broad-scale Study, groundwater head can generally be considered as the elevation of the water table.

All panels show blue shading near and along the Santa Cruz River (SCR) northwest of Tucson, indicating a rise in groundwater levels under all scenarios. This is a result of increased discharge and infiltration of reclaimed water from the Tucson area's two metropolitan water reclamation facilities along the SCR.

More intense blue shading in the far-right portion of the model domain under scenarios B and C, compared to scenarios D, E, and F, indicate projected increases in streamflow in the Tanque Verde and Rillito Creek area under the best-case climate (Bureau of Reclamation, 2021c) Figures 9-18 also shows continued propagation of the groundwater mounds in the lower left portion of the model domain. These areas are created by recharge at the Central Avra Valley Storage and Recovery Project (CAVSARP) and the Southern Avra Valley Storage and Recovery Project (SAVSARP) facilities.

Areas of groundwater table rise related to three new artificial recharge facilities are also shown under all scenarios. These new facilities include the Southeast Houghton Area Recharge Project (SHARP) to the east, Project RENEWS in the Green Valley area, and the Santa Cruz River Heritage Project in central Tucson. (Of the three, SHARP and the SCR Heritage Project are currently operating; Project RENEWS is awaiting the completion of a pipeline to transport renewable supplies). Recharge of reclaimed water from the Green Valley WRF also contributes to the groundwater rise in the Green Valley area in all scenarios.

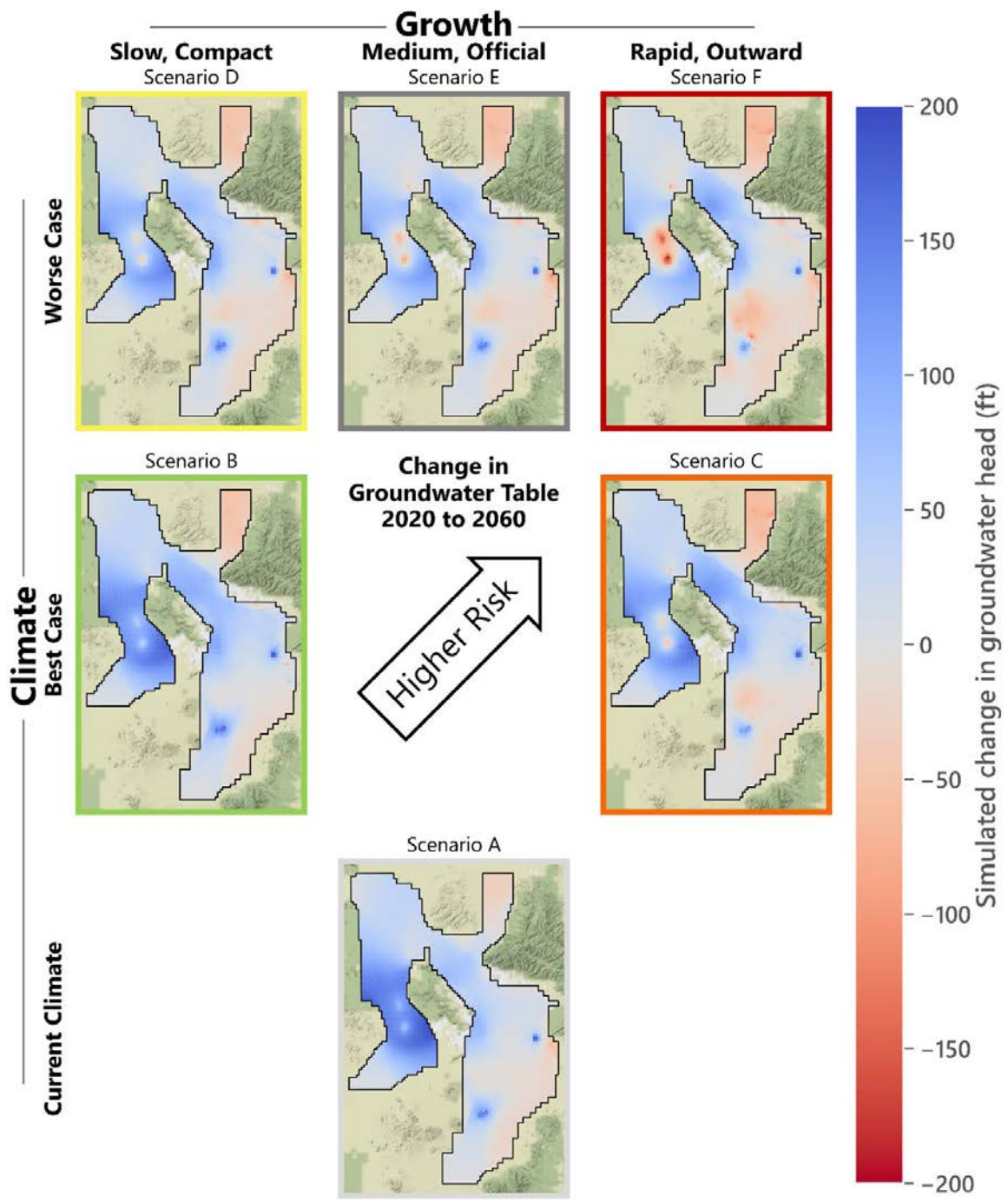


Figure 9-18 – Change in simulated groundwater levels by model cell over the projection period for each groundwater modeling scenario. Color scale is shared among all maps.

9.7 Highest Risk Scenario as a Template for Adaptation

The spatial distribution of changes in groundwater levels is key to understanding the risks to water resources and developing effective adaptation strategies. Figure 9-19 shows a map of the projected changes in groundwater head over the projection period (2020-2060) under scenario F, the scenario which is expected to require the greatest degree of adaptation. Areas of significant declines are labelled 1 – 5 and are discussed below. Maps of the recharge facilities discussed below are shown in Figure 9-7.

The Cañada del Oro/Saddlebrooke area (Area 1) shows substantial declines resulting from a projected increase in pumping of about 50% by the end of the projection period, combined with limited, intermittent natural recharge under the worse-case climate. The groundwater table around the Sabino Canyon and Tanque Verde area (Area 2) is also projected to decline slightly due to projected reductions in natural streamflow and corresponding streamflow infiltration. While small in magnitude, this decline is important because this location contains many of the LSCR Basin's remaining riparian areas that support habitat for a wide variety of plants and animals and provide recreational and aesthetic values.

Southeast Tucson (Area 3) also shows groundwater table declines. These are largely driven by projected reductions in natural streamflow and increases in pumping demand for municipal supply. While the SHARP artificial recharge facility is projected to provide some additional recharge, its impact does not propagate very far to the southeast.

Figure 9-19 also shows groundwater table declines in the Green Valley/Sahuarita area south of Tucson (Area 4). Under scenario F, mining pumping is projected to increase by 30% over the period from 2025 and 2060 and recharge at the Pima Mine Road USF is projected to decrease, due to reductions in available CAP supplies. Natural streamflow in this area is also projected to decline during the initial 30 years of the projection period, followed by some recovery during the last 10 years. These factors combined result in broad declines throughout the Green Valley/Sahuarita area.

Finally, Figure 9-19 also shows substantial groundwater table declines in Avra Valley near the CAVSARP and SAVSARP facilities (Area 5). These declines are a result of recovery of previously stored water from these facilities. This area does not require adaptation in the same sense as the other areas described above, since these impacts are result of the facilities functioning as intended. It does, however, indicate a projected decline in the stored groundwater available for future recovery.

Going forward, the regions described as "areas of concern" are referred to as: (1) Cañada del Oro/Saddlebrooke [CDO]; (2) Sabino Canyon/ Tanque Verde [SC/TV]; (3) Southeast Tucson [SET]; and (4) Green Valley [GV].

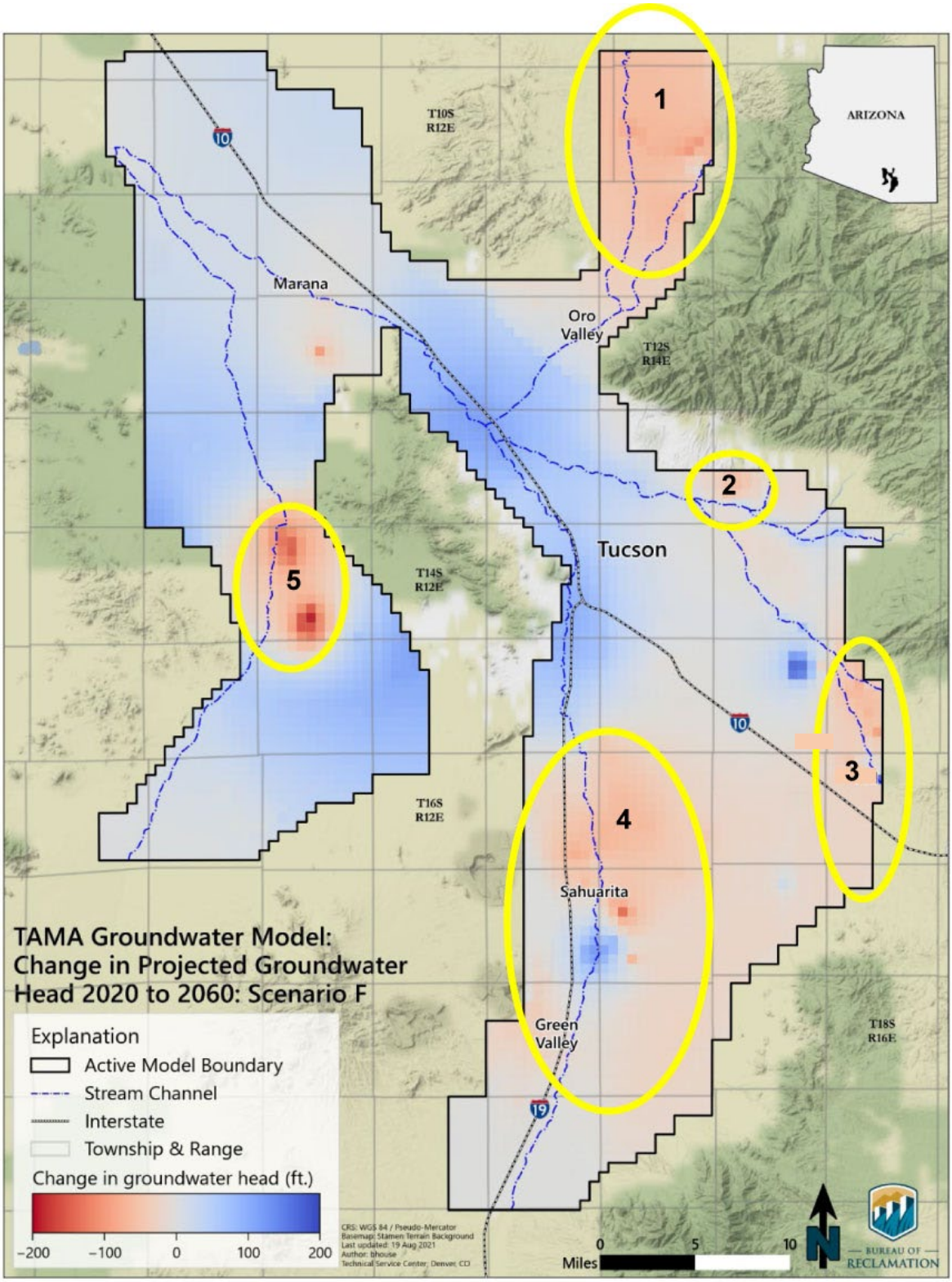


Figure 9-19 – Change in groundwater head by model cell over the Study projection period (2020-2060) for scenario F (higher risk). Areas of substantial decline are labelled 1 – 5 and are discussed individually in the text. The areas within the ovals are approximations for illustrative purposes.

9.8 Climate Impact

The difference between scenarios C and F was calculated for each model cell to evaluate the impacts of future climate on projected groundwater levels (Figure 9-20).

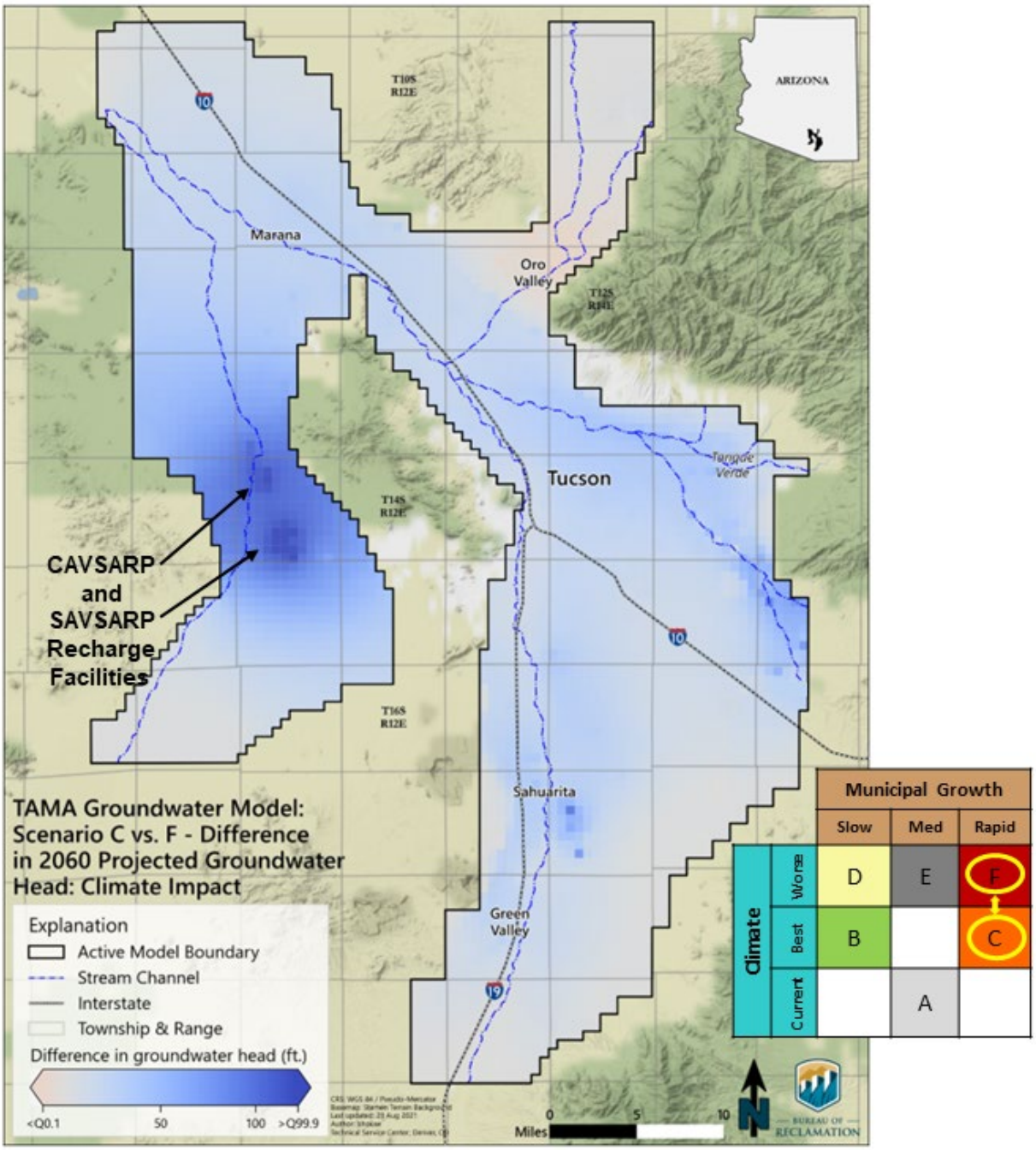


Figure 9-20 – Difference in simulated head between scenarios C and F in 2060. Blue shading indicates areas where scenario C heads are higher than scenario F, vice-versa for red. The minimum and maximum values on the color scale were set to the 0.1 and the 99.9th quantile.

Both groundwater modeling scenarios reflected rapid, outward municipal growth, with scenario C using the best-case climate and scenario F the worse-case climate. The difference in simulated groundwater levels reflected differences in both local streamflow and the availability of CAP water under an RCP 4.5 emissions scenario versus an RCP 8.5 emissions scenario. This comparison yielded similar results in projected groundwater heads and storage to a comparison of scenario B and D.

In Figure 9-20, the blue-shaded areas in Avra Valley near the CAVSARP and SAVSARP facilities receive identical recharge from natural streamflow in Brawley Wash. Differences in groundwater levels in the Avra Valley were therefore due to differences in the levels of CAP deliveries. The volume of CAP water available for recharge at the CAVSARP and SAVARP facilities is approximately 0.5 MAF greater over the projection period under the best-case climate than under the worse-case climate. More CAP water is also available to meet demands under the best-case climate, which reduced the need for recovery (pumping) of stored groundwater.

In contrast, the blue-shaded areas in the vicinities of Tanque Verde Wash, southeast Tucson and Green Valley/Sahuarita in Figure 9-20 were driven by greater recharge from natural streamflow. The best-case climate exhibited greater runoff in this portion of the LSCR Basin, which resulted in greater groundwater recharge from natural streamflow.

9.9 Municipal Growth Impact

In a similar manner, the impact of municipal growth rate and pattern, as well as additional mining demand can be evaluated by comparing results for scenarios D and F. Both scenarios reflect the worse-case climate, with scenario D representing the slow, compact municipal growth and scenario F representing the rapid, outward growth, with an 30% increase in mining demand over the period from 2025 and 2060, centered in the Green Valley area. A comparison of scenarios B and C yielded similar results.

Figure 9-21 shows the difference in projected groundwater levels in 2060 between scenarios D and F. Blue shading indicates areas where the projected groundwater table is higher under scenario D; red shading indicates areas where projected groundwater table is higher under scenario F.

The red shaded areas in Figure 9-21 indicate that the groundwater levels along the SCR northwest of Tucson were higher under scenario F (rapid, outward growth) compared to scenario D (slow, compact growth). This is due to increased population and municipal water use under the rapid, outward growth case, which resulted in increased discharge of reclaimed water to the SCR and subsequently increased recharge in this area.

Figure 9-21 also shows higher groundwater levels under scenario D compared to scenario F (blue-shaded areas) in the Avra Valley near the CAVSARP and SAVSARP recharge facilities.

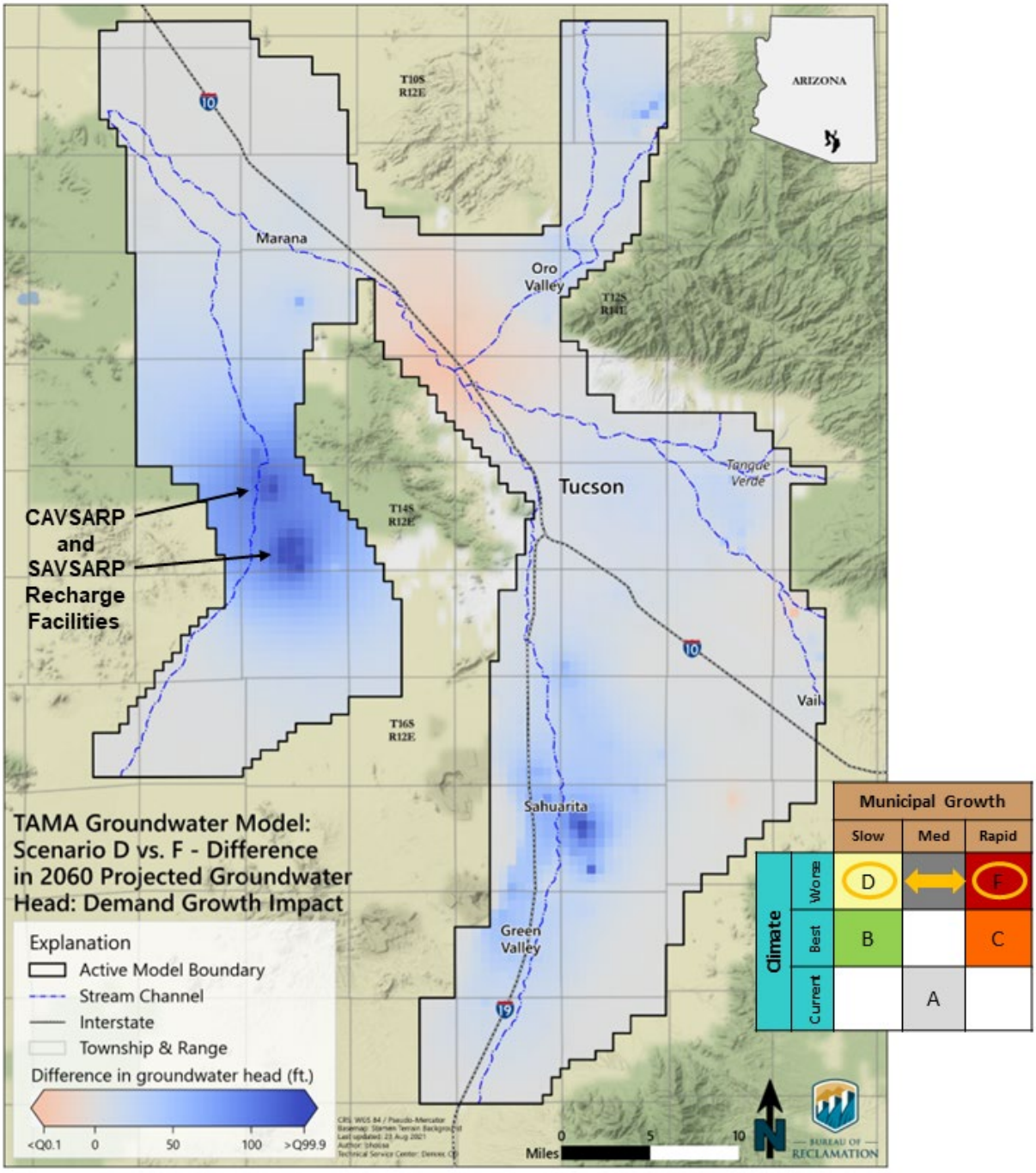


Figure 9-21 – Difference in simulated head between scenarios D and F at the end of the projection period (2060). Blue shading indicates areas where scenario D heads are higher than scenario F, vice-versa for red. Map shows the spatial impact of the different municipal growth cases.

These facilities receive nearly identical volumes of recharge over the projection period under scenarios D and F. However, lower water demands under scenario D (slow, compact municipal growth) resulted in less recovery of stored groundwater from these facilities to meet those demands.

The Green Valley/Sahuarita area, the center of mining activity in the Study Area, is also projected to have higher groundwater levels under scenario D, due to slow, compact municipal growth and constant mining demand, as opposed to Scenario F, which included a 30% increase in groundwater pumping for mining over the period of 2025 - 2060. This result underscores how changes in the mining industry demand impact the groundwater levels in this area. It should be noted that the TAMA Model is known to not perform as well in this area and is undergoing some structural changes for the next update by ADWR (Nelson & Clark, 2020). The spatial distribution of differences in the groundwater heads in this area is therefore better interpreted as a general difference over the area rather than as cell-specific changes.

9.10 Climate vs. Municipal Growth Impact

The relative impacts of climate and municipal growth on projected groundwater storage can be evaluated by comparing results from scenarios B, D, and F. Scenarios B and D share the same municipal growth scenario (slow, compact) but different climate scenarios (best-case for scenario B, worse-case for scenario D). Scenarios D and F share the same climate scenario (worse-case) but different municipal growth scenarios (slow, compact for scenario D, rapid, outward for scenario F).

Cumulative changes in groundwater storage under scenarios B, D, and F are illustrated in Figure 9-22. The difference between scenarios B and D (green area) increased more rapidly than the difference between scenarios D and F (yellow area), suggesting that differences in climate would have an impact on total groundwater storage sooner than differences in municipal growth. By the end of the projection period, about 60% of the projected change in groundwater storage was due to the influence of the climate. This result highlights the impacts of LSCR Basin-wide climate on streamflow recharge. The remaining 40% of the range was due to the difference in the municipal growth scenarios and CAP shortages.

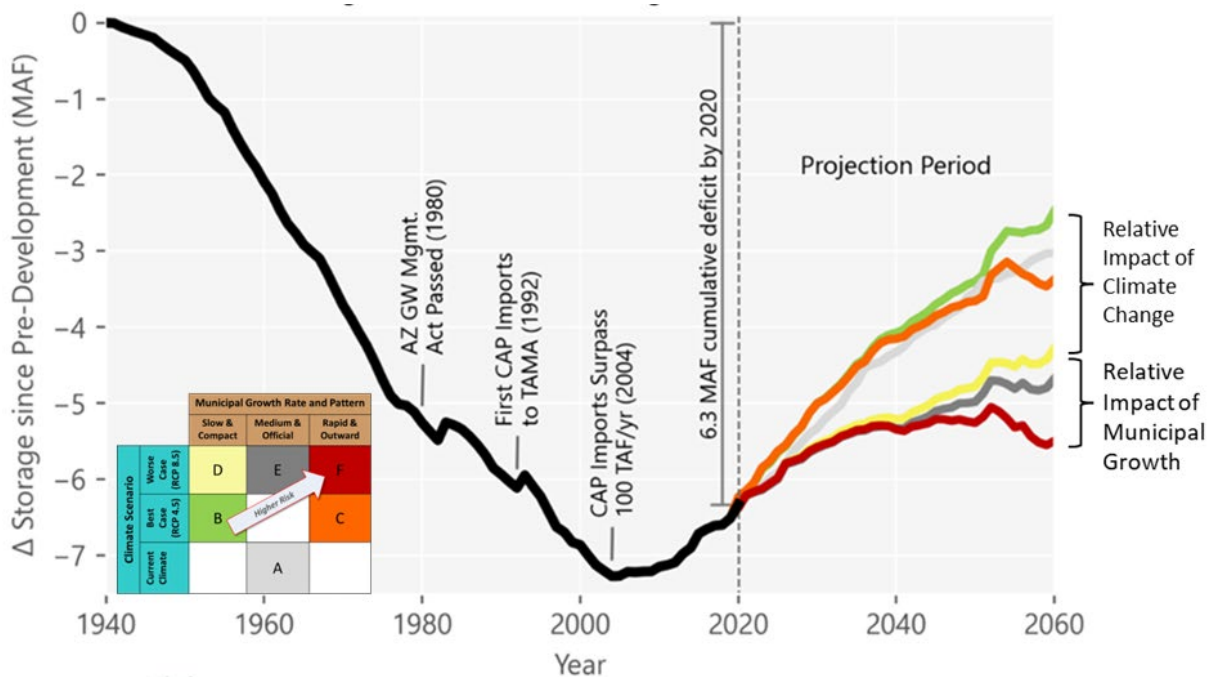


Figure 9-22 – Simulated cumulative change in groundwater storage within the Tucson AMA since pre-development (1940) for scenarios B, D, and F. Historical period is in black starting at 1980 (40 years post-commencement of the simulation). The difference between scenarios B and D represents the impact of climate, while the difference between scenarios D and F represents the impact of demand growth.

9.11 Groundwater Modeling Summary and Conclusions

From the perspective of the entire LSCR Basin, the large amount of CAP and reclaimed water stored in the aquifer provides a sizable level of resilience against Colorado River shortages and potentially reduced streamflow infiltration under climate change. This stored water can be thought of as a "savings account" on which to draw when demands exceed other supplies. How quickly this savings account will be depleted depends on two factors: (1) the extent of climate change impacts and (2) the rate and type of municipal growth that takes place within the LSCR Basin.

Local groundwater declines occurred in areas without direct access to renewable water resources under all scenarios. These localized declines were intensified under the rapid, outward municipal growth conditions. The impact of climate on these areas was driven by reduced streamflow recharge and was not as pronounced as the impact of municipal growth. These results suggest that regardless of the impacts of climate change, focusing growth in areas with physical access to renewable water resources, as opposed to areas without physical access, would have a positive impact on groundwater levels.

Chapter 10 Adaptation Strategies

10.1 Development of Adaptation Strategies

The development of adaptation strategies was a multi-step process that engaged staff from the Study Partners, as well as a wide range of local interests and individuals with subject matter expertise. Ideas for adaptation strategies were solicited at two workshops held on November 21, 2019, and February 22-23, 2022. The workshops also solicited feedback on the screening criteria to be used in the Trade-off Analysis.

The purpose of Workshop One was to brainstorm a wide variety of adaptation strategies using existing knowledge, obtain stakeholder feedback on screening criteria, and prepare to apply strategies to forthcoming groundwater model results. Strategies were based on areas known to be vulnerable to declining groundwater levels. Workshop One was held in person and utilized professional facilitators to moderate discussions and record participant responses.

Suggestions included:

- Maximizing efficient use of Central Arizona Project water within the LSCR Basin, including direct use, stream channel recharge, basin recharge, and wheeling (transporting supplies for a water provider through the unused capacity in a pipeline owned by another water provider).
- Maximizing the use of wastewater in the Tucson Active Management Area, including decentralized treatment, by extending Tucson Water's reclaimed water system, ensuring the presence of reclaimed water in the Santa Cruz River at critical times of year for supporting habitat and developing additional environmental projects using reclaimed water.
- Retrofitting low impact development and green infrastructure in existing and new neighborhoods, prioritizing low income and high flood-risk areas.
- Rainwater harvesting with cisterns to capture post-development runoff at the household level.
- Large-scale stormwater capture projects similar to the Kino Environmental Restoration Project.

The purpose of Workshop Two was to present the groundwater modeling results to the stakeholders and to refine the adaptation strategies consistent with the modeling results. Due to the COVID-19 pandemic, the second workshop was held on-line, using Zoom, for approximately six hours over a two-day period. During these sessions, break-out groups applied specific adaptation techniques to the four areas of concern identified through the groundwater modeling.

Participants specified which of the adaptation strategies developed in Workshop One would apply to specific areas of concern. Workshop Two also featured a discussion of suggested evaluation criteria for the adaptation strategies. Suggested criteria fell into three categories: Water for Society, Environmental Concerns, and Broader Considerations. Zoom polling indicated that the workshop participants were comfortable with these criteria. These categories provided a basis for the final development of criteria in partnership with Reclamation's Technical Service Center staff economist.

Summaries of the workshops and the entire suite of suggested adaptation strategies are presented in Appendices E and F.

10.2 Final Adaptation Strategies

The adaptation strategies developed for the Trade-off Analysis involved a variety of approaches. Strategies addressing specific areas of concern included: 1) transporting water resources to areas of drawdown for groundwater recharge, 2) replacing local groundwater pumping with service by Tucson Water, the area's largest provider, and 3) strategic siting of new wastewater treatment plants with facilities for recharging reclaimed water.

The analysis also considered strategies that could be applied throughout the Study Area. These included the use of parcel-level stormwater harvesting within urban areas, the construction of large stormwater detention basins to enhance recharge or provide water supplies, the restoration of uplands, and the importation of desalinated water via a pipeline from Mexico. Figure 10-1 provides a list of the adaptation strategies for each area of concern, as well as the regional strategies.

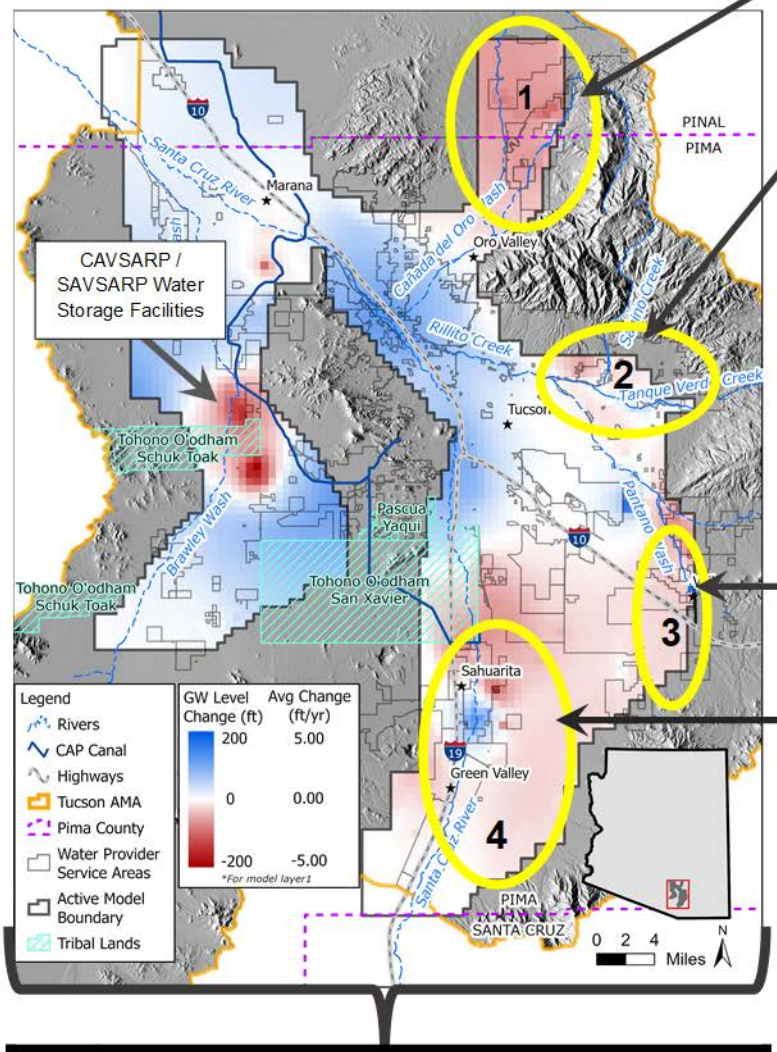
The Co-Study Managers led the effort to provide consistent information on the costs and benefits of the final adaptation strategies to inform the Trade-off Analysis. Information on the strategies came from a variety of sources. Four strategies were developed by technical experts in Reclamation's Phoenix Area Office, who provided planning-level cost estimates and analyses of environmental and cultural impacts. In other cases, local experts were consulted for capital, operations and maintenance, and treatment costs, and other project details. Several strategies were adopted from existing plans developed by local agencies, including the Pima County Regional Wastewater Treatment Department and the Pima County Regional Flood Control District. The cost and benefit analyses of the stormwater harvesting and upland restoration strategies were contributed by Partner staff.

	Canada Del Oro Adaptation Strategies
CDO-1	Convey CAP water for in-stream recharge
CDO-2	Convey recycled water for in-stream recharge
CDO-3	Construct new regional wastewater reclamation plant with in-stream recharge

	Sabino Canyon / Tanque Verde Adaptation Strategies
SC/TV-1	Extend reclaimed water system to replace outdoor potable uses, support environmental needs
SC-TV-2	Replace municipal provider groundwater pumping with wheeled renewable supplies
SC/TV-3	Replace groundwater pumping by private wells with renewable supplies from municipal provider

	Southeast Tucson Adaptation Strategies
SET-1	Wheel renewable supplies to small providers without direct physical access to CAP
SET-2	Phased construction of regional wastewater reclamation facilities with recharge of recycled water

	Green Valley Adaptation Strategies
GV-1	Extend Farmers Investment Company (FICO) Groundwater Savings Facility
GV-2	In addition to GV-1, extend pipeline for environmental enhancement in agricultural off-season
GV-3	Construct new regional wastewater reclamation plant with in-stream recharge



	Regional Adaptation Strategies
REG-1	Site-based Stormwater Management using Low Impact Development Methods
REG-2	Large Stormwater Multi-purpose, Multi-use Basins and Channels
REG-3	Upland Restoration
REG-4	Desalination of Ocean Water with Pipeline from Sea of Cortez, Mexico

Figure 10-1 – Projected groundwater level changes between 2020 and 2060 under Scenario F (worse-case), with areas of concern: 1. Cañada del Oro/Saddlebrooke (CDO), 2. Sabino Canyon/ Tanque Verde (SC/TV), 3. Southeast Tucson (SET), and 4. Green Valley (GV) and associated adaptation strategies.

10.3 Adaptation Strategy Descriptions by "Area of Concern"

10.4.1. Cañada Del Oro/Saddlebrooke adaptation strategies

The three adaptation strategies developed for the Cañada del Oro/Saddlebrooke area focused on in-stream recharge of a new water source. For CDO-1, the recharge volume was assumed to be 5,000 acre-feet per year of new CAP water imported into the Study Area. In CDO-2, the additional source was 10,000 acre-feet per year of reclaimed water recovered from the Santa Cruz River diverted downstream of the reach that is designated as an Underground Storage Facility (past the Trico Road gage). Strategy CDO-3 envisioned a new regional wastewater treatment plant to serve new growth that would discharge 1,120 acre-feet per year of reclaimed water into the Cañada del Oro channel.

Groundwater modeling was performed to determine the extent of a one-foot level groundwater rise, assuming the facility was operated from 2020 -2060. Modeling results are shown below. Full cost information is available in the Adaptation Strategies Technical Memorandum.

In the case of two areas of concern, the Cañada del Oro/Saddlebrooke area and the Green Valley area, there was sufficient information on the volume of water and siting of recharge facilities to model the impact on future groundwater levels. To simplify this analysis, it was assumed that the adaptation strategy would start in 2020 and continue at a constant rate through 2060. Maps showing the boundary of a one-foot water level rise are presented as Figure 10-2, Figure 10-3, and Figure 10-4. For the other strategies, the additional water supplies were deemed too small to make a significant impact on groundwater levels, or not enough information was available to perform groundwater modeling.

10.4 Final Evaluation Criteria

Reclamation TSC Economist Dr. Matthew Elmer reviewed the list of suggested evaluation criteria and helped the Project Team narrow the criteria down to the final ten. His considerations in narrowing the criteria included the following:

- Do evaluation criteria capture the important expected effects of the strategies?
- Do the criteria help distinguish between strategies?
- Is there overlap among the criteria?
- Are the criteria of equal importance?
- Are the criteria quantitative or qualitative?

The final criteria are summarized below in Table 10-1. Three criteria were able to be monetized; the remaining seven relied on quantitative evaluation by the Trade-off Analysis participants. Depending on whether criteria could be considered a cost, a benefit, or both, qualitative criteria scored on a scale of either 0 to 3 (benefit); -3 to 0 (cost), or -3 to 3 (cost-benefit). It should be noted that the "Water Availability and Reliability Benefit" specifically refers to economic

benefits that would be realized by municipal and industrial users. Benefits to the environment are captured in other criteria such as aquifer benefit, quality of life benefit, riparian impact, water quality, and flood risk impact.

Table 10-1 – List of Final Evaluation Criteria for Trade-off Analysis

Criterion	Description	Measurement	Directionality
(1) Water Supply Reliability Benefit	Benefit from reducing future shortages anticipated for the Study Area.	Monetized	Benefit
(2) Capital Cost	Cost of construction or implementation (upfront cost).	Monetized	Cost
(3) O&M Cost	Cost of operation and maintenance (ongoing cost).	Monetized	Cost
(4) Aquifer Benefit	Improvements in groundwater levels to reduce pumping costs, prevent subsidence, or improve general aquifer condition.	0 to 3	Benefit
(5) Quality of Life Benefit	Improvements in recreation, aesthetics, health, safety, heat island effect, or cultural resources.	0 to 3	Benefit
(6) Leverage Existing Resources	Utilizes or enhances existing investments or infrastructure.	0 to 3	Benefit
(7) Barriers to Implementation	Obstacles from public perception, regulations, administrative complexity, or physical limitations.	-3 to 0	Cost
(8) Riparian Impact	Changes to riparian habitat and conditions.	-3 to 3	Cost/Benefit
(9) Water Quality Impact	Changes in the chemical, physical, or biological characteristic of water resources.	-3 to 3	Cost/Benefit
(10) Flood Risk Impact	Changes in flood risk (probability or consequences).	-3 to 3	Cost/Benefit

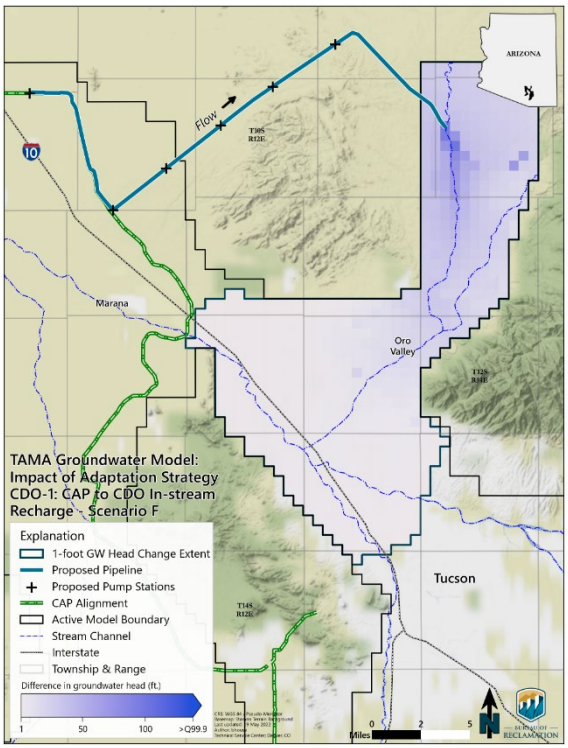


Figure 10-2 – Groundwater Model impact of Adaptation Strategy CDO-1, Recharge of 5,000 AFY of CAP water.

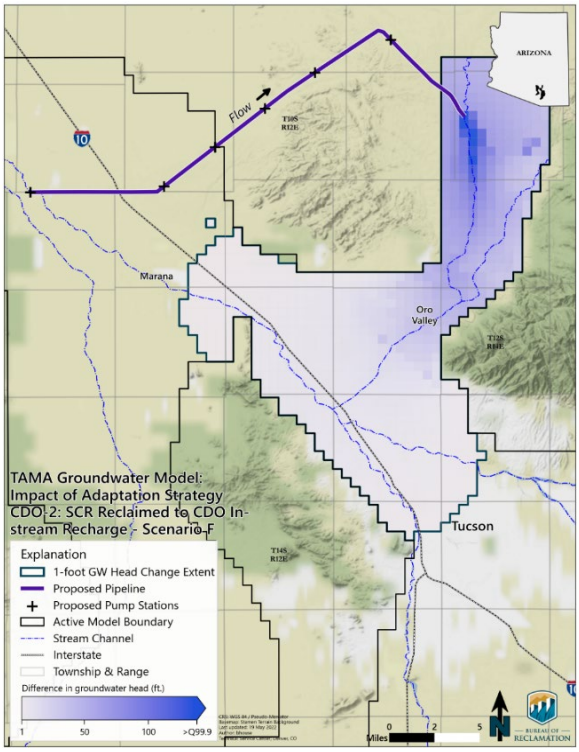


Figure 10-3 – Groundwater Model impact of Adaptation Strategy CDO-2, Recharge of 10,000 AFY of reclaimed water. Note enhanced impact of additional recharge.

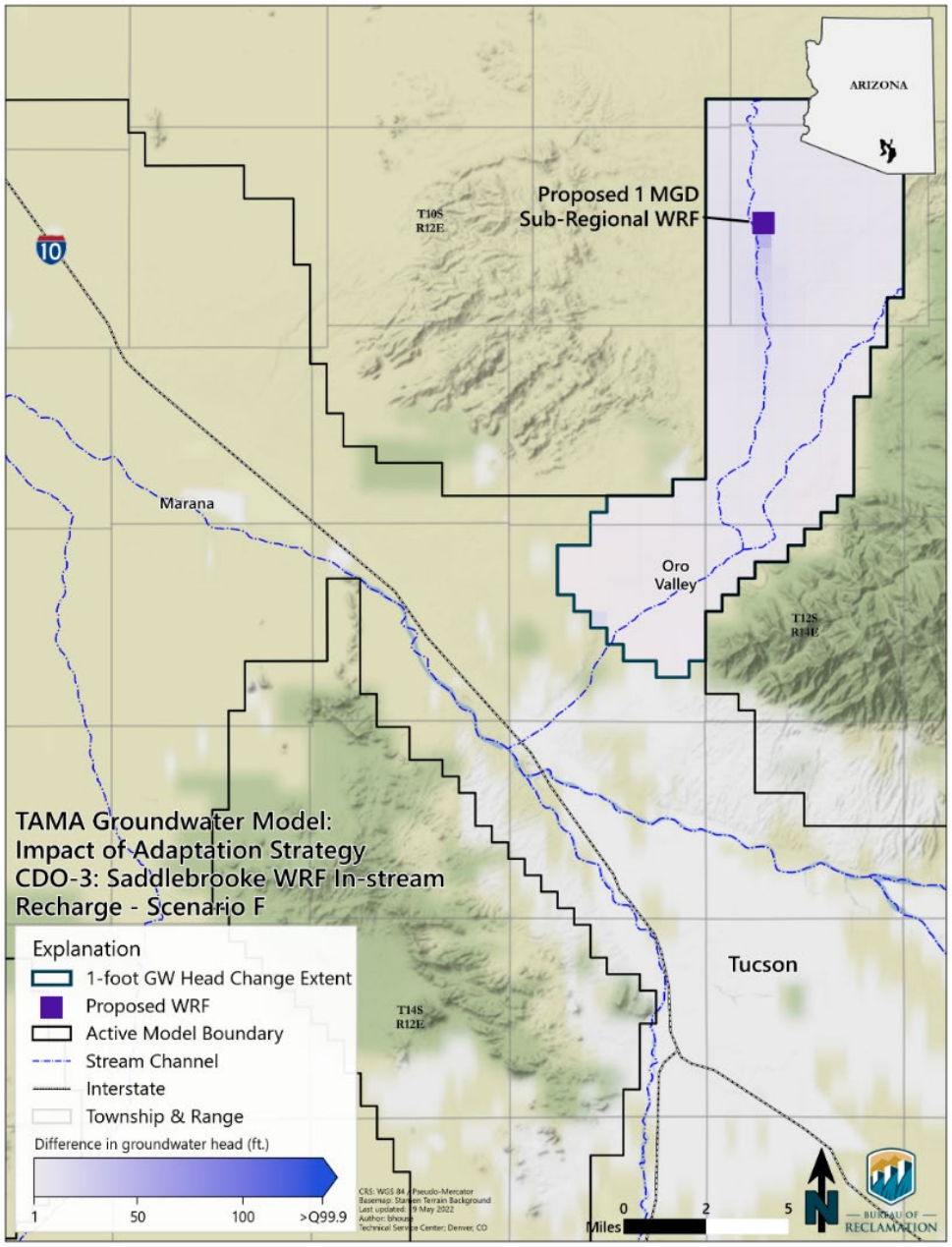


Figure 10-4 – Groundwater Model impact of Adaptation Strategy CDO-3, New regional wastewater treatment plant with reclaimed water discharge of 1,120 AFY.

10.4.2. Sabino Canyon/Tanque Verde adaptation strategies

The Sabino Canyon/Tanque Verde area features some of the LSCR Basin's remaining riparian habitat, some of which are also popular recreational sites. This area is different from the other areas of concern because the amount of groundwater pumping is limited. Most pumping occurs to support the small Hub portion of the Metro Water District, or by private wells associated with specific properties that can legally pump up to 35 gallons per minute. In addition, the aquifer is very shallow in this area.

Adaptation strategies for this area focus on reducing groundwater pumping, replacing the use of potable supplies outdoors and supporting riparian vegetation.

Strategy SC/TV-1 was contributed by partners with expert knowledge of environmental needs in this area. The strategy would consist of a new section of pipeline connecting to Tucson Water's Reclaimed Water System (Figure 10-5). It would supply reclaimed water to two sites that still use potable water for outdoor use and bring supplemental irrigation to the mesquite bosque at the Isabella Lee Natural Riparian Preserve.

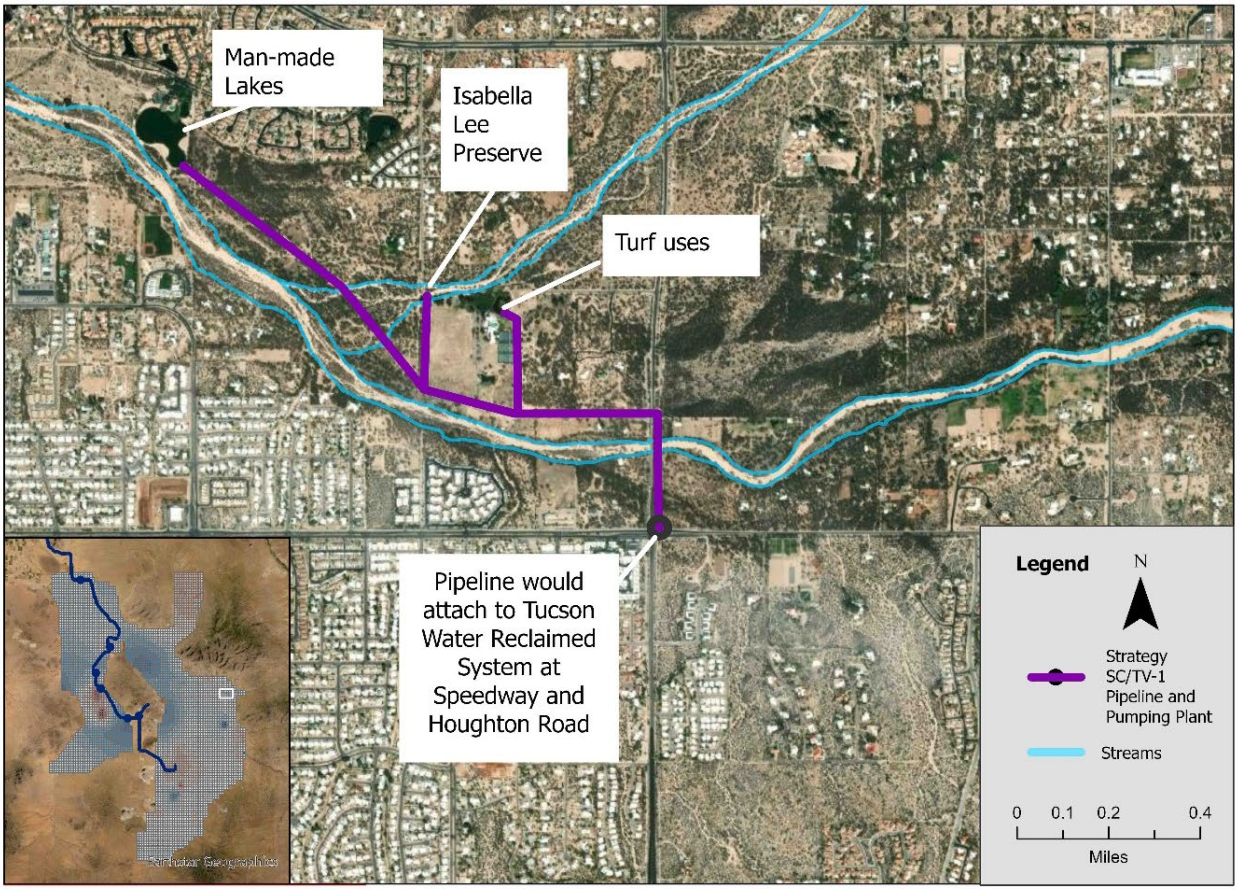


Figure 10-5 – Adaptation Strategy SC/TV-1 - Extend reclaimed water system to replace outdoor potable uses, support environmental needs.

Adaptation Strategy SC/TV-2 would involve wheeling a portion of the Metro Water District's Central Arizona Project water from its recharge facility through Tucson Water's infrastructure to replace the groundwater wells currently serving Metro Water's Hub service area (Figure 10-6). In other words, Tucson Water's infrastructure would be used to transport Metro Water's CAP water to customers in the Metro Water Hub service area. Strategy SC/TV-3 would substitute groundwater pumping by private wells within the Tucson Water service area with service from Tucson Water (Figure 10-7).

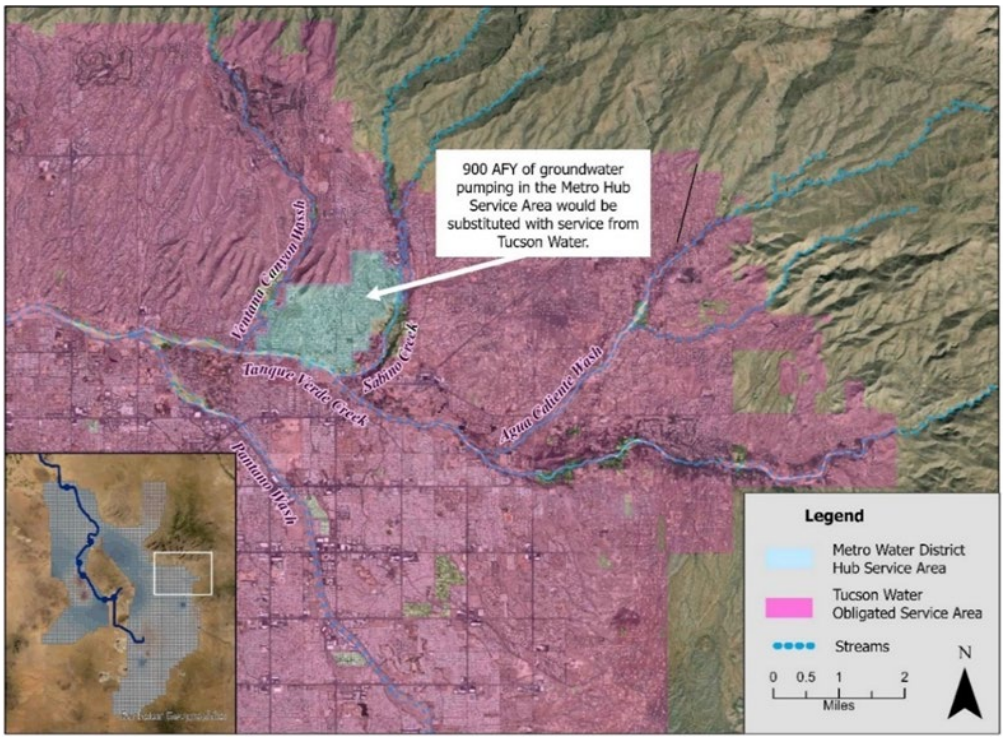


Figure 10-6 – Adaptation Strategy SC/TV-2 – Wheel renewable supplies belonging to other providers via Tucson Water infrastructure.

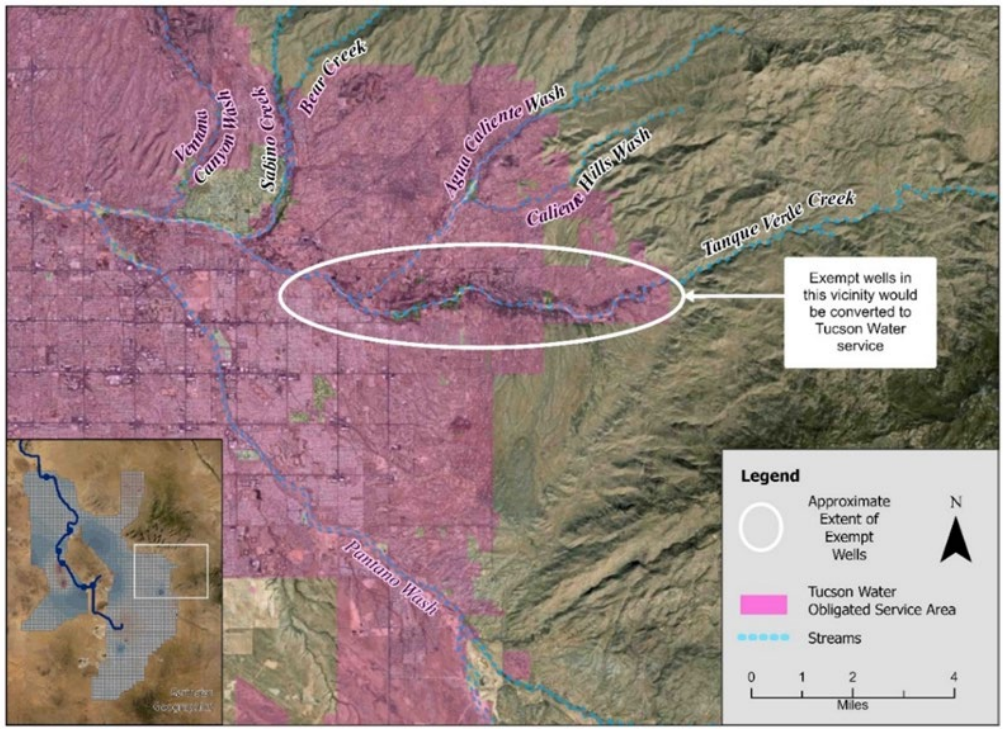


Figure 10-7 – Adaptation Strategy SC/TV-3 - Replace groundwater pumping by private wells within the Tucson Water service area with service from Tucson Water.

10.4.3. Southeast Tucson adaptation strategies

The Southeast Tucson Area of Concern is similar to the Sabino Canyon/Tanque Verde area with regard to the presence of lush riparian areas, as well as its geography on the very edge of the LSCR Basin. It is also the site of new development and lacks direct physical access to renewable supplies, other than a very small amount of reclaimed water. Adaptation Strategy SET-1 is similar to SC/TV-2 in that it would utilize Tucson Water's infrastructure to wheel renewable supplies to these communities, instead of recharging in state-certified facilities (Figure 10-8).

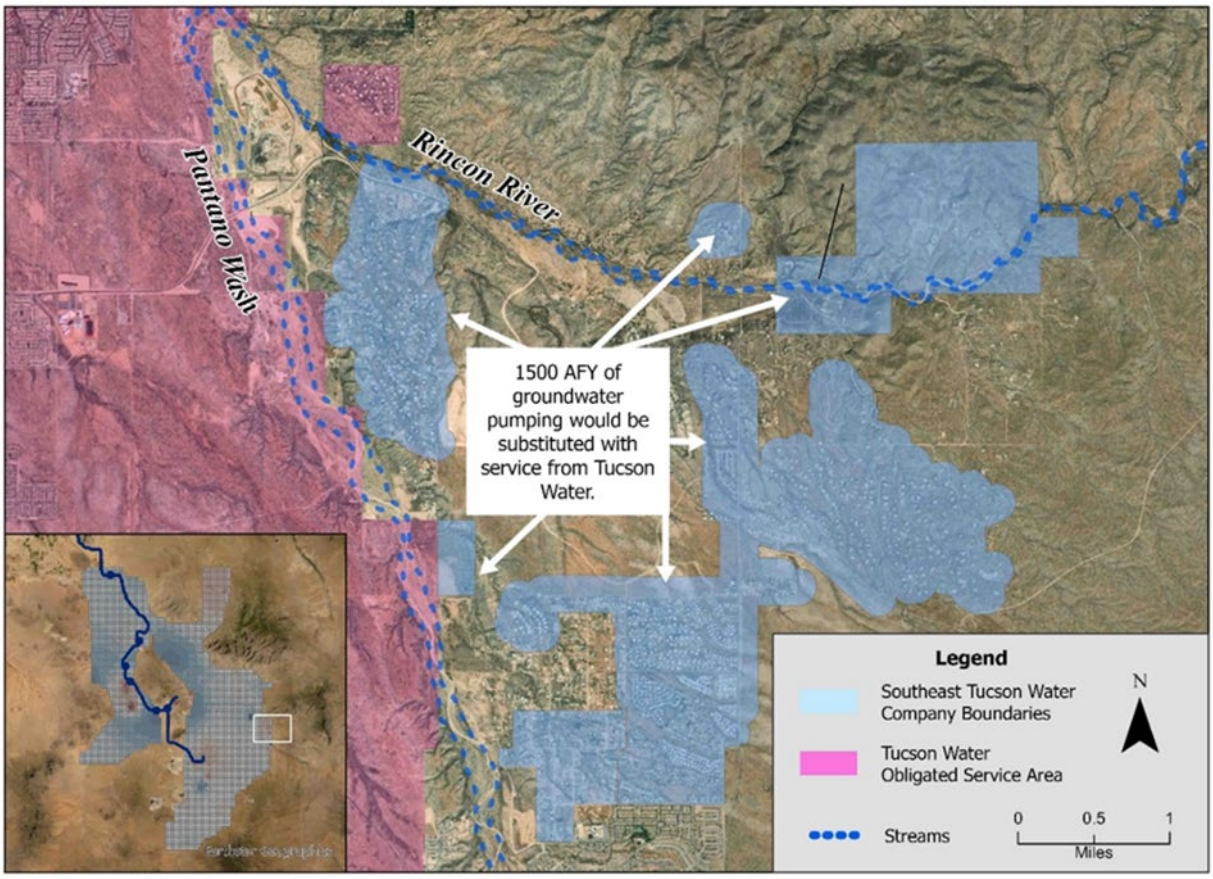


Figure 10-8 – Adaptation Strategy SET-1 - Wheel renewable water supplies belonging to small, outlying providers without physical access to renewable supplies, utilizing Tucson Water infrastructure.

Adaptation Strategy SET-2 (Figure 10-9) is adapted from a Pima County Regional Wastewater Reclamation Department plan to construct a new regional wastewater treatment plant with a recharge facility in this area. The facility is expected to discharge 2,700 AFY of reclaimed water in 2030, increasing to 6,700 AFY in 2060.

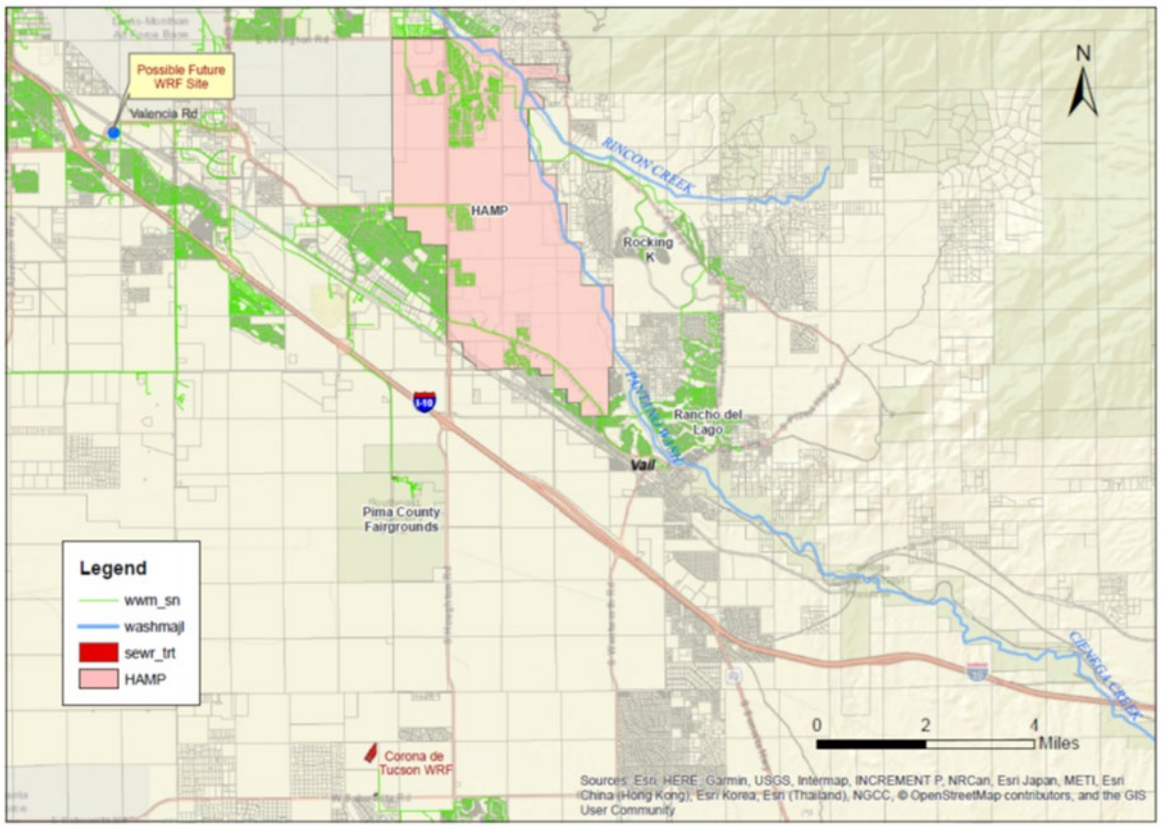


Figure 10-9 – Adaptation Strategy SET-2 - Site new regional wastewater treatment plant per Pima County Regional Wastewater Reclamation Department Plan.

10.5 Green Valley/Sahuarita adaptation strategies

In the Green Valley/Sahuarita Area of Concern, most groundwater pumping supports either agriculture or mining, as opposed to residential uses. Recently a new groundwater savings facility was established in the northern portion of pecan orchards operated by the Farmers Investment Company, or FICO. A pipeline nicknamed “F-CAP” extending from the CAP terminus to the north end of the FICO orchards allows this farm to substitute renewable CAP water for groundwater. Adaptation Strategy GV-1 envisions an extension of this F-CAP pipeline to the southern portion of the FICO orchards (Figure 10-10).

Adaptation Strategy GV-2 would extend this pipeline even farther south to the historic Raul M. Grijalva Canoa Ranch Conservation Park. During the irrigation off-season, this pipeline could supply CAP water for recharge to this historic site for restoration purposes. Groundwater modeling simulation of the impacts of these strategies is shown in Figure 10-11.

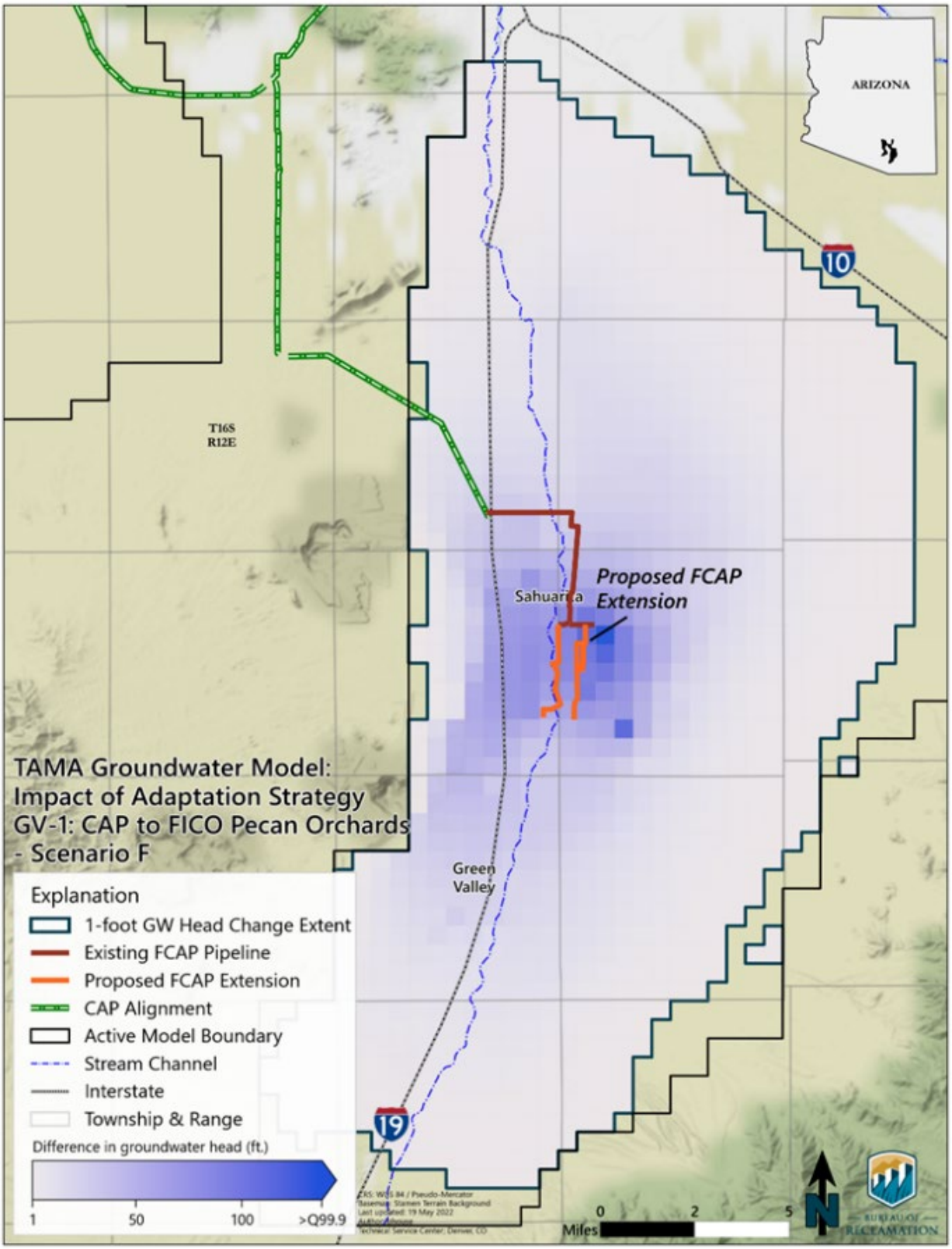


Figure 10-10 – Adaptation Strategy GV-1 – Extend FICO Groundwater Savings Facility F-CAP pipeline to transport CAP water to additional orchards in lieu of irrigation with groundwater.

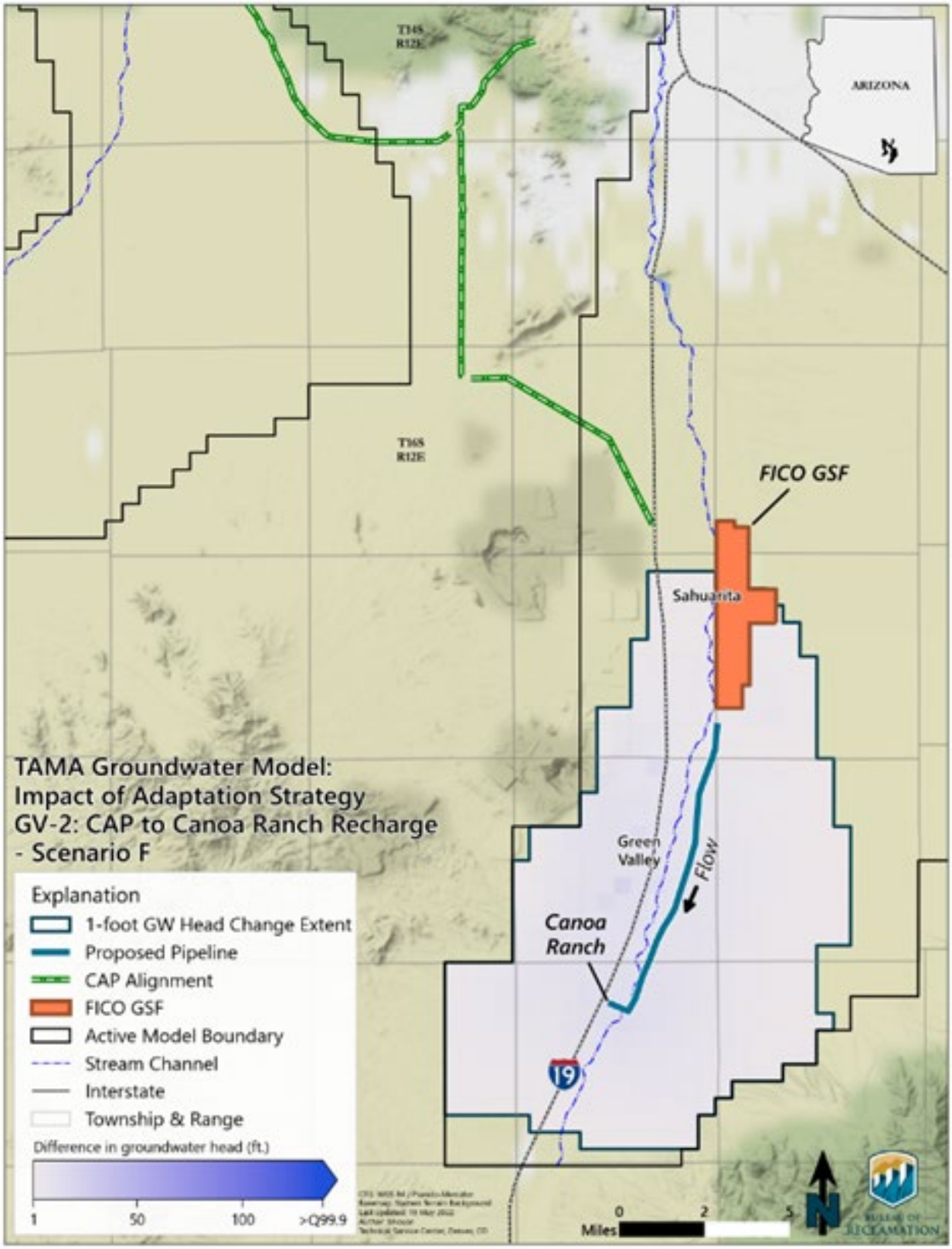


Figure 10-11 – Adaptation Strategy GV-2 – Extend FICO GSF pipeline to Canoa Ranch for recharge into basins in the winter months (when pipeline is not needed for irrigation).

Figure 10-12 is reproduced from the Pima County Regional Wastewater Reclamation Department's 2016 Wastewater Facility Plan. Similar to SET-2, Strategy GV-3 envisions a regional wastewater treatment plant in the Green Valley area with an associated recharge facility. Recharge of reclaimed water from this facility would offset groundwater decline due to pumping.

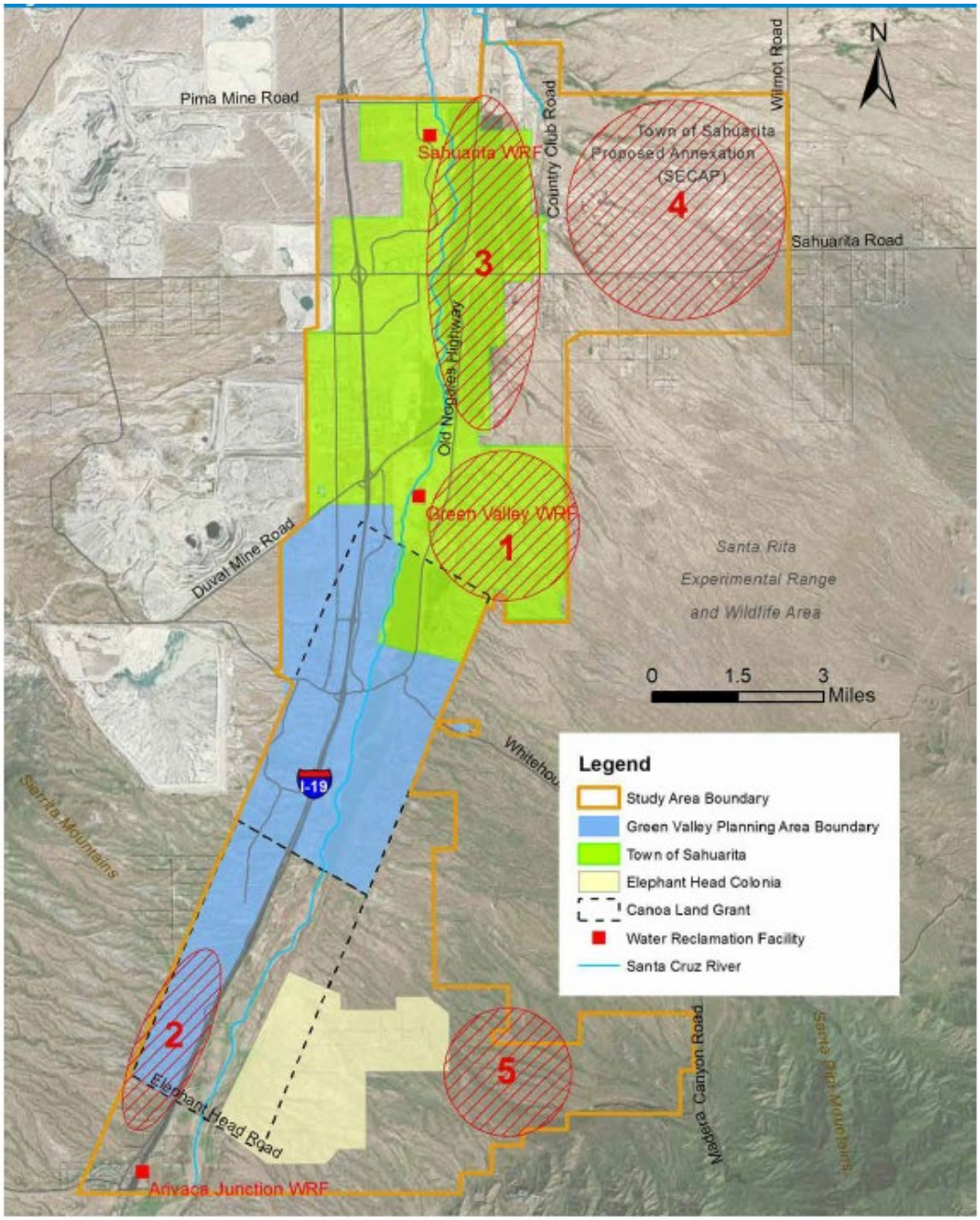


Figure 10-12 – Adaptation Strategy GV-3 - New regional wastewater treatment plant with recharge facility (source, PCRWRD 2016 Wastewater Facility Plan, Figure B-5, page 158). The orange boundary shows PCRWRD's Green Valley Study Area. The red, cross-hatched areas have been identified as vacant lands with a high potential for future development.

10.6 Regional Strategies

Regional Adaptation Strategy 1, or REG-1, consists of stormwater management at the lot level using Low Impact Development. This strategy entails offsetting non-renewable water supplies with renewable stormwater. Figure 10-13 shows examples of water management methods included in REG-1. Restoration features would be constructed to utilize storm and rainwater resources generated from impervious surfaces to increase infiltration and soil moisture in urban areas; they could consist of:

1. Features that catch and direct rainfall or stormwater runoff to facilities that store or utilize the harvested water:
    a. Berms, swales, or check dams
    b. Collector pipe/inlets, like curb cuts, downstream of impervious surfaces
    c. Infiltration structures such as bioretention basins and porous surfaces
    d. Desert-adapted vegetation for landscape

2. Storage features that offset existing demand for potable water or reclaimed water:
    a. Cisterns or rain barrels to store rainwater
    b. Constructed basins to infiltrate the water or hold it for later use

Figure 10-13 – Examples of Adaptation Strategy REG-1 - constructed basin (left) and rain harvesting with 2,500-gallon collection tank (right).

Regional Adaptation Strategy 2, or REG-2 consists of stormwater multi-purpose, multi-use basins and channels. An example of this type of strategy is the Pima County Kino Environmental Restoration Project (KERP), pictured in Figure 10-14.

Figure 10-14 – Adaptation Strategy REG-2 - Passive recreation for bird watching (left) and active recreation (baseball and soccer, right).

This strategy would construct large multi-benefit basins and channels that collect and slow down stormwater to allow for infiltration and percolation into the vadose zone and groundwater system. Large multi-use stormwater basins and channels, whether they are for retention or detention, collect stormwater from impervious areas to mitigate flooding, reduce pollutants in urban runoff, store water in lined basins for later use, or aid habitat restoration.

Regional Adaptation Strategy 3 consists of stormwater management using upland restoration techniques. Examples are pictured in Figure 10-15.

Figure 10-15 – Adaptation Strategy REG-3 - Check dam, November 2009 (left) and December 2020 (middle) (Nichols, M.H., Polyakov, V.O., Nearing, M.A., Hernandez M, 2016); Rainwater collector (right) by Arizona Trail Association

The goal of this strategy is to improve watershed resilience to support environmental water needs. Small, distributed features would be constructed to improve environmental conditions in uplands. Stormwater and rainwater harvesting, natural channel design, and erosion/grade control techniques would be used to restore, protect, and enhance surface water resources.
Features could include:

1. Stormwater Rock Detention: Construct check dams, media lunas, zuni bowls, and other grade control structures using rocks (earthworks). Utilize passive stormwater harvesting to provide ephemeral water sources for wildlife tanks. Use natural channel design, such as induced meander, in arroyos, tributaries and mountain-front creeks.

2. Wildlife Drinkers: Where consistent water is needed for wildlife and hiking safety, use active rainwater harvesting cisterns to sustain spring habitat, ponds, wildlife drinkers, and ranch tanks. Utilize active rainwater harvesting to provide sustained water sources for wildlife tanks.

Appropriate locations include undeveloped (or less developed) tributaries, headwaters, and mountain-front systems near springs or perennial and intermittent streams with riparian habitat and perched/shallow groundwater.

Regional Adaptation Strategy 4 consists of water supply augmentation with desalinated water from the Sea of Cortez. Figure 10-16 presents a conceptual map of this strategy. This project would augment Pima County water supplies by 100,000 acre-feet per year by constructing a pipeline to transport desalinated ocean water from the Sea of Cortez in Mexico to the Southern Avra Valley Storage and Recovery Project (SAVSARP) in Tucson. A desalination facility would be constructed near Puerto Libertad, Mexico. The 196-mile pipeline would require five pump stations for elevation lift of 3,853 feet from Puerto Libertad to Tucson. The pipeline would follow a 36-inch natural gas pipeline through Northern Mexico (north of Altar Municipality) to Avra Valley. Power is available through 240 kilovolt (kV) electrical transmission lines that run north from Puerto Libertad to serve the communities of Caborca and Altar.

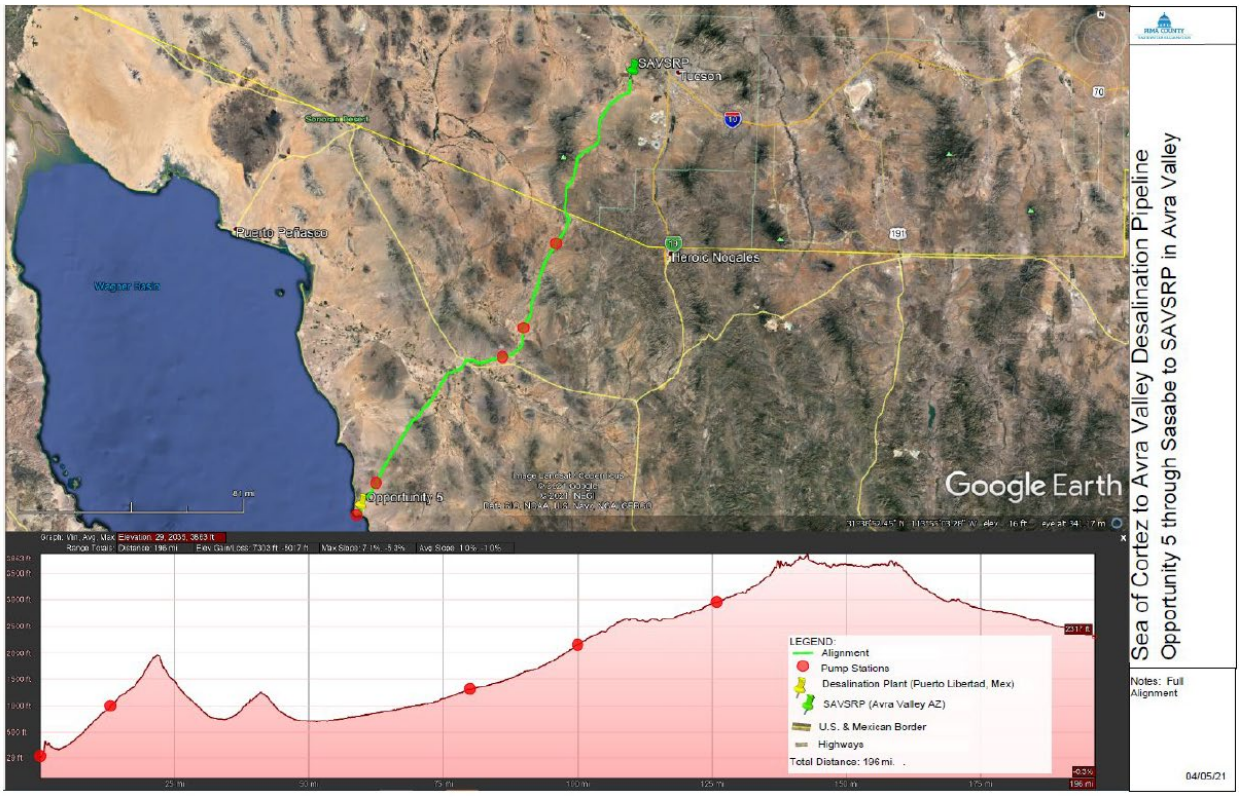


Figure 10-16 – Adaptation Strategy REG-4 - Pipeline from Puerto Libertad, Mexico to Pima County, Arizona (adapted from Pima County Board of Supervisors Memorandum).

Appraisal level information on the costs and benefits of each of these strategies was compiled and is presented in the Adaptation Strategies Technical Memorandum, Appendix F. In the next step of the Study, each strategy was evaluated by staff of the Study Partners to develop the Trade-off Analysis.

Chapter 11 Economic and Trade-off Analyses

11.1 Introduction

This chapter describes the Economic and Trade-off analyses of the LSCR Basin Study's adaptation strategies. An economic analysis generally compares monetized costs and benefits to examine whether the total benefit outweighs the total cost for an action, indicating whether the action is considered economically feasible. A preliminary-level economic analysis is provided here to assess the adaptation strategies considered for the LSCR Basin Study. The analysis included the cost of construction, the cost of operation and maintenance (O&M), and the water reliability benefit associated with each strategy. For select strategies, a groundwater pumping benefit was also calculated.

All monetary estimates are at a preliminary level and for a 40-year period of analysis. This analysis also excluded several costs and benefits that could not be monetized. While an economic analysis was not required for Basin Studies, the analysis can inform more detailed future assessments of the strategies.

A trade-off analysis is broader than an economic analysis and allows for both quantified and unquantified effects to be systematically evaluated together in a single assessment, considering a diverse range of impacts along economic, environmental, and social dimensions. A trade-off analysis is a mandatory component of a Basin Study and serves to identify the strengths and weaknesses of each adaptation strategy. A trade-off analysis is also consistent with the Council on Environmental Quality Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies (PR&G) for evaluating water resource projects, which recommends considering both quantified and unquantified measures (Bureau of Reclamation, 2016).

Building from the Economic Analysis, a trade-off analysis was conducted to evaluate the performance of each adaptation strategy with monetized costs and benefits, as well as additional criteria measured qualitatively using a low to high scale. The Trade-off Analysis served as a screening tool to identify which adaptation strategies warrant further consideration.

11.2 Existing Guidance

Under Reclamation Guidance, a trade-off analysis examines proposed strategies in terms of their ability to meet the Study objectives, the extent to which they minimize imbalances between water supply and demand and address the possible impacts of climate change, the level of stakeholder support, the relative cost (when available), the potential environmental impacts, or other attributes common to the strategies. The analysis also identifies potential institutional,

legal, and regulatory constraints affecting the strategies and possible next steps. When available, existing information must be used to satisfy the required elements.

The Trade-off Analysis conducted for the LSCR Basin Study is consistent with these requirements and included both quantitative and qualitative measures, relying on both existing and new information.

11.3 Adaptation Strategies

A total of 15 adaptation strategies were evaluated as part of the Trade-off Analysis. Some of these strategies were developed for the LSCR Basin Study, while others were developed previously for other purposes.

The broad array of strategies considered made it challenging to compare strategies in a consistent manner. The strategies reflected supply-side and demand-side approaches, structural and non-structural courses of action, varied scales of impact, and different levels of detail from a range of sources. The key commonality across the strategies was that they focus on reducing future water supply and demand imbalances in the Study Area.

Table 11-1 provides a brief description of each strategy considered in the Economic and Trade-off analyses. In this section, the strategy abbreviations are used for simplicity.

Table 11-1 – Adaptation Strategies Evaluated

Strategy Abbreviation	Adaptation Strategy	Location	Description
CDO-1	CAP water to CDO area with In-stream Recharge	Cañada del Oro/ Saddlebrooke	Construct pump stations and a pipeline to transport water from the Central Arizona Project (CAP) Red Rock Pumping Plant to the Cañada del Oro (CDO) Wash area for in-stream recharge.
CDO-2	SCR Reclaimed water to CDO area with In-Stream Recharge	Cañada del Oro/ Saddlebrooke	Construct pump stations and a pipeline to transport reclaimed water in the Santa Cruz River (SCR) past Trico Road to the Cañada del Oro (CDO) Wash area for in-stream recharge. Includes treatment for PFAS and 1,4 dioxane.
CDO-3	Saddlebrooke area Sub-regional WRF with In-stream Recharge	Cañada del Oro/ Saddlebrooke	Construct a new sub-regional wastewater reclamation facility (WRF) in the Saddlebrooke area with a pipeline for in-stream recharge.
SC/TV-1	TW Reclaimed System Extension to Isabella Lee	Sabino Canyon/ Tanque Verde	Extend Tucson Water reclaimed water pipeline to replace outdoor use of potable water at new sites and support irrigation at Isabella Lee Preserve.

Strategy Abbreviation	Adaptation Strategy	Location	Description
	Preserve and other sites		
SC/TV-2	Wheel TW Renewable Supplies to Metro Water District Hub Service Area	Sabino Canyon/ Tanque Verde	Use existing and new infrastructure to connect the Metro Water District's Hub Service Area to the Tucson Water central potable system. Wheel renewable supplies, replacing need for local groundwater pumping.
SC/TV-3	TW Renewable Supplies to Exempt Well Owners	Sabino Canyon/ Tanque Verde	Connect exempt well owners to Tucson Water central potable system to provide renewable supplies, retire exempt wells.
SET-1	TW Wheeling to SE Tucson Providers	SE Tucson, Cienega Creek	Construct new interconnections between Tucson Water central potable system and Southeast Tucson water providers, wheel renewable supplies, reducing local groundwater pumping.
SET-2	SET Wastewater Plan	SE Tucson, Cienega Creek	Phased construction of Water Reclamation Facilities to provide reclaimed water to Southeast Tucson.
GV-1	CAP Supplies to FICO Continental Farms (pecan orchards)	Green Valley/ Sahuarita	Extend Farmers Investment Co (FICO) groundwater savings facility (GSF) pipeline to transport CAP water to additional pecan orchards in lieu of irrigation with groundwater.
GV-2	CAP Supplies to Canoa Ranch Recharge via FICO Pipeline Extension	Green Valley/ Sahuarita	Extend FICO GSF pipeline to Canoa Ranch for recharge into basins in the winter months (when pipeline not needed for irrigation)
GV-3	GV Area Wastewater Plan	Green Valley/ Sahuarita	Phased construction of Water Reclamation Facilities to provide reclaimed water to the Green Valley /Sahuarita area.
REG-1	Stormwater Management using Low Impact Development	Regional	Retrofit existing properties and incorporate Low Impact Development features into new developments to harvest and use renewable stormwater at the residential scale. Build-out takes place from 2020 -2060; benefits accrue over time.
REG-2	Stormwater Multi-purpose, Multi-use Basins and Channels	Regional	Construct large multi-benefit retention and detention basins to collect and slow stormwater from impervious areas for flood mitigation, storage and/or habitat restoration.
REG-3	Stormwater Management	Regional	Perform upland restoration using small, distributed features to restore, protect and enhance surface

Strategy Abbreviation	Adaptation Strategy	Location	Description
	using Upland Restoration		water resources. May improve infiltration and soil moisture and restore groundwater levels.
REG-4	Augmentation with Desalinated Water from the Sea of Cortez	Regional	Construct a desalination plant on Mexico's Sea of Cortez with a pipeline to transport desalinated water to the Tucson region.

11.4 Evaluation Criteria

To evaluate the adaptation strategies, a set of criteria was developed and tailored to the Study. The evaluation criteria were based on the scope and objectives of the Study while also considering the most likely effects to result from the strategies. In consultation with the Project Team, criteria developed during the Adaptation Strategy Workshops were combined or removed to avoid redundancy. The criteria were ultimately selected to help distinguish between strategies and identify the key strengths and weaknesses of each strategy.

In total, 10 criteria were defined and used to evaluate adaptation strategies. Criteria 1-3 measure impacts in monetary terms, while the remaining criteria were measured qualitatively using a low-high scale. For the Trade-off Analysis, the monetized criteria and qualitative criteria were evaluated together. The qualitative criteria included aquifer benefit, impacts on water quality, riparian conditions, flood risk, and quality of life, as well as whether the strategy leverages existing resources and whether there are major barriers to implementation.

The qualitative criteria were scored through online polling by representatives of the partner agencies and were intended to capture impacts from adaptation strategies that could not be easily quantified or monetized. For simplicity, all criteria were defined as either a cost or benefit to indicate directionality, but the criteria spanned economic, social, and environmental considerations.

Table 11-2 provides a brief overview of the 10 evaluation criteria used to evaluate the 15 adaptation strategies.

Table 11-2 – Evaluation Criteria Used for the Trade-Off Analysis

Criterion	Description	Measurement	Directionality
(1) Water Supply Reliability Benefit	Benefit from reducing future shortages anticipated for the Study Area.	Monetized	Benefit
(2) Capital Cost	Cost of construction or implementation (upfront cost).	Monetized	Cost
(3) O&M Cost	Cost of operation and maintenance (ongoing cost). Does not include replacement	Monetized	Cost
(4) Aquifer Benefit	Improvements in groundwater levels to reduce pumping costs, prevent subsidence, or improve general aquifer condition.	0 to 3	Benefit
(5) Quality of Life Benefit	Improvements in recreation, aesthetics, health, safety, heat island effect, or cultural resources.	0 to 3	Benefit
(6) Leverage Existing Resources	Utilizes or enhances existing investments or infrastructure.	0 to 3	Benefit
(7) Barriers to Implementation	Obstacles from public perception, regulations, administrative complexity, or physical limitations.	-3 to 0	Cost
(8) Riparian Impact	Changes to riparian habitat and conditions.	-3 to 3	Cost/Benefit
(9) Water Quality Impact	Changes in the chemical, physical, or biological characteristic of water resources.	-3 to 3	Cost/Benefit
(10) Flood Risk Impact	Changes in flood risk (probability or consequences).	-3 to 3	Cost/Benefit

The benefit of reduced groundwater pumping costs was also included in the Economic Analysis for strategies that were assessed using a groundwater model. For the Trade-off Analysis, aquifer benefit (criterion 4) was used instead of reduced groundwater pumping cost. “Aquifer Benefit” reflects a broad qualitative criterion, part of which includes a groundwater pumping benefit, as well as consideration for land subsidence and general aquifer condition.

For the Trade-off Analysis, criteria 4-6 captured benefits with impacts measured qualitatively from 0 to 3, criterion 7 was defined as a cost measured from -3 to 0, and criteria 8-10 were measured from -3 to 3 since impacts could be positive or negative, depending on the strategy under consideration.

All 10 criteria were evaluated for the Trade-off Analysis to identify strategy strengths and weaknesses. The performance along each criterion was then combined to derive an overall score for each of the adaptation strategies. This was used to compare strategies in three ways: 1) within

each Area of Concern, 2) across the areas of concern, and 3) overall across all strategies considered. To account for the fact that some criteria might be viewed as more important than others, polling was also conducted to gather subjective preferences and incorporate "importance weights" based on the preferences of the Study Partners. Both the unweighted results (all criteria treated equal) and weighted results (more influence for more important criteria) are presented.

11.5 Water Supply Reliability Benefit

11.5.1. Introduction

A water supply reliability benefit was estimated based on the CAP:SAM model projections of water supply and demand and the potential for future shortages. See Chapter 8 and the Supply and Demand Assessment Technical Memorandum for more information on the CAP:SAM model and its supply and demand projections.

The benefit of additional water supply was based on the extent of future shortages and the ability of each adaptation strategy to mitigate those shortages. A water reliability benefit was estimated using both a benefit transfer (BT) approach as well as a market-based (MB) approach. Both approaches are considered acceptable under the PR&G guidance, but they are fundamentally different, and each has pros and cons. Both methods were explored to ensure the robustness of the water reliability benefit estimates.

Willingness to pay (WTP) can be defined as the dollar amount that an individual is willing to give up in order to acquire a good or service. The BT approach relies on previous studies and applied their estimates to the Study Area based on shortages at the household level and household WTP to avoid a shortage. Under the BT approach, CAP:SAM information on housing growth, households under shortage, and shortage severity was combined with WTP estimates from prior studies to estimate a reliability benefit for each strategy.

The MB estimate instead focused on renewable water supply and demand from a regional market perspective to examine how future shortages may affect water prices and wellbeing for municipal users in the Study Area. Under this approach, the benefit was calculated based on water supply and demand from CAP:SAM and compared the shortage volume and changes in wellbeing with, versus without, a strategy in place. Rather than looking at household WTP to avoid a shortage, this approach focused on the WTP for the volume of water generated by a strategy based on recent water transactions in the Study Area. More details on this analysis are provided in Appendix G, the Trade-off Analysis Technical Memorandum.

Table 11-3 summarizes the annual water volume provided by each strategy (used for the MB estimate), the average annual housing units supported by each strategy (used for the BT estimate), the 40-year BT best estimate, and the 40-year MB best estimate.

Table 11-3 – Best Estimate for Water Supply Reliability Benefit, Scenario F

Adaptation Strategy	Annual Water Volume (AF)	Average Annual Housing Units Supported	40-Year Benefit, BT Best Estimate ($ millions)	40-Year Benefit, MB Best Estimate ($ millions)
CDO-1	5,000	48,540	$133.19	$127.44
CDO-2	10,000	92,108	$230.28	$236.11
CDO-3	1,120	10,880	$30.02	$28.70
SC/TV-1	200	1,943	$5.36	$5.14
SC/TV-2	900	8,743	$24.12	$23.08
SC/TV-3	217	2,110	$5.82	$5.58
SET-1	1,500	14,572	$40.20	$38.40
SET-2	4,033[c]	36,186	$88.32	$94.62
GV-1	8,000	75,055	$196.21	$196.63
GV-2	2,000	19,429	$53.60	$51.12
GV-3	10,333[c]	90,923	$223.66	$233.89
REG-1[a]	39,245[c]	252,260	$552.72	$929.42
REG-2	350	3,400	$9.38	$8.99
REG-3[b]	0	0	$0.00	$0.00
REG-4[a]	100,000[d]	1,340,547	$3,003.73	$2,685.92

[a] Water volume exceeds the shortage volume in the LSCR Study Area for the study period, so additional water is assumed to benefit users in the 3-county area outside the LSCR Study Area.
[b] Water volume is for environmental needs in areas where delivery is not feasible to support municipal use.
[c] Water volume grows across the period; this represents the average annual volume.
[d] Annual water volume set at the maximum desalination capacity.
[e] HUs supported varies annually based on the CAP:SAM scenario; this represents the average annual HUs supported.
Note: Benefit estimates reflect the PV discounted using the FY21 federal planning rate of 2.5%.

As shown in Table 11-3, both the BT approach and MB approach provided similar benefit estimates. Note that some strategies provided a constant annual water volume across the period, while for others, the volume grows over time. The table also shows the average annual housing units supported by each strategy, but note that this varies across the period based on CAP:SAM Scenario F. Even though the volume of water used per housing unit decreases over time, the strategies generally support fewer housing units over time since the shortage severity grows (outweighing improvements in household water efficiency). In this way, the severity of shortage was incorporated into the BT estimate. That said, for simplicity, the benefit per housing unit is assumed to remain constant based on the range estimated in past studies.

For most strategies, the number of housing units supported by a strategy increases and then decreases across the period, due to the opposing forces of increasing household efficiency and increasing shortages across the period. The exceptions were REG-1 (LID) and REG-4 (Sea of Cortez Pipeline). For these strategies, the number of housing units supported increased across the entire period because they met the entire shortage volume in the LSCR Study Area in all years. For these two strategies, additional water was assumed to benefit users in the 3-county CAP Service Area outside the LSCR Basin. Without including spillover benefits for these strategies, the benefit estimates would not reflect the full volume of water and full reliability benefit provided by these strategies. To highlight the uncertainty around the best benefit, estimates in Table 11-4 show the low and high benefit estimates under the BT approach and MB approach.

Table 11-4 – Estimate Range for Water Supply Reliability Benefit, Scenario F

Adaptation Strategy	40-Year Benefit, BT Estimates ($ millions)			40-Year Benefit, MB Estimates ($ millions)		
	Low ($HU=$50)	Best ($HU=$100)	High ($HU=$200)	Low (ε_D=1)	Best (ε_D=0.5)	High (ε_D=0.25)
CDO-1	$66.60	$133.19	$266.38	$63.72	$127.44	$254.87
CDO-2	$115.14	$230.28	$460.56	$118.05	$236.11	$472.21
CDO-3	$15.01	$30.02	$60.03	$14.35	$28.70	$57.41
SC/TV-1	$2.68	$5.36	$10.72	$2.57	$5.14	$10.28
SC/TV-2	$12.06	$24.12	$48.24	$11.54	$23.08	$46.16
SC/TV-3	$2.91	$5.82	$11.64	$2.79	$5.58	$11.16
SET-1	$20.10	$40.20	$80.40	$19.20	$38.40	$76.80
SET-2	$44.16	$88.32	$176.64	$47.31	$94.62	$189.23
GV-1	$98.11	$196.21	$392.43	$98.31	$196.63	$393.26
GV-2	$26.80	$53.60	$107.20	$25.56	$51.12	$102.24
GV-3	$111.83	$223.66	$447.32	$116.95	$233.89	$467.78
REG-1[a]	$276.36	$552.72	$1,105.44	$464.71	$929.42	$1,858.84
REG-2	$4.69	$9.38	$18.76	$4.50	$8.99	$17.98
REG-3[b]	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
REG-4[a]	$1,501.86	$3,003.73	$6,007.46	$1,342.96	$2,685.92	$5,371.84

[a] Water volume exceeds the shortage volume in the LSCR Study Area for the Study period, so additional water is assumed to benefit users in the 3-county area outside the LSCR Study Area.
[b] Water volume is for environmental needs in areas where delivery is not feasible to support municipal use.
Note: Benefit estimates reflect the PV discounted using the FY21 federal planning rate of 2.5%.

Both the BT and MB approaches are considered acceptable under the PR&G and Reclamation guidance, but they are fundamentally quite different. Here, the MB estimates were deemed preferable to the BT estimates since they rely on recent market transactions in Arizona, making

them more relevant to the Study Area than relying on previous reliability benefit studies outside Arizona. Therefore, the MB estimate range was used for the Economic Analysis, and the MB best estimate was used for the Trade-off Analysis.

11.6 Economic Analysis

11.6.1. Introduction

The Economic Analysis focused on the monetized costs and benefits of each adaptation strategy to evaluate the economic feasibility of strategies over a 40-year period from 2021-2060. This included the water reliability benefit for municipal users estimated in the previous section, as well as the cost of construction, and the cost of O&M. For some strategies, the groundwater pumping benefit was also evaluated. Costs and benefits were evaluated from a national perspective consistent with federal guidance under the PR&G. The Economic Analysis provided here is preliminary, only looking at a 40-year snapshot while relying on simplifying assumptions and excluding several costs and benefits that could not be easily monetized for the Study.

11.6.2. Groundwater pumping benefit

The cost to pump groundwater depends on depth to water (DTW) and the cost of energy used for pumping, meaning the cost is unique to each user. For the Study, a handful of the adaptation strategies were evaluated using groundwater modeling. For these strategies, changes in DTW were combined with information on energy prices to calculate a monetary benefit associated with a reduced pumping cost for wells affected by recharge. See the Trade-off Analysis Technical Memorandum for the details on how energy costs were estimated.

To calculate the groundwater pumping benefit for each strategy, the annual cost to pump groundwater was compared with, versus without, a strategy in place for affected wells. In other words, the benefit was calculated as the cost difference for pumping with a strategy in place. The volume of water varied across CAP:SAM scenarios, but attention was placed on Scenario F, as done elsewhere. As done for the reliability benefit estimates, pumping benefits were estimated annually and discounted (using the FY21 rate of 2.5%) and summed from 2021-2060 to estimate a 40-year pumping benefit. For simplicity, the real price of energy was held constant across the period, but the benefit of having a recharge strategy in place would be greater if real energy prices increase across the period and vice versa.

For the LSCR Basin Study, 5 of the 15 strategies were evaluated in the groundwater model (CDO-1, CDO-2, CDO-3, GV-1, and GV-2). These strategies were focused on recharge and sufficient information was available to model the location of recharge and model changes in DTW. Table 11-5 summarizes the 40-year groundwater pumping benefit for these select strategies, along with the recharge volume modeled.

Table 11-5 – Groundwater Pumping Benefit for Select Strategies, Scenario F

Adaptation Strategy	Recharge Volume	40-Year Pumping Benefit[a]
CDO-1	5,000	$925,811
CDO-2	10,000	$1,880,136
CDO-3	1,120	$194,062
GV-1	8,000	$5,007,378
GV-2	2,000	$1,090,863

[a] Annual benefits vary, the 40-year benefit reflects the PV discounted using the FY21 federal planning rate of 2.5%.

The groundwater pumping benefits were small in magnitude compared to the water reliability benefit estimates. For the Economic Analysis, the groundwater pumping benefit estimated for these strategies was added to the reliability benefit. As previously discussed, this monetized benefit was not included in the Trade-off Analysis, but instead, was replaced by a qualitative criterion for aquifer benefit.

11.6.3. Construction and O&M costs

The cost estimates for the 15 strategies considered for the LSCR Basin Study were preliminary and come from a variety of sources and efforts by Partners involved in the Study. The cost estimates ranged from Class 4/Class 5 engineering estimates for structural strategies to "back-of-the-envelope" simplified calculations for non-structural strategies. Thus, inconsistencies were expected across the cost estimates and future studies should consider developing more refined cost estimates. See the Adaptation Strategies Technical Memorandum for more details on how the cost estimates were developed for each adaptation strategy. Table 11-6 summarizes the construction (upfront) cost and O&M (ongoing) cost estimates for each adaptation strategy.

Construction cost generally includes the cost of facilities and pipelines and any sort of infrastructure investment necessary to implement a strategy, including the cost of constructing a treatment facility when relevant. The O&M cost generally includes the ongoing cost for operation and includes the cost of labor, equipment, and energy associated with a strategy continuing to provide benefits. Note that the O&M cost doesn't include a component for replacement cost since the lifecycle is unknown for the major components of each strategy. Due to the diversity of the adaptation strategies considered, there was a wide variation in the components included under the capital and O&M cost estimates for each strategy. Therefore, comparisons across strategies were imperfect and served only to help screen adaptation strategies, and the Economic Analysis was considered preliminary with a wide uncertainty range around all monetary estimates.

Table 11-6 – Adaptation Strategy Construction and O&M Costs

Adaptation Strategy	Construction Cost ($ millions)	Annual O&M Cost ($ millions)
CDO-1	$97.86	$0.17
CDO-2	$157.00	$6.24
CDO-3	$37.00	$3.30
SC/TV-1	$8.11	$0.11
SC/TV-2	$0.00	$0.45
SC/TV-3	$0.95	$0.15
SET-1	$1.20	$0.94
SET-2	$96.00	$10.80
GV-1	$6.50	$0.26
GV-2	$25.04	$0.37
GV-3	$228.80	$25.70
REG-1	$348.80	$23.00[a]
REG-2	$77.00	$0.94
REG-3	$1.46	$0.07
REG-4	$4,100.00	$171.83

[a] Cost grows across the period; this represents the average annual O&M.

An economic analysis generally includes an assessment of interest during construction (IDC), which represents the difference between funds appropriated for construction and the economic cost of capital invested in the project when the project is brought into service at the end of construction. IDC could not be calculated for the LSCR Basin Study adaptation strategies since the construction/implementation time is unknown for each strategy. Furthermore, because some strategies are non-structural, IDC was not necessarily an applicable concept, or would at least have varied in application. That said, future studies should consider including estimates of IDC where appropriate and feasible, which would add to the total economic cost of a strategy.

11.6.4. Cost-Benefit comparison

An economic analysis generally culminates into a comparison of total cost and total benefit over a specified period of time. This section provides a 40-year cost-benefit comparison for each strategy that includes the cost of construction, the cost of O&M, the water reliability benefit for municipal users, and the groundwater pumping benefit for select recharge strategies. Both a net present value (NPV) and benefit-cost ratio (BCR) are presented for each strategy, recognizing that the estimates are only at a preliminary level and exclude several costs and benefits that could not be monetized. NPV highlights the magnitude of net benefit (benefit less cost) while the BCR

highlights the benefit generated for each dollar spent. It is possible to have a high BCR and low NPV, or vice versa, so both a high BCR and high NPV is generally preferable in terms of economic feasibility.

The Economic Analysis was constrained to the 40-year period defined for the Study. It is important to note that the BCR (and NPV) would likely be larger with a longer study period due to upfront costs being spread across more years. This is particularly true for those strategies with a very large upfront cost. The analysis provided here is intended to motivate and inform future assessments of adaptation strategies at a more detailed level. Table 11-7 shows the 40-year total cost estimate for each strategy, which encompasses the construction cost and PV of 40 years of O&M costs discounted using the FY21 federal planning rate of 2.5%.

Table 11-7 – 40-Year Total Cost Estimate

Adaptation Strategy	Construction Cost ($ millions)	40-Year O&M Cost[a] ($ millions)	40-Year Total Cost ($ millions)
CDO-1	$97.86	$4.45	$102.31
CDO-2	$157.00	$160.45	$317.45
CDO-3	$37.00	$84.91	$121.91
SC/TV-1	$8.11	$2.73	$10.84
SC/TV-2	$0.00	$11.58	$11.58
SC/TV-3	$0.95	$3.86	$4.81
SET-1	$1.20	$24.12	$25.32
SET-2	$96.00	$277.89	$373.89
GV-1	$6.50	$6.69	$13.19
GV-2	$25.04	$9.55	$34.59
GV-3	$228.80	$661.27	$890.07
REG-1	$348.80	$942.66	$1,291.46
REG-2	$77.00	$24.24	$101.24
REG-3	$1.46	$1.88	$3.34
REG-4	$4,100.00	$4,421.25	$8,521.25

[a] Reflects the PV of 40 years of annual O&M costs discounted using the FY21 federal planning rate of 2.5%.

These cost estimates range from Class 4/Class 5 engineering estimates to back-of-the-envelope simplified calculations. It is generally desirable for all cost estimates to be consistent, but this was not possible for the Study and the wide range of adaptation strategies considered. Class 5 engineering estimates (lowest accuracy) generally have an accuracy range of -20% to -50% on the low end and +30% to +100% on the high end, while Class 4 estimates have a range of -15% to -30% on the low end and +20% to +50% on the high end. Table 11-8 shows the 40-year total cost for each adaptation strategy assuming a -20%/+30% range to calculate a low-high range for total cost.

Table 11-8 – Forty-Year Total Cost Estimate, Low-High Range (-20%/+30%)

Adaptation Strategy	40-Year Total Cost ($ millions)	Low Estimate (-20%) ($ millions)	High Estimate (+30%) ($ millions)
CDO-1	$102.31	$81.85	$133.00
CDO-2	$317.45	$253.96	$412.69
CDO-3	$121.91	$97.53	$158.48
SC/TV-1	$10.84	$8.67	$14.09
SC/TV-2	$11.58	$9.26	$15.05
SC/TV-3	$4.81	$3.85	$6.25
SET-1	$25.32	$20.26	$32.92
SET-2	$373.89	$299.11	$486.05
GV-1	$13.19	$10.55	$17.15
GV-2	$34.59	$27.67	$44.96
GV-3	$890.07	$712.06	$1,157.09
REG-1	$1,291.46	$1,033.17	$1,678.89
REG-2	$101.24	$80.99	$131.61
REG-3	$3.34	$2.67	$4.34
REG-4	$8,521.25	$6,817.00	$11,077.62

To compare the monetized costs and benefits for each strategy over a 40-year period, the construction cost was modeled as a lump-sum upfront cost in 2020, followed by 40 years of O&M costs and reliability benefits for the period 2021-2060. This simplified framework ensured consistency and allowed for comparisons across the strategies given that the implementation time and lifecycle was unknown for each strategy. Table 11-9 shows the 40-year cost-benefit comparison under CAP:SAM Scenario F. To highlight the high level of uncertainty around these monetary estimates, the 40-year low-high range is presented for both the cost and benefit estimates, resulting in a low-high range for the 40-year NPV and 40-year BCR. The low-end for NPV and BCR reflects the high-end cost and low-end benefit estimates, while the high-end reflects the low-end cost and high-end benefit estimates.

Table 11-9 – Forty-Year Cost-Benefit Comparison, Scenario F

Adaptation Strategy	40-Year Total Cost, Low-High ($ millions)	40-Year Benefit, MB Estimate Low-High ($ millions)	40-Year NPV, Low-High ($ millions)	40-Year BCR, Low-High
CDO-1	$81.85 - $133.00	$64.64 - $255.80[a]	$(68.36) - $173.95	0.49 - 3.13
CDO-2	$253.96 - $412.69	$119.93 - $474.09[a]	$(292.76) - $220.13	0.29 - 1.87
CDO-3	$97.53 - $158.48	$14.55 - $57.60[a]	$(143.94) - $(39.93)	0.09 - 0.59
SC/TV-1	$8.67 - $14.09	$2.57 - $10.28	$(11.52) - $1.61	0.18 - 1.19
SC/TV-2	$9.26 - $15.05	$11.54 - $46.16	$(3.51) - $36.90	0.77 - 4.98
SC/TV-3	$3.85 - $6.25	$2.79 - $11.16	$(3.46) - $7.32	0.45 - 2.90
SET-1	$20.26 - $32.92	$19.20 - $76.80	$(13.72) - $56.54	0.58 - 3.79
SET-2	$299.11 - $486.05	$47.31 - $189.23	$(438.75) - $(109.88)	0.10 - 0.63
GV-1	$10.55 - $17.15	$103.32 - $398.26[a]	$86.17 - $387.71	6.03 - 37.7
GV-2	$27.67 - $44.96	$26.65 - $103.33[a]	$(18.31) - $75.66	0.59 - 3.73
GV-3	$712.06 - $1,157.09	$116.95 - $467.78	$(1,040.14) - $(244.27)	0.10 - 0.66
REG-1	$1,033.17 - $1,678.89	$464.71 - $1,858.84	$(1,214.18) - $825.67	0.28 - 1.80
REG-2	$80.99 - $131.61	$4.50 - $17.98	$(127.11) - $(63.01)	0.03 - 0.22
REG-3	$2.67 - $4.34	$0.00[b]	NA	NA
REG-4	$6,817.00 - $11,077.62	$1,342.96 - $5,371.84	$(9,734.66) - $(1,445.16)	0.12 - 0.79

[a] Includes the 40-year groundwater pumping benefit estimate.

[b] Water volume is for environmental needs in areas where delivery is not feasible to support municipal use.
Note: All estimates reflect the PV discounted using the FY21 federal planning rate of 2.5%.

A strategy is considered economically feasible if the NPV is positive and the BCR is greater than one. This was the case for 9 of the 15 strategies under the high-end estimates for NPV and BCR. Across the 9 strategies that were potentially economically feasible, REG-1 had the highest NPV, but second lowest BCR. Meanwhile, strategies such as GV-1 and CDO-1 had a relatively large NPV and BCR. This highlights the importance of considering both measures of economic feasibility.

Under the low-end NPV and BCR, only GV-1 was estimated to be economically feasible, at least over a 40-year period. The strong performance of this strategy was likely due to a relatively low cost, which stems from much of the pipeline already being constructed and the water being delivered efficiently to a small area. The wide range of costs and benefits shown in Table 11-9 highlights the importance of more refined estimates for future economic assessments. The Trade-off Analysis therefore offers a more holistic view of each strategy and identifies various strengths and weaknesses that were not included in the Economic Analysis shown here.

11.7 Qualitative and Importance Scoring

11.7.1. Introduction

The Economic Analysis in the previous section examined 3 of the 10 evaluation criteria outlined Figure 11-1. For the Trade-off Analysis, the remaining 7 criteria were measured (scored) qualitatively for each adaptation strategy using a low to high scale. Qualitative criteria scoring was achieved by polling all Partner representatives who attended the Study's strategy rating workshop and using the average of their responses. The seven qualitative criteria were therefore scored for the 15 strategies based on the expertise of those directly involved in the LSCR Basin Study.

To capture the fact that some of the 10 criteria might be viewed as more important than others, polling was also used to ask the participants about the importance they placed on each criterion. For the Trade-off Analysis, both the unweighted results (all criteria treated as of equal importance) and the weighted results (criteria weighted for importance) are presented. This section covers the results of the qualitative criteria scoring and criteria importance scoring used for the Trade-off Analysis.

11.7.2. Scoring process

Qualitative criteria scoring and criteria importance scoring was done through a live poll conducted during a 4-hour workshop, inviting staff from the partners involved in the LSCR Basin Study. The online polling format proved to be a highly efficient process for gathering information and has been repeated for another Basin Study. During the workshop, 24 participants were given a brief summary presentation on the details of each strategy before starting the polling, and people were able to ask clarifying questions while the poll was open.

All responses were kept anonymous, and participants were informed that only the average scores across all responses would be reported and used. For those unable to attend the workshop, a strategy summary document was provided along with a scoring worksheet for them to complete and return. In total, the criteria importance scores reflect the average of 24 responses and the qualitative criteria scores reflect the average across 15-20 responses. The number of responses varied for the qualitative scoring since respondents were asked to leave a score blank if they felt it was outside of their expertise (based on the criterion and/or strategy being considered).

11.7.3. Criteria importance weights

To address the fact that some criteria might be deemed more important than others, a trade-off analysis typically involves criteria weighting to assign different preferences to each criterion. A weight is a measure of the relative importance of a criterion and assigning weights is a method for incorporating human judgments about the relative value of a criterion. To ensure transparency and highlight the sensitivity to criteria weighting, best practice is to generally report the unweighted results as well as the weighted results.

For the LSCR Basin Study Trade-off Analysis, the rating method was used to determine criteria importance weights. This is similar to the rating process used for rating one's satisfaction with a purchase or experience, which often involves a 1 to 5-star rating scale. To determine the importance that the Study Partners place on each criterion, a simple 1 to 3 (low to high) scoring scale was submitted by each respondent. Respondents could also enter a 0 if they felt the criterion was not important at all. Table 11-10 shows the criteria importance scale used.

Table 11-10 – Criteria Importance Scoring Scale

Category	Score
Not Important	0
Low Importance	1
Moderate Importance	2
High Importance	3

Across the 24 responses, the water reliability benefit criterion and the aquifer benefit criterion received the highest importance weights. On average, the remaining criteria were considered moderately important. For the Trade-off Analysis, scores were normalized as a percentage of the maximum score so that the highest-scoring criterion was assigned a 100% weight and all other criteria were weighted proportionally based on their importance score.

Table 11-11 shows the average importance score for the 10 evaluation criteria and the corresponding weight placed on each criterion for the Trade-off Analysis (weighted results).

Table 11-11 – Importance Score for Evaluation Criteria

Criterion	Average Score	Weight Applied
(1) Water Reliability Benefit	2.79	100%
(2) Capital Cost	2.25	81%
(3) O&M Cost	2.38	85%
(4) Aquifer Benefit	2.75	99%
(5) Quality of Life Benefit	2.08	75%
(6) Leverage Existing Resources	1.96	70%
(7) Barriers to Implementation	1.96	70%
(8) Riparian Impact	2.04	73%
(9) Water Quality Impact	2.25	81%
(10) Flood Risk Impact	1.96	70%

Note: Total Responses=24. Weights are based on normalizing scores as a percentage of the maximum score.

11.7.4. Qualitative criteria scores

For the seven qualitative evaluation criteria included in the Trade-off Analysis, impacts were assessed based on the average score assigned by respondents. The number of responses varied from 15-20 for the qualitative scoring since respondents were asked to leave a score blank if they felt it was outside of their expertise (based on the criterion and/or strategy being considered). As done for rating criteria importance, a simple low to high scoring scale was used to keep the process straightforward. The qualitative criteria were carefully defined to have a particular directionality, either defined as a benefit scored from 1 to 3, as a cost scored from -3 to -1, or with the potential to go in either direction scored from -3 to 3. Respondents were asked to enter a score of 0 if they thought the strategy would have no impact for the criterion in question.

Table 11-12 shows the scoring scale used to measure the qualitative evaluation criteria.

Table 11-12 – Qualitative Criteria Scoring Scale

Directionality	Category	Score
Benefit	High	3
	Moderate	2
	Low	1
	No Impact	0
Cost	Low	-1
	Moderate	2
	High	3

Criteria 4-6 (aquifer benefit, quality of life benefit, and leverage existing resources) were scored from 0 to 3, criterion 7 (barriers to implementation) from -3 to 0, and criteria 8-10 (riparian impact, water quality impact, and flood risk impact) from -3 to 3. Table 11-13 shows the average score for each criterion and adaptation strategy. These scores were used in the Trade-off Analysis, along with the monetized criteria (1-3), to identify the strengths and weaknesses of each strategy and evaluate the overall performance of strategies across all criteria.

Table 11-13 – Average Qualitative Criteria Scores

Strategy	Aquifer Benefit	Quality of Life Benefit	Leverage Existing Resources	Barriers to Implement	Riparian Impact	Water Quality Impact	Flood Risk Impact
CDO-1	2.70	1.85	1.45	1.68	1.80	0.10	0.75
CDO-2	2.58	1.84	1.11	1.94	1.58	-0.28	-0.11
CDO-3	1.68	1.42	1.21	-1.47	1.79	0.47	-0.16
SC/TV-1	1.76	1.76	2.29	-0.88	1.65	-0.12	-0.12
SC/TV-2	2.42	0.78	2.53	-1.37	1.11	0.16	-0.05
SC/TV-3	1.81	1.31	2.00	2.13	0.81	0.27	0.06
SET-1	2.42	1.42	2.16	-1.18	1.39	0.05	0.06
SET-2	1.64	0.60	1.41	-1.00	0.53	-0.20	0.13
GV-1	2.72	0.89	2.06	-0.89	0.47	-0.25	0.00
GV-2	1.72	1.06	2.06	-1.25	1.50	-0.24	0.06
GV-3	1.59	0.63	1.81	-1.00	0.27	0.07	0.20
REG-1	1.47	2.24	1.29	-1.35	1.38	0.94	0.88
REG-2	1.33	2.39	1.35	-1.00	1.89	1.06	1.11
REG-3	1.18	1.71	1.06	-0.56	2.06	0.94	0.94
REG-4	2.50	0.73	0.87	2.63	-0.38	0.53	0.19

Note: Number of responses varies from 15-20.

11.8 Trade-Off Analysis

11.8.1. Introduction

A trade-off analysis is an application of multi-criteria decision analysis (MCDA), which is a general framework for evaluating complex decision making under multiple and often conflicting objectives. Most multi-criteria problems have conflicting criteria and as a result there is no unique solution that can optimize all criteria simultaneously. A trade-off analysis therefore does not necessarily identify a "best" strategy, but rather, highlights the strengths and weaknesses of each strategy and trade-offs when choosing between strategies. It serves to identify trade-offs within strategies (between criteria) as well as across strategies.

A trade-off analysis provides a methodology for comparing different types of benefits and costs that cannot all be reliably quantified in monetary terms. Both quantified and unquantified considerations are evaluated simultaneously, which means the analysis includes a broader range

of effects than a typical economic analysis which evaluates impacts only in monetary terms. The key categories of benefits and costs will differ by strategy, depending on the expected impacts of each strategy.

11.8.2. Adaptation strategy trade-offs

To evaluate trade-offs across both quantitative and qualitative criteria, all criteria must be scored on an equivalent scale, which is typically done with normalization. Normalization allows everything to be converted to an equivalent scale while ensuring the magnitude of differences (proportionality) is retained in the process. This also ensures that all criteria are treated equally prior to weighting criteria for importance. With a large number of criteria, radar diagrams offer a quick way to identify the trade-offs within each strategy.

Figure 11-1 and Figure 11-2 show a radar diagram for each of the 15 strategies considered for the LSCR Basin Study. These show the performance of strategies along each of the 10 criteria, prior to any weighting for criteria importance. The normalized 0-1 scale is shown from 0-100% where 100% indicates that a strategy was the top-performing strategy for that criterion. As shown, at least one strategy scores 100% for each criterion, but no strategy scores well across all criteria, highlighting the fact that several trade-offs exist. These diagrams quickly show the strengths and weaknesses of each adaptation strategy.

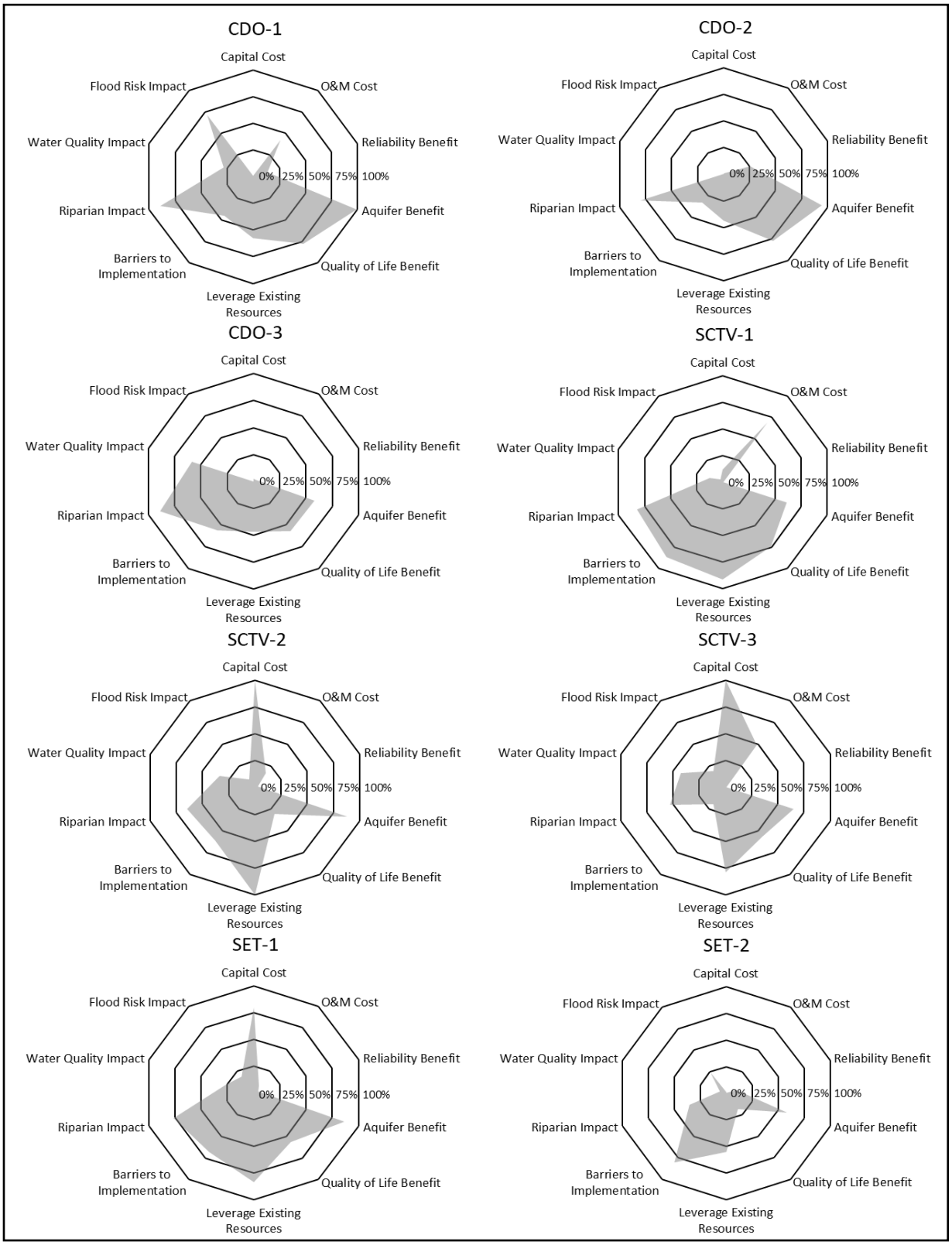


Figure 11-1 – Radar diagrams showing the evaluations of each strategy for the ten evaluation criteria for the Cañada del Oro, Sabino Canyon / Tanque Verde and Southeast Tucson areas of concern.

Figure 11-2 – Radar diagrams showing the evaluations of each strategy for the ten evaluation criteria for the Green Valley area of concern and the regional strategies.

Looking at the radar diagrams in Figure 11-1 and Figure 11-2, no two diagrams look alike, meaning each strategy comes with a unique set of costs and benefits and trade-offs. Those diagrams with the most shaded area reflect strategies that perform well across several criteria and well for the unweighted overall score. That said, accounting for criteria importance weights will influence the overall score for each strategy, which is not reflected in these diagrams.

The next section examines the overall score and performance for each strategy, both the unweighted score and weighted score based on criteria importance. This was then used to rank strategies based on the area of interest.

11.8.3. Adaptation strategy overall performance and ranking

The tables and diagrams from the prior section highlight the performance and trade-offs for each strategy, but it does not show how strategies compare in relation to one another. To examine how strategies perform overall and rank relative to one another, and to incorporate criteria importance weights into the analysis, this section evaluates the overall scores for each strategy. The maximum unweighted total score a strategy could receive was 10, scoring a 1 for all criteria. This was only possible if a strategy dominated all other strategies along every criterion considered, which would then imply no trade-offs exist between strategies and the best strategy is clear. For the strategies and criteria considered here, there was no dominant strategy, meaning no strategy performed the best across every criterion, and trade-offs existed between strategies. For the weighted scores, the maximum overall score a strategy could receive is 8.03.

Comparing overall scores and ranking the performance of strategies depends on the set of strategies being considered. The Study identified four areas of concern; therefore, it made sense to compare strategies within each area of concern, as well as across areas of concern, and across all strategies considered. As such, a “location rank,” “areas of concern rank,” and “overall rank” are provided for each strategy. The location rank focuses on the strategies in each area of concern. The areas of concern rank looks at all strategies that target one of the four areas of concern. This excludes the regional strategies which are generally much larger in scale and were not developed and tailored to the Study and areas of concern in the same fashion as the other strategies. Finally, the overall rank compares all 15 strategies identified for the LSCR Basin Study, which included the regional strategies and those strategies targeting the areas of concern. Table 11-14 shows the overall weighted score and rankings for each strategy. Unweighted scores are presented in Table 5-4 in Appendix G, the LSCR Basin Study Economic and Trade-off Analysis Technical Memorandum.

Table 11-14 – Adaptation Strategy Overall Score and Ranking, Weighted

Adaptation Strategy	Strategy Type	Total Score	Normalized Score	Location Rank	Areas of Concern Rank	Overall Rank
CDO-1	Transport CAP supplies for in-stream recharge	4.13	0.75	1st	3rd	6th
CDO-2	Transport reclaimed water supplies for in-stream recharge	2.89	0.53	3rd	9th	13th
CDO-3	Construct regional WRF with in-stream recharge	2.96	0.54	2nd	7th	10th
SC/TV-1	Extend reclaimed system, support environmental needs	3.83	0.70	3rd	5th	8th
SC/TV-2	Wheel CAP supplies directly to replace municipal gw pumping	4.17	0.76	1st	1st	4th
SC/TV-3	Replace gw pumping by private wells with renewable municipal supplies	3.99	0.73	2nd	4th	7th
SET-1	Wheel CAP supplies to replace municipal gw pumping	4.15	0.76	1st	2nd	5th
SET-2	Construct regional WRF with in-stream recharge	2.30	0.42	2nd	11th	15th
GV-1	Substitute agricultural gw pumping with renewable supplies	3.33	0.61	1st	6th	9th
GV-2	Extend agricultural water transport infrastructure, use for off-season environmental enhancement	2.95	0.54	2nd	8th	11th
GV-3	Construct regional WRF with in-stream recharge	2.64	0.48	3rd	10th	14th
REG-1	Site-based Stormwater Management using Low Impact Development	4.71	0.86	2nd	-	2nd
REG-2	Large Stormwater Multi-purpose Basins and Channels	4.43	0.81	3rd	-	3rd
REG-3	Upland Restoration	5.48	1.00	1st	-	1st
REG-4	Desalination of ocean water with pipeline from Sea of Cortez, Mexico	2.91	0.53	4th	-	12th

Note: Weighted scores treat criteria differently based on the criteria importance weights (max score possible=8.03).

REG-3 performed the best across the set of evaluation criteria used here using both unweighted and weighted scores. Recall that this strategy was not fully evaluated in the Economic Analysis since it was assumed that this strategy does not provide any reliability benefit for municipal users. This highlights how fundamentally different the Economic Analysis and Trade-off Analysis are. By accommodating a range of measurement scales and including both quantitative and qualitative measures, the Trade-off Analysis accommodates a wide range of information to assist decision making.

In general, those strategies that perform well in both the Economic Analysis and Trade-off Analysis are most likely to be preferable strategies. As the analysis provided here is only preliminary, further work is warranted to get a more accurate picture of economic feasibility and the trade-offs associated with strategies of interest.

11.9 Limitations

This Economic and Trade-off analyses relied on existing data and the outputs identified in parts of the Basin Study Final Report and Adaptation Strategies Technical Memorandum. As a result, several areas of measurement and evaluation were limited, and several uncertainties and limitations exist. The Economic Analysis is considered preliminary since it relied on several simplifying assumptions and excluded several costs and benefits that could not easily be monetized.

The Trade-off Analysis included a broader range of effects, but including criteria measured qualitatively using a simple low-high scale offered limited insight. In general, quantitative measurement is more objective and informative than qualitative measurement, which is largely reflective of the input and expertise provided by the Study Partners. Here, several impacts were evaluated qualitatively, which offers a first look at strategy strengths and weaknesses. In future studies, quantifying (and possibly monetizing) more effects would offer a more objective and concrete evaluation.

Another limitation of this assessment is that strategies were evaluated independently. This misses any potential synergies or dissonance associated with implementing strategies together. As it is unlikely that any one strategy alone will be able to fully address future water shortages and groundwater imbalances, it is important to understand which combination of strategies might be preferable. There is therefore an opportunity for future work to assess potential synergies and trade-offs with combined strategy implementation, and the results from this analysis can help inform which strategies might be worth further consideration. It is also important to note that not all strategies were developed by the Project Team to address the specific water supply imbalances identified for the LSCR Basin Study. Future analyses would benefit by ensuring that strategies are developed in a consistent manner to meet the same purpose and need.

Chapter 12 Study Conclusions

The Lower Santa Cruz River Basin Study's overarching goal was to identify where physical water resources are needed to mitigate supply-demand imbalances due to climate change and other factors, and to develop strategies to improve water reliability for municipal, industrial, agricultural, and environmental sectors. The Hydroclimate Analysis (Chapter 7), Supply and Demand Assessment (Chapter 8), and Groundwater Modeling (Chapter 9) sections estimated the magnitude and location of these supply-demand imbalances at present and in the future under a range of climate change and municipal growth scenarios. Their results established a foundation for the development of strategies to improve water reliability within the LSCR Basin.

This Study involved a wide-ranging and inclusive process for eliciting ideas for the adaptation strategies, as well as for the strategy-evaluation criteria. The Trade-off Analysis examined fifteen separate strategies and rated them according to ten criteria developed from stakeholder input. The Trade-off Analysis results showed that each strategy had unique strengths and weaknesses, and that a suite of strategies will likely be necessary to address all supply-demand imbalances, regardless of the extent of municipal growth and climate change.

12.1 Key Findings

12.1.1. Key Hydroclimate Analysis findings

Within the Hydroclimate Modeling area shown in Figure 7-7:

- Projections of future climate indicate consistently higher temperatures and hotter extremes.
- Precipitation is projected to become more variable under all climate scenarios.
- The best-case climate scenario shows relatively minimal change in seasonal precipitation.
- The worse-case climate scenario indicates less monsoon and winter precipitation.
- Reduced monsoon and winter precipitation translates to lower streamflows, more dry stream days, less stream recharge, and lower soil moisture.

12.1.2. Supply and Demand Assessment findings

Within the LSCR Basin Study Area:

- Projected changes in demand for municipal, industrial, agricultural, and tribal uses through 2060 range from a 5% decrease under Scenario B to a 37% increase under Scenario F, compared to current levels.

- Under all scenarios, municipal water providers will need to recover water stored for the future in terms of Long-Term Storage Credits. In some scenarios, providers may require new infrastructure to "recover" this water and transport it to its point of use.
- Under all scenarios, some municipal providers will need to acquire additional renewable water resources to replenish their groundwater pumping under Arizona's Assured Water Supply Rules. The total volume required in the year 2060 ranges from 8,800 acre-feet under Scenario B to 38,100 acre-feet under Scenario F.

12.1.3. Groundwater Modeling Analysis findings

Within the Tucson AMA Groundwater Modeling area shown in Figure 9-3:

- The extent of groundwater level declines depends on the future climate at two scales:
    - Future climate over the Study Area will impact precipitation, stormwater runoff and stream recharge within its boundaries.
    - Future climate over the entire Colorado River Basin is a key factor in the availability of Colorado River water for artificial recharge at Groundwater Storage Facilities and Underground Storage Facilities.
- Factors other than climate, such as the rate of population growth and state and local water and land use policies, have a strong influence on the location and extent of groundwater level declines.
- Location matters – by containing growth within existing providers' service areas, groundwater pumping without nearby replenishment is lessened.
- Four areas of concern were identified that are projected to experience declining groundwater levels.

12.1.4. Adaptation Strategies Development findings

- Many adaptation strategies are available to address supply-demand imbalances at the area of concern level as well as at the regional level. Each has unique strengths and weaknesses.
- Developing infrastructure to transport renewable water supplies to the location of municipal demand can effectively address local groundwater declines.
- Strategic siting of new water reclamation facilities is another strategy to address local-supply demand imbalances.
- Certain strategies could be applied region-wide, including site-based stormwater management, development of large stormwater basins and channels, upland restoration, and importation of desalinated water from the Sea of Cortez, Mexico.

12.1.5. Economic and Trade-off Analyses findings

- Most strategies could not address all the LSCR Basin's adaptation needs individually, and those that could had significant obstacles.
- A comprehensive adaptation plan would likely include multiple strategies to address local supply-demand imbalances and potentially regional strategies to augment the total water supply.
- Results also revealed strong support for projects that incorporated environmental benefits as well as meeting human needs.
- Many of the adaptation strategies considered in-stream recharge of reclaimed water for ecosystem support to meet human needs and provide environmental benefits.
- Upland restoration, a region-wide strategy, received strong support from participants in the Trade-off Analysis. Upland restoration includes activities such as developing erosion and grade control structures and enhancing natural channel design to detain stormwater and restore, protect, and enhance surface water resources.

12.2 Additional Investigations

Several additional analyses would enhance this Study's findings. One example is an investigation of projected changes to the LSCR Basin's mountain-front recharge rate. While the Study used the parameters developed for the ADWR TAMA Groundwater Model using the historic climate, climate change is expected to impact this critical recharge process.

The Study's surface water modeling could also be enhanced by including streamflow routing. At present, the surface water model only generates estimates of stream discharge for the watershed, and the groundwater model uses a very simple method to calculate infiltration along a watercourse. Supplemental modeling efforts could also evaluate the impacts of reduced water availability on riparian areas, including their plant and animal populations.

Additional adaptation strategies could be investigated, including projects that recover and use stored water to meet future demands. The adaptation strategies evaluated in this Study are just a sample of the ideas generated by participants in the Adaptation Strategy Workshops. A complete list of these ideas is provided in the Adaptation Strategy Workshop documentation.

As noted in Chapter 11, the Economic and Trade-off analyses could be refined by more quantitative estimates of benefits, as well as by evaluating groups of adaptation strategies to identify an optimal combination. In addition, a more systematic development of strategies specifically intended to address supply-demand imbalances would make the strategies easier to compare and evaluate.

Further refinement of the Study results could address specific concerns of individual water sectors, such as ensuring reliable supplies during periods of peak demand, preparing for the impact of increased heat on water resources and facilities, and maintaining biodiversity in areas projected to become hotter and potentially drier.

12.3 Next Steps and Future Considerations

This Study lays a foundation for water-related climate adaptation planning for the LSCR Basin. The holistic picture of the impacts of climate change, municipal growth, and other factors over the entire LSCR Basin Study Area is a benefit to all water providers and users. It also provides insights into the role of state and local water and land use policies on the extent and location of supply-demand imbalances. The information in this Study can enhance ongoing efforts by individual water providers, partnerships, and government to address these imbalances and their impacts.

12.4 Individual Providers

Water providers in the LSCR Basin Study area are already undertaking activities that address the need to maintain sustainable supplies, such as promoting conservation and the use of alternative sources like stormwater. Examples of individual providers' on-going adaptation measures include rebates for water efficient toilets and for graywater and rainwater harvesting systems, an online portal that alerts customers to high water use issues, free water use audits for homes and businesses, and the creation of a Citizens' Water Academy. Water providers could expand these programs as a part of their adaptation efforts and target areas of local supply-demand imbalance.

Of particular note is Tucson Water's One Water 2100 Master Plan (Plan), a comprehensive, long-range plan that aims to protect the reliability and quality of Tucson's water supply through 2100. The Study has already provided climate information used to underpin the Plan (HDR, Inc., 2021). The One Water approach values all types of water resources, recognizing the interconnectedness of the surface water and groundwater supply, recycled water, and rain and stormwater harvesting. The Plan guides Tucson Water's capital and financial planning, conservation practices, and provides information to support policy decisions.

12.5 Collaboration and Partnerships

LSCR Basin water providers have a long history of collaboration, including approaches akin to some of this Study's adaptation strategies. For example, Tucson Water has established "wheeling" agreements with the Metro Water District, the Towns of Oro Valley and Marana, the Vail Water Company, and the Pascua Yaqui Tribe. In this arrangement, Tucson Water takes delivery of some or all these providers' CAP allocations and recharges them in its facilities. When supplies are needed, water is delivered to these providers through Tucson Water's distribution system. These agreements provide a template for adaptation strategies where renewable supplies would be wheeled to additional providers near the Study's areas of concern.

Other collaborations involve transporting CAP water to points of use to reduce the need for groundwater pumping. One such project, still in the implementation stage, is the Northwest Recharge Recovery and Delivery System (NWRRDS), sponsored by the Metro Water District, the Town of Marana, and the Town of Oro Valley. The project will recover CAP water recharged in the Avra Valley Recharge Project and deliver it to the sponsors' service areas, reducing the need for groundwater pumping. By developing common infrastructure, the sponsors reduce the costs and minimize the permitting associated with building a conveyance project.

LSCR Basin Study Partners can make progress by continuing to work together as demonstrated by the examples described above. They should also consider extending their partnership to other agencies concerned with water-related resources, such as flood control districts, natural resource management and recreation-oriented agencies. Adaptation strategies that may not appear to be economically feasible when considered from a single use perspective may become feasible when additional benefits such as enhanced riparian areas and quality of life are considered.

Additionally in 2021, the Governor's Water Augmentation, Innovation and Conservation Council Post-2025 AMAs Committee recognized the "hydrologic disconnect" as an issue in most of the state's AMAs and suggested policy solutions. In 2023, the successor Governor's Water Policy Council Assured Water Supply Committee reiterated this concern and also proposed solutions. If these policies are adopted, they would provide a direct incentive for water providers to address the Study Area's local supply-demand imbalances.

12.6 Wider Implications of Study Findings

In a broader sense, the information generated in this Study is applicable to many entities besides water providers. Interest in the Study results has been expressed by agencies involved in flood control, city planning, public health, and environmental quality. Thus, this Study lays the groundwork for a wide range of adaptation activities that address current conditions while developing the resilience necessary to thrive in the future.

Disclaimer

This Basin Study is a technical assessment and does not provide recommendations or represent a statement of policy or position of Reclamation, the Department of the Interior, or the Study Partners and interested parties. The Basin Study does not propose or address the feasibility of any specific project, program, or plan. Nothing in the Study is intended, nor shall the Study be construed, to interpret, diminish, or modify the rights of any participant under applicable law. Nothing in the Study represents a commitment for provision of local, State, or federal funds. All water volume and cost estimates included in this study are preliminary and intended only for comparative purposes.

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Appendix A

Plan of Study

Attachment A to Amendment No. 3 of 16-MOA-32-0010
Lower Santa Cruz River Basin Study Plan of Study
Revised September, 2021

About this document:

This document outlines the intentions of Reclamation and the Non-Federal Cost-Share Partners for the Lower Santa Cruz River Basin Study at the commencement of the three-year study period. It is intended to be a "living document" that can be adjusted according to the future needs and opportunities that may occur during the study period. If Reclamation and the Non-Federal Cost-share Partners are in consensus that a change in the activities described in the Plan of Study is necessary and feasible, the Plan of Study may be modified in writing to reflect the change without amending the Memorandum of Agreement.

I. Introduction:

A. Study Purpose and Objectives

For over sixty years the Lower Santa Cruz River (LSCR) Basin, including the Tucson, Arizona metropolitan area, relied on groundwater to meet most water supply needs, with pumping greatly exceeding replenishment. Since the mid-1970s, LSCR Basin (Basin) water users have made use of recycled water to offset groundwater pumping. In 1993, Reclamation's Central Arizona Project (CAP) began delivering Colorado River water to the Basin. As a result, groundwater levels have rebounded in many areas.

However, there are still significant imbalances within the Basin due to a lack of transmission infrastructure, insufficient recharge and recovery capacity, a lack of recharge and recovery facilities in up-gradient parts of the basin, and the cost of constructing new facilities. There is concern regarding supply reliability for water users without physical access to CAP water, as well as impacts to the environment.

Uncertainty about the future compounds these issues. The Central Arizona Project (CAP) has junior priority rights on the Colorado River; thus CAP sub-contractors will bear the brunt of imminent shortages. Certain agricultural users will be the first affected under the CAP's priority system, but if the shortages are severe enough, reductions to municipal users will also take place.

In addition, Southern Arizona, which naturally experiences episodic droughts, has been in an extended drought for the last fifteen years. Water providers without physical access to renewable supplies are already experiencing declining groundwater levels. Climate change poses additional threats to the Basin. Increased temperatures and possible decreases in precipitation— will likely increase supply-demand imbalances and aggravate the impacts of future droughts.

The study will evaluate the current and future water supply and demand imbalances in the LSCR Basin, taking climate change impacts into consideration; analyzing how existing infrastructure will perform in response to changing water realities; developing adaptation and mitigation strategies, and analyzing each strategy for its effectiveness in addressing these imbalances. The Study's planning horizon is 2015 through 2060. It will identify institutional, legal and regulatory constraints affecting each strategy and develop next steps toward implementation.

The study's overarching goal is to identify where physical water resources are needed in order to mitigate supply-demand imbalances due to climate change and other factors and develop a strategy to improve water reliability for municipal, industrial, agricultural, cultural and environmental sectors in the Lower Santa Cruz River (LSCR) Basin.

B. Description of Study Area

The proposed Lower Santa Cruz River Basin (LSCR Basin) Study will encompass the groundwater basin designated by the Arizona Department of Water Resources as the "Tucson Active Management Area" (TAMA). The TAMA is one of five basins designated as "Active Management Areas" (AMAs) under Arizona's Groundwater Management Code. Each AMA carries out its programs in a manner consistent with its individual goals, while considering the unique character of the basin and its water users.

Geographically, the LSCR Basin Study Area generally coincides with the Lower Santa Cruz River Basin between the Pima County/Santa Cruz County boundary south of the Tucson metropolitan area and Pima County/Pinal County boundary to the north. The Santa Cruz River is a tributary to the Colorado River, a major river system within the Bureau of Reclamation's service area.

The LSCR Basin watershed is comprised of two parallel sub-basins; the Upper Santa Cruz Valley sub-basin on the east and the Avra Valley sub-basin on the west. Both sub-basins flow from south to north. Figure 1 depicts the LSCR Basin Study boundaries.

C. Organization of Plan of Study

This Plan of Study generally follows the format suggested in the Reclamation Basin Study Framework. The Technical Sufficiency Review Plan and Communications and Outreach Plan are described separately and attached as Appendices I and II, respectively.

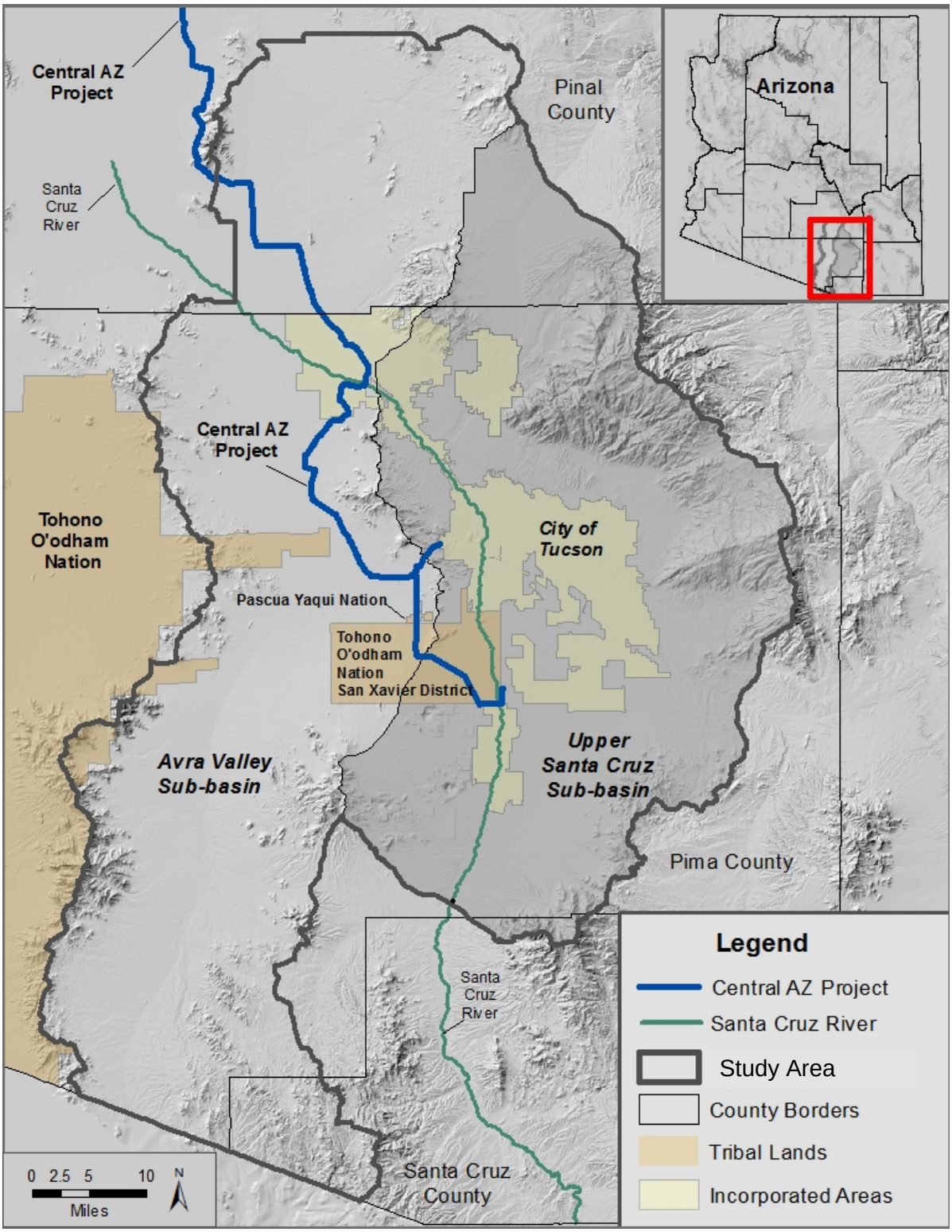

Figure 1- Lower Santa Cruz River Basin Study Area

II. Study Description

A. Problems, Needs and Opportunities

The LSCR Basin relies on water from the Colorado River delivered through the Central Arizona Project (CAP) to meet water demands for municipal, industrial and agricultural sectors. Shortages to Colorado River supplies will intensify the spatial supply-demand imbalances within the Basin and negatively impact water users, including the environment. The municipal and industrial (M&I) sector took delivery of approximately 170,000 acre-feet of CAP water in 2014, while the agricultural sector took delivery of 2,635 acre-feet. Tribes within the LSCR Basin are entitled to up to 66,500 acre-feet per year of CAP water.

In 2012 Reclamation published the Colorado River Basin Water Supply and Demand Study, which projected future imbalances between supply and demand on the Colorado River. Reclamation's study determined that demand on the Colorado River is beginning to outpace supply. Central Arizona Project water has junior priority rights on the Colorado River and Reclamation's study indicates shortages are likely, therefore CAP sub-contractors are expected to bear the brunt of these shortages. Initially, shortages on the CAP will impact agricultural users who have lower priority allocations. However, continued shortages could result in reductions to M&I and Indian water supplies. Arizona is anticipated to experience substantial growth in municipal and industrial water demand, hence the great potential for supply and demand imbalances[1].

Key areas in the Lower Santa Cruz River (LSCR) Basin are experiencing groundwater declines due to lack of access to renewable supplies in conjunction with drought conditions. Subsidence and the loss of riparian habitat have already occurred. Degradation of groundwater quality, increased pumping costs, the need to deepen wells and shortages of supplies to users may be exacerbated without more timely intervention.

[1] Arizona's Next Century: A Strategic Vision for Water Supply Sustainability, January 2014, Arizona Department of Water Resources.

B. Previous Work and Available Data and Models

A list of available data, models and reports is listed in Table 1 below:

Data or Model	Description	Source
Regional Groundwater Flow Model for the Tucson Active Management Area in Arizona. Model Update and Calibration, Modeling Report No. 24. April 2013	Upgrades previous numerical groundwater flow model and provides a more current tool to assist in management of Tucson Active Management Area water resources	Arizona Department of Water Resources (ADWR)
Draft Fourth Management Plan for Tucson Active Management Area 2010-2020	Water management programs for the Tucson Active Management Area over the next ten years. Projections about future conditions, assessment of progress toward achieving safe yield goal for groundwater and recommendations regarding future water management strategies	ADWR
Tucson Active Management Area Water Demand and Supply Assessment: 1985-2025	Historical water demand and supply characteristics for 1985 through 2006 and projections to 2025. Evaluates possible scenarios for future groundwater overdraft using low, medium and high reasonable water demand	ADWR
Recovery of Water Stored by the Arizona Water Banking Authority, April 2014	Provides strategy for recovering water stored underground by the Arizona Water Banking Authority using the Colorado River Simulation System model and a custom recovery model that calculates the probability of specific recovery volumes occurring through time based on a range of supply and demand conditions. A joint plan by Arizona Water Banking Authority, Arizona Department of Water Resources, Central Arizona Water Conservation District	Central Arizona Water Conservation District (CAWCD)
Draft 2015 Central Arizona Groundwater Replenishment District Plan of Operation, December 2014	Provides an estimate of projected groundwater replenishment obligations for 100 years, a description of the water resources that the Groundwater Replenishment District plans to use to meet obligations and description of infrastructure and projects to be used for replenishment	CAWCD
Recycled Water Master Plan, Tucson Water, December 2013	Provides integrated recycled water program that maximizes the benefits of the City of Tucson's recycled water resource and provides framework for activities to ensure implementation of recycled water projects and programs	City of Tucson
Water & Wastewater Infrastructure, Supply & Planning Study, 2010	Study of water and wastewater infrastructure, supply and planning issues with ultimate goal of assuring a sustainable community water source given continuing pressures on water supply caused by population growth.	City of Tucson and Pima County

Data or Model	Description	Source
Assessment of Climate Change in the Southwest U.S.	Evaluates and synthesizes information from a wide range of sources and assesses climate change effects on sectors including water. Various climate change models will be reviewed to determine the optimum model to be used to assess water supply and demand in the LSCR Basin area	University of Arizona - Climate Assessment for the Southwest
Conservation Effluent Pool Task Force Report, July 2014	Identification of 13 candidate project sites that might quality for a portion of water available under the conservation Effluent Pool	Community Water Coalition Task Force
Metropolitan Domestic Water Improvement District Long Range Water Resources Plan, February 2015	Strategy for managing water resources for the next 50 years. Water demand and supply scenarios through 2065	Metropolitan Domestic Water Improvement District
A Forecast Model of Single Family Residential Water Demand for Pima County, November 2014	Forecasts significant changes in single family residential demand using a dynamic simulation model	Montgomery & Associates
Shallow Groundwater Areas in Eastern Pima County, Water Well inventory and Pumping Trend Analysis, 2012	Identification of 32 shallow groundwater areas grouped into ten regions using ADWR and PAG well data to describe water level changes, water use trends, well densities and drilling histories	Pima Association of Governments
2014 Effluent Generation and Utilization Report	Quantity of effluent produced at Pima County regional wastewater reclamation facilities and utilization of effluent in the LSCR Basin Study Area	Pima County
Sonoran Desert Conservation Plan	Plan for balancing the conservation and protection of cultural and natural resource heritage with effort to maintain an economically vigorous and fiscally responsible community	Pima County
Multi-species Conservation Plan	Plan to address endangered species compliance that minimizes and mitigates the effects for incidental take on federal listed species	Pima County
Water Accounting Areas	WAAs refine the study area into regions that are experiencing different aquifer responses to groundwater use.	Safe Yield Task Force
2012 Update: Water Plan 2000 – 2050	Scenario planning based long-term water resource plan for the Tucson Water Service Area.	Tucson Water
Water Usage Report 2010-2053	A report of current and projected water usage for the upper Santa Cruz River encompassing the Green Valley area	Upper Santa Cruz Providers and Users Group

C. Current Activities:

A water supply and demand assessment conducted by ADWR in 2010 described water supply and demand characteristics for 1985 through 2006 as well as projections to 2025 for the LSCR Basin. The assessment included municipal, industrial, agricultural and Indian water demand and evaluated scenarios to address groundwater overdraft. A subsequent ADWR effort in 2013, *Regional Groundwater Flow Model of the Tucson Active Management Area, Model Update and Calibration*, projected water level changes in the LSCR Basin through 2025. The model identifies areas where groundwater levels are expected to recover, stabilize, or decline. Adaptive strategies need to be developed in areas where groundwater is expected to decline.

The City of Tucson recently completed *its Recycled Water Master Plan* for the planned use of the City's recycled water. This effort complements their *2012 Water Plan Update* that provides for long term water reliability for the Tucson Water service area through 2050. Metropolitan Domestic Water Improvement District completed its 50-year *Long Range Water Resources Plan* in 2015. Other regional water providers are collaborating on groundwater replenishment programs, including underground storage and recovery of Central Arizona Project (CAP) water and recycled water. A study sponsored by the Southern Arizona Water Users Association (SAWUA) completed in 2015, *Municipal Water Demand Trends Project*, evaluated anticipated trends in water use in the LSCR Basin.

D. Potential Alternatives

The study will develop strategies to address water supply and demand imbalances. Adaptation and mitigation strategies may include, but are not limited to: changes to the operation of water supply systems, modifications to existing facilities, development of new facilities, or non-structural changes. Some examples are:

1) Development of new water management or operating plans;

2) Development of water conservation and demand reduction strategies or projects;

3) Development of new water infrastructure or water augmentation programs or projects, including treatment of poor quality water.

4) Development or improvement of hydrologic models and other decision support systems; and

5) Development of a monitoring plan to acquire and maintain water resource data to strengthen the understanding of water supplies and assist in future assessments and analysis.

III. Study Approach and Interested Parties

A. Study Approach

Existing data, studies and modeling tools will be used for the Basin Study. The Study is striving for a full integration of information and predictive models. A partnership between ADWR and major water users has divided the Basin into "Water Accounting Areas" to delineate large contiguous areas with common features, including local geography, hydrology, legal, political and corporate boundaries. A large part of the effort will focus on the ADWR TAMA groundwater flow model (MODFLOW), which will provide the means to evaluate different water management strategies and infrastructure projects on each of the Water Accounting Areas.

Input files of the TAMA model will be developed based on recent water demand trends, recent infrastructure projects affecting groundwater pumping and climate change projections, which will affect stream flows and evapotranspiration, as well as mountain front recharge. The study will also incorporate information on potential CAP shortages developed by its operator, the Central Arizona Water Conservation District.

Utilizing the scenario planning process will provide a family of future scenarios to provide a broad range of projections of future water supply and demand. The scenarios are meant to represent a range of plausible futures to assist in the assessment of future risks and the development of mitigation and adaptation options and strategies.
The TAMA model will be used to evaluate the effects of water supply and demand scenarios on future groundwater levels, and to simulate strategies necessary to evaluate the effects of mitigation and adaptation options. The study will also identify institutional, legal and regulatory constraints affecting each strategy and develop next steps toward implementation.

Throughout the process, we will engage regional stakeholders (interested parties who are not Non-Federal Cost-Share Study Partners), including those representing municipal, agricultural, environmental, industrial and tribal water providers and users. We will garner and incorporate their input at key intervals in the process. Our overarching goal is to identify where physical water resources are needed in order to mitigate climate change impacts and improve water reliability for municipal, agricultural and environmental sectors in the LSCR Basin.

B. Interested Parties

1. Cost-Share Partners

The local cost share study partners for the LSCR Basin Study are:

- Southern Arizona Water Users Association
- Arizona Department of Water Resources

- Central Arizona Water Conservation District
- Cortaro-Marana Irrigation District
- Pima Association of Governments
- The University of Arizona

Southern Arizona Water Users Association (SAWUA). SAWUA members represent diverse regional interests including municipal water providers, wastewater providers and agricultural interests. SAWUA members have water delivery authority to over 80 percent the study area population. Member agencies include Avra Valley Water Co-op, BKW Farms, Community Water Company of Green Valley, Farmers Investment Co., Flowing Wells Irrigation District, Green Valley Water Improvement District, Kai Farms, the Town of Marana Municipal Water System, Metropolitan Domestic Water Improvement District, Oro Valley Water Utility, Pima County Regional Wastewater Reclamation Department, Red Rock Utilities, Sahuarita Water Company, the Town of Sahuarita Water Reclamation Facility and the Tucson Water Department. SAWUA members will be providing water supply and demand data, infrastructure data and long term planning information for the study.

The Arizona Department of Water Resources (ADWR) prepares water management plans for the basin area to address groundwater overdraft. ADWR has a regulatory authority in implementation of Arizona's Groundwater Management Act and provides regulatory permitting of underground water storage facilities and groundwater pumping. ADWR represents the State of Arizona in policy negotiations of Colorado River operations and administration of Colorado River entitlements. ADWR will provide access to the Regional Groundwater Flow Model and will provide limited staff time to participate in modeling-related meetings and to provide technical advice concerning model development and use.

The Central Arizona Water Conservation District (CAWCD) operates and manages the Central Arizona Project which is designed to bring about 1.5 million acre-feet of Colorado River Water to central Arizona through a 336-mile system of aqueducts, tunnels, pumping stations and pipelines. CAWCD delivers over 230,000 acre-feet of Colorado River water to municipal, industrial, agricultural and Indian customers in the LSCR Basin area. CAWCD is evaluating how near-term shortages on the Colorado River will impact CAP water delivery to central Arizona's farmers and is working closely with stakeholders in the LSCR Basin area to identify and address the impacts of future potential Colorado River shortages

Cortaro-Marana Irrigation District serves the agricultural needs of the Marana, Avra Valley and Cortaro communities, all within the LSCR Basin study area. The District provides irrigation water to more than 12,000 acres of farmland and offers

water storage and non-potable service within its service area. This District helps sustain, promote and advance the economic viability of irrigation agriculture within its boundaries.

Pima Association of Governments (PAG) is the study area's regional metropolitan planning organization for transportation planning, environmental planning and technical services. It is the Designated Planning Agency (DPA) under Section 208 of the Clean Water Act, which addresses wastewater and non-point source pollution in stormwater. PAG will lead the stakeholder engagement process by convening outreach meetings and communications support. PAG expertise will be used to inform and engage decision makers through its Watershed Subcommittee, Environmental Planning Advisory Committee, Management Committee and Regional Council. PAG will provide its technical expertise by providing input to the study and document review.

The University of Arizona, another water provider located within the LSCR Basin Area, has extensive expertise in water issues and climate change. The Climate Assessment for the Southwest (CLIMAS) housed at the University's Institute of the Environment, conducts research on the nature, causes and consequences of climate change and variability in the Southwest. CLIMAS and colleagues from the University's Hydrology and Water Resources, and Atmospheric Sciences Departments, will partner with Reclamation to identify appropriate climate projections that will be coordinated with ADWR Regional Groundwater Flow Model and water supply and demand projections. The Center for Climate Adaptation and Science and Solutions (CCASS), also housed at the Institute of the Environment, brings together the University's expertise in climate impacts and vulnerability assessment at regional, national and international scales. The Water Resources Research Center, housed at the University's College of Agriculture and Life Sciences, promotes understanding of critical state and regional water management and policy issues through research, community outreach and engagement and public education.

2. Other Potentially Interested Parties

a) Tribal Nations

Tohono O'odham Nation
(San Xavier District and Schuk Toak District)
Pascua Yaqui Nation

b) Environmental Groups

Sonoran Institute
Tucson Audubon Society
The Nature Conservancy

Community Water Coalition

c) Industry Groups

Freeport McMoRan-Sierrita
ASARCO
Hudbay Copper Company
Southern Arizona Home Builders Association
Tucson Electric Power

d) Others

Bureau of Land Management
U.S. Forest Service
National Park Service
Arizona State Land Department

IV. Study Management Requirements

A. Project Management Plan

1. Study Management Structure

a) Co-Study Managers

One Co-Study Manager will be designated from Reclamation and one Co-Study Manager will be designated from the Non-Federal Cost-Share Partners.

b) Project Team

The Project Team will steer and guide the Study efforts such that the objectives of the Study are met in an effective, efficient manner, and within the Study's financial and time constraints. The Project Team will ensure that the tasks that relate to the Study are completed in a cost-effective, timely manner and are technically sound. Members of the Project Team provide the expertise, experience, and knowledge that relate to the Study's scope and objectives. Members include staff from Reclamation and staff from the non-Federal Cost-Share Partners. The Co-Study Managers will lead the Project Team.

c) Sub-Teams

Various Sub-Teams may be formed as needed to perform specific tasks. Sub-Team members provide specific expertise, information, knowledge and support required to perform those tasks. Members are comprised of Project Team members, additional staff from Reclamation and the non-

Federal Cost-Share Partners, and staff from contracted entities. Membership may also include representatives from other groups and volunteers with a particular expertise sought by the Sub-Team.

d) Stakeholder Advisory Team

This group will consist of interested parties, not representing a Cost-Share Partner, who wish to provide input throughout the course of the study. The stakeholder advisory team will be coordinated through Pima Association of Governments' Watershed Planning Subcommittee or Environmental Planning Advisory Committee, both open meeting forums.
Public stakeholder meetings may take place during one of the standing committee meetings that are open to the public and will function as a public engagement forum for discussion and comment, as appropriate.

2. Decision-Making Process

The Co-Managers and the Project Team will make the day-to-day and strategic decisions for the Study. They will also consider feedback provided by the Stakeholder Advisory Group. This Study is a collaborative effort between all the Non-Federal Cost-Share Partners and Reclamation. Important decisions will be made on a consensus/consent basis.

Every effort will be made to achieve consensus among the Study Partners for key decisions within the LSCR Basin Study. If after significant effort, the Partners are unable to reach consensus on critical decisions for the Study, Reclamation will make the final determination, taking into account technical assessments, Cost-Share Partner input and budget constraints.

However, final study assessments will be solely a product of local Cost-Share Partner input. If there are differences in opinion among the local Cost-Share Partners regarding final study assessments, the Final Report will document this situation.

3. Roles and Responsibilities

The Non-Federal Cost-Share Partners will contribute staff time and in-house data to the Study. They will provide the direction for scenario development, infrastructure and reliability metrics and formulation of adaptation and mitigation strategies. Their expertise will be critical in performing the trade-off analysis. The Non-Federal Cost-Share Partners will also develop the assessments for the next steps for the study, and review technical work by Reclamation to ensure that it is appropriate for local needs.

Reclamation will be the main source of climate change data, with input from the University of Arizona, and will perform the groundwater modeling required for

the study, in consultation with ADWR. Reclamation will produce periodic progress reports and financial status reports to monitor progress.

Reclamation will draft the technical work products, incorporating the views of the Non-Federal Cost-Share Partners and other stakeholders. The final report will document the selection of scenarios, adaptation and mitigation measures assessed by the Study partners, with input from the public contributed through the Communications and Outreach Plan. Reclamation will be responsible for the formatting and publication of Study documents.

Where necessary, Reclamation and the Non-Federal Cost-Share Partners will consult outside experts to access expertise not available within the respective organizations. Reclamation will coordinate with the Non-Federal Cost-Share partners in all aspects of the study.

4. Study Team Coordination

The Co-Study Managers will be responsible for all coordination between the various Teams. The Co-Study Managers will set dates and locations for meetings of the teams, be responsible for outreach and formation of the Stakeholder Advisory Team, and field inquiries from the general public on the Study.

5. Administrative Record

Reclamation will maintain the Administrative Record for this Study. Data to be retained include:

- All meeting summaries
- All contract documentation
- All public comments received in writing
- Report findings for each task
- Cost share documentation
- Final report
- Other documentation that is produced during the study

6. Schedule and Cost Control

The Study will begin after the execution of the Memorandum of Agreement and will continue through June 30, 2022. This Study will consist of the tasks identified in Section V below. Specific costs are identified in Section VI, Milestone Schedule and Costs.

Schedule and cost control measures will be monitored by the Co-Study Managers to ensure that project tasks stay on track and within budget. These measures will include semi-annual reviews of the schedule and budget and providing this information to the Project Team along with Reclamation's Basin Study management team in Denver.

7. Deliverables and Project Documentation

a) Status Reports

Status reports will be developed on a semi-annual basis. These reports will contain the following:

- Progress of each element identified in the plan of study
- Timeline of each element identified in the plan of study compared to the proposed schedule
- A report of cost share contribution by the Non-Federal Cost-Share Partners
- Expenditures of funds

b) Final Report

The Final Basin Study Report will contain, at a minimum, the following four elements:

- Projections of water supply and demand, including an assessment of risks to the water supply relating to climate change as defined in §9503(b)(2) of the Secure Water Act (SWA).
    - Changes in snowpack
    - Changes in the timing and quantity of runoff
    - Changes in groundwater recharge and discharge
    - Any increase in the demand for water as a result of increasing temperatures
- Analysis of how existing water and power infrastructure and operations will perform in the face of changing water realities, such as population growth and climate change.
- Development of options to improve operations and infrastructure to supply adequate water in the future.
- A trade-off analysis of the options identified, findings and assessments as appropriate. Such analysis simply examines all proposed alternatives in terms of their relative cost, environmental impact, risk, stakeholder response, or other attributes common to the alternatives.

- Following the trade-off analysis, the Cost-Share Partners will prepare findings and conclusions.

8. Internal and Technical Sufficiency Reviews

Internal review of work products will be done by both Reclamation and the Non-Federal Cost-Share Partners, with input from interested parties, government agencies and academicians, depending on the nature of work to be reviewed. The internal review process will be augmented by the process described in Appendix I, the Technical Sufficiency Review Plan. The Study Partners, in consultation with Reclamation, will select the study reviewers, taking into account comments by the public. The Co-Study Managers will be responsible for sending out work products to designated reviewers and ensuring timely return of relevant comments. Reviews will occur at defined intervals throughout the project, particularly as key tasks are initiated and completed. Changes to work products will be agreed upon in advance of final publication by Reclamation and the Non-Federal Cost-Share Partners.

V. Study Tasks

A. Develop Climate Change Projections

1. Selection of Downscaling Method and Hydrologic Variables

Reclamation, in consultation with the Study Partners, will develop climate change projections and select appropriate climate and hydrologic variables for input into scenarios for the Tucson Active Management Area (TAMA) Regional Groundwater Flow Model (MODFLOW). Climate change projections specific to the study area will be provided. Due to the study area's reliance on CAP water, climate change projections specific to the Colorado River Watershed, to the extent they impact flows to the mainstem of the Colorado River, will also be provided.

Reclamation staff, in consultation with the University of Arizona climate experts, will provide guidance as to which set of climate projections are most appropriate for the study purposes (e.g. earlier or later version of the Coupled Model Inter-comparison Project datasets, type of downscaling used). Projections are available for the following variables: total precipitation, minimum and maximum air temperature and mean wind speed.

2. Evaluation of Data Products

Specific data products may be available for the Tucson area, but the method used to generate them will be evaluated to determine if they are appropriate for the model. Products include: soil moisture, snow water equivalent, total runoff depth, and potential and actual evapotranspiration. Parameters will be selected for their

relevance to the processes simulated in the groundwater model, including mountain-front and stream recharge and evapotranspiration. Basin Study Partners will specify the statistics of interest that will be derived from the variables selected.

This task will also consider how climate change scenarios affect natural recharge, which will be reflected in the (1) modeled discharge rates to shallow groundwater areas in each of the water accounting areas, (2) the magnitude of discharge rates, and (3) the direction under each scenario. It will address how, based on existing literature, the effects of higher temperatures and longer growing seasons may affect water demands for riparian vegetation, streams and springs.

3. Selection of Climate Change Assumptions for Supply and Demand Scenarios

The Study Partners will select the climate change scenarios to be considered in water supply and demand projections.

4. Documentation of Selection Process

Reclamation will provide a technical memorandum of the climate change projections and selected scenarios.

B. Conduct Supply and Demand Assessment

1. Conduct Assessment of Current Supply:

Study Partners and Reclamation will update the quantity and locations of current water supplies. Study data inputs will include imported and local potable supplies, recycled water, groundwater, remediated water and stormwater. Data sources will include the ADWR TAMA Water Use and Demand Assessment, ADWR's draft Fourth Management Plan, Safe Yield Task Force water management accounting areas and other available supply data. Another aspect of existing supplies to be assessed is water for the environment from existing uses of groundwater, recycled water and stormwater. The extent of these evaluations will depend on the available data and models. If the groundwater modeling budget allows, seasonal variation in supply will be incorporated into the assessment.

2. Develop Future Supply Projections:

Study Partners and Reclamation will conduct a future water supply assessment considering the potential effects of:

- climate variability and climate change using the results from Task A
- projected availability of CAP water, recycled water, remediated water,
- recovery of stored or banked water,
- natural recharge and groundwater

Using a planning horizon to 2060, specific supply scenarios will be developed by the Study Partners, and appropriate model variable values representing these conditions will be selected. The future scenarios will evaluate the availability of stormwater, groundwater, and recycled water for environmental purposes. The extent of these evaluations will depend on the available data and models. If the groundwater modeling budget allows, seasonal variation in supply will be incorporated into the supply projections.

3. Conduct Assessment of Current Demand:

Study Partners and Reclamation will update the quantity and locations of current water demands of the municipal, industrial, agricultural, cultural and environmental sectors. Data sources will include the ADWR TAMA Water Use and Demand Assessment, ADWR's draft Fourth Management Plan, Safe Yield Task Force Water Accounting Areas and other available demand data. If the groundwater modeling budget allows, seasonal variation in demand will be incorporated into the assessment.

4. Develop Future Demand Projections:

Study Partners and Reclamation will conduct a future water demand assessment using the potential effects of climate variability and climate change using the results from Task A. Projected water demand from the municipal, industrial, agricultural, cultural and environmental sectors. A planning horizon of 2060 will be used, consistent with the planning scenarios developed. The CAP Service Area Model (CAP SAM) may be used to develop multiple demand projections for municipal providers. Considerations and input from each of the water sectors will be necessary. If the groundwater modeling budget allows, seasonal variation in demand will be incorporated into the projections.

A Water Demand Sub Team will provide input on projected water demand for each sector. The Sub Team may include land managers, agricultural interests, municipal and industrial water users and knowledgeable stakeholders. The Sub team investigation should address how agricultural and environmental water demands will change with climate change, such as changes in cropping patterns, increased demand as a result of increased salinity and higher evapotranspiration rates for agriculture, riparian vegetation and higher energy use for cooling of homes during times of intense heat. Reclamation can provide input on transpiration rates. Specific demand scenarios will be developed by the partners, and appropriate model variable values representing these model conditions will be selected.

5. Study Partners and Reclamation will prepare a technical memorandum summarizing the current and future water supply and demand assessments. This will be consistent with the selected supply and demand scenarios.

C. Update Groundwater Model

In consultation with ADWR modelers, Reclamation staff (or contractor) will modify the existing TAMA Regional Groundwater Model to include current and future water supply and demand developed in Task B. The model will include the change in infiltration rates in the Santa Cruz River due to improved effluent quality and the operation of near-term recharge facilities in the Green Valley area, Northwest Tucson area, as well as other areas of importance to the Study Partners. The output of the updated model will provide a baseline that reflects the condition of the watershed and projected groundwater levels when existing and near-term projects are in operation.

D. Run Groundwater Model with Suite of Climate Change and Water Supply and Demand Assessment

The supply and demand scenarios incorporating climate change that have been developed by Reclamation and the Study Partners will be translated into inputs for the Tucson Active Management Area Groundwater Model. Climate related variables will include mountain-front recharge, stream recharge and evapotranspiration components. Other model inputs sensitive to temperature and precipitation may also be included in simulations.

1. The Study Partners and Reclamation will prepare a technical memorandum summarizing the current and future water supply and demand assessments, indicating the condition of the LSCR Basin groundwater levels. Projected water supply and demand imbalances for the 2060 planning horizon under a suite of scenarios will be identified in ten-year increments according to the Water Accounting Areas.

E. Conduct System Reliability Analysis

The Study Partners and Reclamation will conduct an assessment of the capability of existing and near-term regional water supply infrastructure to meet current and projected water demand under each set of the future supply conditions and impact to future groundwater levels.

1. Identify Model and System Reliability Metrics

The Study Partners will determine System Reliability Metrics such as delivery capacity, groundwater elevation limits, groundwater rates of decline, recharge and storage capacity, components of regional water infrastructure, and wells.

a) A Reliability Sub Team will identify the Reliability Metrics to be used for the reliability analysis.

2. Conduct Baseline Reliability Analysis

The Study Partners and Reclamation will provide input on the assumptions used for the models and the baseline scenarios, such as groundwater regulatory thresholds.

3. Projections of Future Reliability

The Study Partners and Reclamation will determine how their reliability metrics will change under the groundwater elevation outputs for each scenario.

4. Evaluate Supply Risks for the Following Sectors

The Study Partners will strive for consensus on what composes "system reliability" for the LSCR Basin Study. If the study budget allows, more than one concept of reliability may be evaluated. Some questions that may be addressed by the Study Partners are:

- What does "reliable system infrastructure" mean?
- Will municipal, industrial and agricultural needs continue to be met with existing delivery infrastructure?
- If recovery of long term storage credits is necessary, where will this be done and how will recovered water be delivered to users?
- Will the basin be in safe-yield?
- How will environmental resources be impacted?
- How will impacts be distributed throughout the basin and between Water Accounting Areas?
- What are the risks of not meeting reliability metrics?

a) Municipal

The Study Partners will assess the types and volume of supplies used by the municipal sector in the TAMA, their associated reliability risks and how losses of renewable supplies could increase groundwater pumping and affect Safe Yield. (Safe-yield is defined as a long-term balance between the annual amount of groundwater withdrawn in the AMA and the annual amount of natural and artificial recharge.) The range of municipal water supplies in the TAMA includes groundwater, CAP water, remediated water, and recycled water.

The risks to municipal water will be dependent on groundwater levels, CAP shortages beyond the scope of the interim shortage guidelines, CAP

rates, the use of long term storage credits to meet water supply, recovery capacity and water quality.

A municipal sector Sub-team will provide input on the following:

1) Geographical areas that are expected to continue to depend on groundwater for physical deliveries.
2) How CAP shortages will impact municipal water delivery and cost under different supply and demand scenarios.
3) Information on the geographical areas expected to depend on groundwater pumping for recovery of long term storage under different scenarios.

b) Industrial

The Study Partners will assess the types and volumes of supplies used by the industrial sector in the TAMA, their associated reliability risks and how losses of renewable water could increase groundwater pumping and affect the Tucson AMA goal of Safe Yield using agreed upon scenarios. The range of industrial water supplies in the TAMA includes groundwater, CAP water and recycled water.

An industrial sector Sub-team will provide input on the following:

1) Geographical areas where industry is expected to continue to rely on groundwater
2) How CAP shortages will impact industry
3) If long term storage is recovered, which geographical areas will be impacted and what impacts may occur

c) Agriculture

The Study Partners will assess the types and volume of supplies used by agriculture in the TAMA, their associated reliability risks and how losses of renewable supplies could increase groundwater pumping and affect Safe Yield. The range of agricultural water supplies in the TAMA includes groundwater, CAP water and recycled water.

The risk to agriculture in the TAMA, with respect to the CAP Agricultural Pool (Ag Pool), will be dependent upon CAP shortages based on the water levels at Lake Mead. Reclamation's Colorado River and Climate Change Modeling will help predict the shortages to the CAP Ag Pool. Each farm will be able to assess their risk by utilizing the model results and provide input on mitigating shortages. If shortage will be mitigated by additional groundwater pumping, those values will be included in Reclamation's groundwater modeling to assess effects to Safe Yield.

An agricultural Sub-team will provide input on the following:

1) Current uses of water from the various sources of supply.
2) Impacts due to shortages and/or the CAP Ag Pool reductions.
3) Impacts of any potential increase in agricultural groundwater use in TAMA and its impacts to groundwater levels
4) The type of water used by each farm will be dependent upon its proximity to these supplies and the supply's reliability.

d) Cultural

Cultural water use includes consumptive (agricultural) and non-consumptive uses (sacred, ceremonial, social, habitat and aesthetic) necessary to maintain Tribal cultures. The Study Partners will consult Tribal experts on the water supplies required for cultural uses in the TAMA, their associated reliability risks and how losses of water supplies could affect these uses.

A cultural Sub-team will provide input on the following:

1) Current uses of water from the various sources of supply
2) Impacts due to decreased groundwater levels and surface water availability
3) Types of water needed (type of use, required water quality)
4) Additional elements as identified by the cultural Sub-team

e) Environmental

The Study Partners will assess the types and volumes of supplies used for environmental water in the TAMA, its associated reliability risks and how losses of renewable supplies and projected groundwater levels could affect environmental water demands including:

1) Impacts to aquatic and terrestrial ecosystems resulting from decreased flows in the Santa Cruz River
2) Impacts to groundwater dependent ecosystems from declining groundwater levels
3) Impacts to urban vegetation.
4) Financial impacts to costs for water for the environment (recycled water and potable use) to environmental flow rights, and to riparian preserve investments
5) The analysis will consider how different water demand scenarios affect pumping in shallow groundwater areas (SGWAs). Some Water Accounting Areas have multiple SGWAs, others have none. This can be derived from the groundwater model. The analysis will evaluate how groundwater changes in the various SGWA and where reversals in groundwater gradients are projected. It will

describe effects based on thresholds from the literature and local experts.

6) The analysis will determine how water demand affects availability of recycled water, and stormwater for environmental purposes, in general and specifically to existing projects in the various WAA. It will include analysis of effects to recycled water discharged to Santa Cruz River from Agua Nueva and Tres Rios Wastewater Reclamation Facilities.

An environmental Sub-team will provide input on:

1) Preservation of existing habitat under agreed upon scenarios
2) Needs and opportunities for future restoration
3) Opportunities for multi-benefit public projects using stormwater and recycled water
4) Preservation of riparian and aquatic habitat along the recycled water dependent reach of the Santa Cruz River
5) Development of a reliable water supply for the environment

5. Summary of Findings

Reclamation will prepare a Technical Memorandum summarizing potential risks and projections of future reliability.

F. Adaptation and Mitigation Strategies

1. Develop Strategies to Meet Future Supply Needs

The Study Partners, in consultation with the members of the Sub-Teams, the Stakeholder Advisory Group and the public, will identify preliminary adaptation strategies to address supply and demand imbalances. They may include, but are not limited to:

Supply augmentation	Demand management	Infrastructure and Non-Infrastructure adaptation
Desalination	Operational changes	Legislative changes
Development of new conveyance and storage facilities	Land fallowing and retirement	Policy changes
Water recycling and reuse	Rehabilitation or replacement of existing facilities	Collaborative opportunities
Weather modification	Water conservation and efficiency	Legal and institutional changes
Importation projects	Vegetation management	Conjunctive use
Remediation of poor quality water	Urban runoff management	Long term storage

2. Refine Strategies for Further Evaluation

The Study Partners will refine strategies and identify key, feasible candidate strategies for analysis based on effectiveness, implementability and cost, to address a range of future scenarios.

3. Conduct Analysis of Strategies to Meet Future Supply Needs

Each of the Adaptation and Mitigation Strategies developed by the Basin Study Partners will be analyzed and evaluated by Reclamation technical staff to determine its approximate cost and effectiveness in addressing system reliability issues. If applicable, Reclamation staff will provide conceptual cost estimates and designs.

The strategies will include ways that shallow groundwater areas, streams, springs, and riparian and aquatic habitats can be restored or at least made less vulnerable to future water demands and climate change. It will identify the infrastructure that can assist in protection or restoration and if changes in groundwater pumping demands will impact shallow groundwater areas, streams, springs and riparian and aquatic habitats.

a) Technical Analysis

Reclamation will conduct a technical evaluation including a uniform cost comparison, environmental impacts, permitting requirements. Risk and uncertainty will be assessed. An assessment of effectiveness in addressing future supply-demand imbalances will be conducted.

b) Legal and Institutional Analysis

Reclamation, with input from the Study Partners, will conduct an analysis of legal and institutional implementation issues associated with each mitigation and adaptation strategy. This will include a high-level analysis of the potential environmental and cultural impacts of the alternative. The analysis will be conducted in enough detail to allow the partners to rate each alternative against their selection criteria and choose one or more alternatives to incorporate into a basin plan.

c) Social and Economic Analysis

Reclamation, in partnership with the Study Partners, will conduct an analysis of social and economic impacts of each strategy. If possible, this will include an evaluation of changes to ecosystem services.

4. Summary of Analyses

Reclamation will prepare technical memorandum summarizing the results adaptation and mitigation strategies analysis

G. Prepare Trade-off Analysis of Strategies to Meet Future Supplies

The Study Partners will identify viable strategies to be analyzed and develop a trade-off matrix for viable strategies that includes criteria, such as performance measures, costs, ability to implement, risks, benefits and impacts.

1. Summary of Trade-off Analysis

Study Partners will prepare a technical memorandum of the trade-off analysis.

H. Prepare Basin Plan

Basin Studies identify basin-wide water supply issues that could potentially be resolved with changes to the operation of water supply systems, modifications to existing facilities, development of new facilities, or non-structural changes. The desired outcome of the LSCR Basin Study is a basin-specific plan describing collaboratively developed solutions that will help meet water demands and foster sustainable development.

For each of the groundwater and basin conditions predicted by the selected future scenarios, the Study will present an evaluation of the use of infrastructure and range of other options to deliver water, including direct delivery and recovery of stored water.

I. Prepare Basin Study Report

1. Draft Final Report

Reclamation will prepare a draft final report that summarizes the strategies addressing projected water supply and demand imbalances in the Lower Santa Cruz River Basin, including trade-offs, technical feasibility, environmental impacts, legal and institutional analysis and social and economic analysis. The draft report will include the study purpose, general methodology for each model, economic tools and water management strategies.

2. Review Draft Final Report

The Study Partners will review the draft final report and provide input and comments to Reclamation.

3. Publish Final Report

Reclamation will address and incorporate the Study Partners comments and publish the final report. The final report and its findings will be presented to the Stakeholder Advisory Team (see definition in Communications and Outreach Plan), Study Partners and the public upon completion of the project.

J. Conduct Technical Sufficiency Review

A technical sufficiency review will be conducted for each of the key tasks, as described in Appendix I. The Study Partners and Reclamation will identify technical reviewers.

K. Conduct Communications and Outreach

The Study Partners and Reclamation will conduct communications and outreach to allow and work with input from interested parties who are not Non-Federal Cost-Share Partners, as described in the communications and outreach plan included in the Plan of Study. Throughout the study, the Cost-Share Partners will make information available to basin stakeholders and request their input. Stakeholder input will then be incorporated into the Basin Study as appropriate.

L. Administer Study

The Study Partners and Reclamation will administer the study throughout the study period.

M. Federal Contracting

If necessary, Reclamation will obtain non-federal contractors to conduct key study tasks and sub-tasks as agreed upon by both the Study Partners and Reclamation.

VI. Milestone Schedule and Costs

A. Cost Table

Tasks and Description	Non Federal $ Share	Federal $ Share	Total Cost
A. Develop Climate Change Projections	$74,183	$99,367	$173,550
B. Conduct Supply and Demand Assessment 1. Conduct Assessment of Current Supply 2. Develop Future Supply Projections 3. Conduct Assessment of Current Demand 4. Develop Future Demand Projections	$226,764	$158,820	$385,583
C. Update Groundwater Model	$115,000	$70,352	$185,352
D. Run Groundwater Model with Suite of Climate Change and Supply/Demand Assessment	$39,246	$141,792	$181,039
E. Conduct System Reliability Analysis 1. Identify Model and System Reliability Metrics 2. Conduct Baseline Reliability 3. Prepare Projections Future Reliability 4. Evaluate Supply Risks for Sectors	$30,000	$35,000	$65,000
F. Adaptation & Mitigation Strategies 1. Develop Strategies to Meet Future Supply Needs 2. Refine Strategies for Further Evaluation 3. Conduct Analysis of Strategies to Meet Future Supply Needs a) Technical Analysis b) Legal and Institutional Analysis c) Conduct Social and Economic Analysis	$64,728	$100,000	$164,728
G. Prepare Trade Offs Analysis of Strategies to Meet Future Supplies	$67,800	$101,000	$168,800
H. Develop Prepare Basin Plan	$40,000	$10,000	$50,000
I. Prepare Basin Study Report 1. Draft Final Report 2. Review Final Report 3. Publish Final Report	$35,000	$75,000	$110,000
J. Conduct Technical Sufficiency Review	$20,000	$39,233	$59,233
K. Conduct Communications and Outreach	$57,455	$58,553	$116,008
L. Administer Study	$262,824	$143,633	$406,457
M. Federal Contracting	$0	$0	$0
Total Costs	$1,033,000	$1,032,750	$2,065,750

B. Milestone Schedule

LSCR Basin Study Project Schedule - Amendment 3

<---------- 78 month Study Duration ----------->

	2016				2017				2018				2019				2020				2021				2022	
Study Activity	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
A Climate Change Projections			X	X	X	X	X	X	X																	
B. Supply and Demand	X	X	X	X	X	X	X	X	X	X	X	X	X	X												
C. Update GW Model									X	X	X	X	X	X	X	X	X									
D.Run GW Model										X	X	X	X	X	X	X	X	X	X							
E. System Reliabiilty Analysis																				X						
F. Adaptation Stratgy Development																X	X	X	X	X	X					
G. Trade-Off Analysis																					X					
H. Prepare Plan (Report Contents)																						X	X	X		
I. Final Report																							X	X	X	X
J. Technical Sufficiency Review															X	X	X	X	X	X	X	X	X	X	X	X
K. Communications and Outreach	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
L. Study Administration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M. Reclamation Contracting				X	X	X	X	X																		

ends June 30, 2022 ---------->

VII. Study Products

A. Technical memorandum on climate change projections and selected scenarios

B. Technical memorandum summarizing the current and future water supply and demand assessments

C. Technical memorandum indicating the condition of the LSCR Basin and groundwater levels. Projected water supply and demand imbalances for the 2060 planning horizon under a suite of scenarios identified in ten-year increments.

D. Technical memorandum summarizing potential risks and projections of future reliability

E. Technical memorandum summarizing the results adaptation and mitigation strategies analysis

F. Technical memorandum summarizing the results of the trade-off analysis

G. Assessments for strategies and infrastructure needs to address future supply and demand imbalances using groundwater and basins conditions predicted by selected future scenarios

H. Draft Final report

I. Final Report

Appendix I – Technical Sufficiency Review Plan

The technical sufficiency review will ensure that technical information, data, models, analyses, and conclusions resulting from a basin study are technically supported and defensible.

A. Coordination, Timing and Scope

The co-study managers will coordinate the technical sufficiency review. A technical review of each work product from the Basin Study will be conducted before it is made final.

B. Selection of Reviewers

Reclamation and the Non-Federal Cost-Share partners will coordinate with the non-federal cost-share partners to select the reviewers. The technical sufficiency review will be conducted by reviewers who were not directly involved with conducting the portion of the basin study they are reviewing. There will be multiple reviewers for each work product, and the reviewers' scientific and technical background and expertise will be relevant to the content of the basin study under review.

C. Documentation of the Results

Co-Study managers will document the results of the Technical Sufficiency Review and will make the results available to all of the Non-Federal cost-share partners. Reviewer comments and/or suggestions will be documented in writing.

All reviewer comments will be considered and incorporated where relevant and appropriate. The Co-Study Managers will prepare a response to all comments and suggestions submitted by reviewers. Technical uncertainties identified by reviewers will be identified and characterized in the Final Basin Study Report.

Appendix II – Community and Outreach Plan

Throughout the LSCR Basin Study, stakeholders (interested parties who are not Study Partners) will be informed and their input will be garnered and considered at key intervals as the project progresses. The Pima Association of Governments will be the lead agency for stakeholder involvement and public communications. However, the project team will be invited to participate in all events and will have input on all materials distributed.

As the Study progresses, the effectiveness of the public involvement will be assessed periodically, based on the level of public response and feedback from the Study Partners and stakeholders. If necessary, adjustments will be made as necessary to ensure that appropriate communication and feedback is occurring.

A. Stakeholder Information Meetings

Annual public meetings will be held to inform and garner input about the project. These three meetings will be held in a publicly accessible location and will be noticed through press releases, social media, printed media and flier distribution. Particular efforts will be made to invite key stakeholders. Public stakeholder meetings may take place during one of the standing committee meetings that are open to the public and will function as a public engagement forum for discussion and comment, as appropriate.

B. Regional Standing Committee Meetings

Pima Association of Governments will engage technical experts, professionals and interest groups through its Environmental Planning Advisory Committee (EPAC) and its Watershed Planning Subcommittee. EPAC is a 35-member standing committee with the following representation:

- Member governments (City of Tucson, Pima County, Towns of Marana, Oro Valley and Sahuarita, City of South Tucson, Tohono O'odham Nation, Pascua Yaqui Tribe)

- Citizen representatives from each of the above listed member jurisdiction area

- Interest groups (public interest, professional technical, environment, natural resources conservation, energy industry, mining industry, construction industry, local business, education/research, transportation)
- Ex Officio: State and federal entities (Arizona Department of Water Resources, Arizona Department of Environmental Quality, Arizona State

Land Department, Davis Monthan Air Force Base, U.S. Environmental Protection Agency).

In addition, all meetings are public and widely distributed through a large mailing list. PAG plans to have presentations on the Lower SCR Basin Study at a minimum of four EPAC meetings and two Watershed Planning Subcommittee meetings during the course of the project. If needed, EPAC can also be utilized to receive direct feedback on project elements because it is a voting body with standing representation.

C. Regional Managers and Decision Makers

This basin study will develop adaptation and mitigation strategies to address water supply and demand imbalances in the face of climate change. In order to move into future implementation and collaboration, it is essential that management and political decision makers be well informed and have opportunity to provide input during the evaluation. PAG will ensure that jurisdictional managers are informed about the LSCR Basin Study to through its top policy advisory committee, the PAG Management Committee. Members of this committee include the Pima County Administrator, the city managers from the cities of Tucson and South Tucson, the town managers from the towns of Marana, Oro Valley, and Sahuarita, a Tribal Council member from the Pascua Yaqui Tribe and the Roads Division Manager from the Tohono O'odham Nation.

During the study process, key elected officials will be kept abreast of project progress and results through information provided to the PAG governing board and the PAG Regional Council. The Regional Council includes a Pima County Supervisor, mayors from the City of Tucson, the City of South Tucson, the Town of Marana, the Town of Oro Valley and the Town of Sahuarita, the Vice Chairwoman from the Pascua Yaqui Tribe, the Chairman of the Tohono O'odham Nation and a member of the Arizona State Transportation Board.

D. Comment Responses

Reclamation will prepare a response for all comments received. Responses will be posted on the project website established by Reclamation. All information received regarding technical aspects of the Study will be considered and feedback regarding that consideration will be provided.

E. Records

Reclamation will archive all outreach materials, information received, and feedback provided in a centralized electronic filing system. As the Study progresses, Reclamation will assess the effectiveness of the public involvement

periodically and adjustments will be made as necessary to ensure that appropriate communication and feedback is occurring.

F. Other Types of Communications

Additional methods of communication that will be used to disseminate information and accept input during the course of this Study include the following:

- A Study website will be maintained to provide up-to-date, on-line information;
- An e-mail address will be established to facilitate communication electronically;
- News releases and informational mailings will be provided as appropriate;
- An email list will be established and maintained to ensure that all interested stakeholders receive information;
- Meetings with interested stakeholders groups will be held as appropriate.

1. Web Site

Reclamation's Study web site will be used to post up-to-date information. Web site content will be updated periodically, particularly at major milestones and prior to public meetings. In addition, the web site will be used as a tool for soliciting input from stakeholders.

2. E-mail

Reclamation will establish a Study e-mail address to disseminate information regarding the Study and to receive input.

3. News Releases and Informational Mailings

News releases and other informational mailings will occur near major milestones throughout the Study to inform stakeholders and the public of the Study status, provide opportunities for input, and provide meeting information including dates and locations of the public meetings.

4. E-Mailing List

Informational e-mails will be sent to interested stakeholders on the Study email list. Individuals will be added to the email list when requested through the Study e-mail address or through attendance at a public meeting captured on the sign-in sheet.

5. Additional Meetings with Interested Stakeholder Groups

During the course of the Study, additional meetings may be held with interested stakeholder groups to solicit additional input, expertise, data, and information. As appropriate, representatives of interested stakeholder groups may participate and provide input through ad hoc groups formed for specific study tasks or through the public participation venues described in the Communication and Outreach Plan.

Interested stakeholder groups may include, but are not limited to Federal agencies, Native American tribes and communities, water districts, scientific research groups, environmental groups, and representatives of the recreational industry. An initial mailing will be made to a list of interest groups involved in similar prior studies to gauge their interest and capability for participating in the Study. Other interest groups are encouraged to provide their contact information via one of the communication methods listed above.

Appendix B

Hydroclimate Analysis

BUREAU OF RECLAMATION

Technical Memorandum No ENV-2020-056

Hydroclimate Analysis Lower Santa Cruz River Basin Study

U.S. Department of the Interior

February 2021

Mission Statements

The mission of the Department of the Interior is to conserve and manage the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provide scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honor the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgements

The authors gratefully acknowledge the input and review of members of the Lower Santa Cruz River Basin Study Project Team, led by Eve Halper of Reclamation and Kathy Chavez of Pima County. Christopher Castro and Hsin-I Chang at the University of Arizona contributed dynamically downscaled climate analysis and expert review. Tom Pruitt with Reclamation provided Sac-SMA modeling and technical support.

Cover Photo: Sabino Creek in May (Reclamation/Bearup)

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Technical Memorandum No. ENV-2021-35

Lower Santa Cruz River Basin Study Hydroclimate Analysis

Prepared for:

Phoenix Area Office

Lower Colorado Region
Bureau of Reclamation

Prepared by:

Water, Environmental and Ecosystems Division

Water Resources Engineering and Management Group (86-68210)

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Abbreviations and Acronyms

°F	degrees Fahrenheit
ADWR	Arizona Department of Water Resources
AR5	5th Assessment Report
AZMET	Arizona Meteorological Network
CAP	Central Arizona Project
CBRFC	Colorado Basin River Forecast Center
CMIP5	Coupled Model Intercomparison Project phase 5
ET	evapotranspiration
GCM	Global Climate Model
IPCC	Intergovernmental Panel on Climate Change
km	kilometer
LOCA	Localized Constructed Analogs
LR	low resolution
LSCR	Lower Santa Cruz River
MAP	mean areal precipitation
MAT	mean areal temperature
MPI-ESM	Max-Planck-Institute Earth System Model
MR	mid resolution
NA CORDEX	North American Coordinated Regional Downscaling Experiment
NAM	North American Monsoon
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PET	Potential Evapotranspiration
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RSD	relative standard deviation
Sac-SMA	Sacramento Soil Moisture Accounting
Study	Lower Santa Cruz River Basin Study
TAMA	Tucson Active Management Area
WGIII	Working Group III
WRF	Weather Research and Forecasting Model
WRF-MPI	Max-Planck-Institute Earth System Model downscaled using WRF

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Executive Summary

This Technical Memorandum covers the climate change and surface water modeling elements of the Lower Santa Cruz River Basin Study (Study). The Study's goal is to identify where physical water resources are needed to mitigate supply-demand imbalances and to develop strategies to improve water reliability for the municipal, industrial, agricultural and environmental sectors within the Tucson Active Management Area (TAMA) (see Figure ES-1). However, for the purposes of evaluating changes to runoff and streamflow, this analysis focused on the extent of the surface watershed area contributing flow to the TAMA, as delineated by the Sacramento Soil Moisture Accounting Model. We refer this area, which is shaded blue in Figure ES-1, as the "surface water model boundary area" throughout the report. For reference, summary climate change statistics are provided for the area of the TAMA and the Tucson Metro Area Public Forecast Zone, as defined by the National Weather Service (see Figure ES-1).

Study Formulation

The Study's Project Team, which represents the cost-share partners, made several key decisions that shaped this hydroclimate analysis. First, it chose to simplify the analysis and concentrate on the range of risks to water users by examining two climate scenarios. This approach contrasts with similar Reclamation Basin Studies that have analyzed three to five separate climate scenarios.

For this Study, the Project Team requested a "best-case" future climate, a scenario in which action is taken to reduce the rate of worldwide greenhouse gas emissions and thus represents conditions under which a minimum of adaptation would be necessary. On the opposite end of the range, they requested a "worse-case" climate scenario, where greenhouse gas emissions continued to increase, and the impacts would be on the high end of the range. The use of the term "worse-case" emphasizes that while this scenario represents greater impacts than the "best-case," it does not describe the most extreme possible outcomes of climate change. More detail on the emissions scenarios used in this Study is provided in Section 2.2. Climate Scenarios.

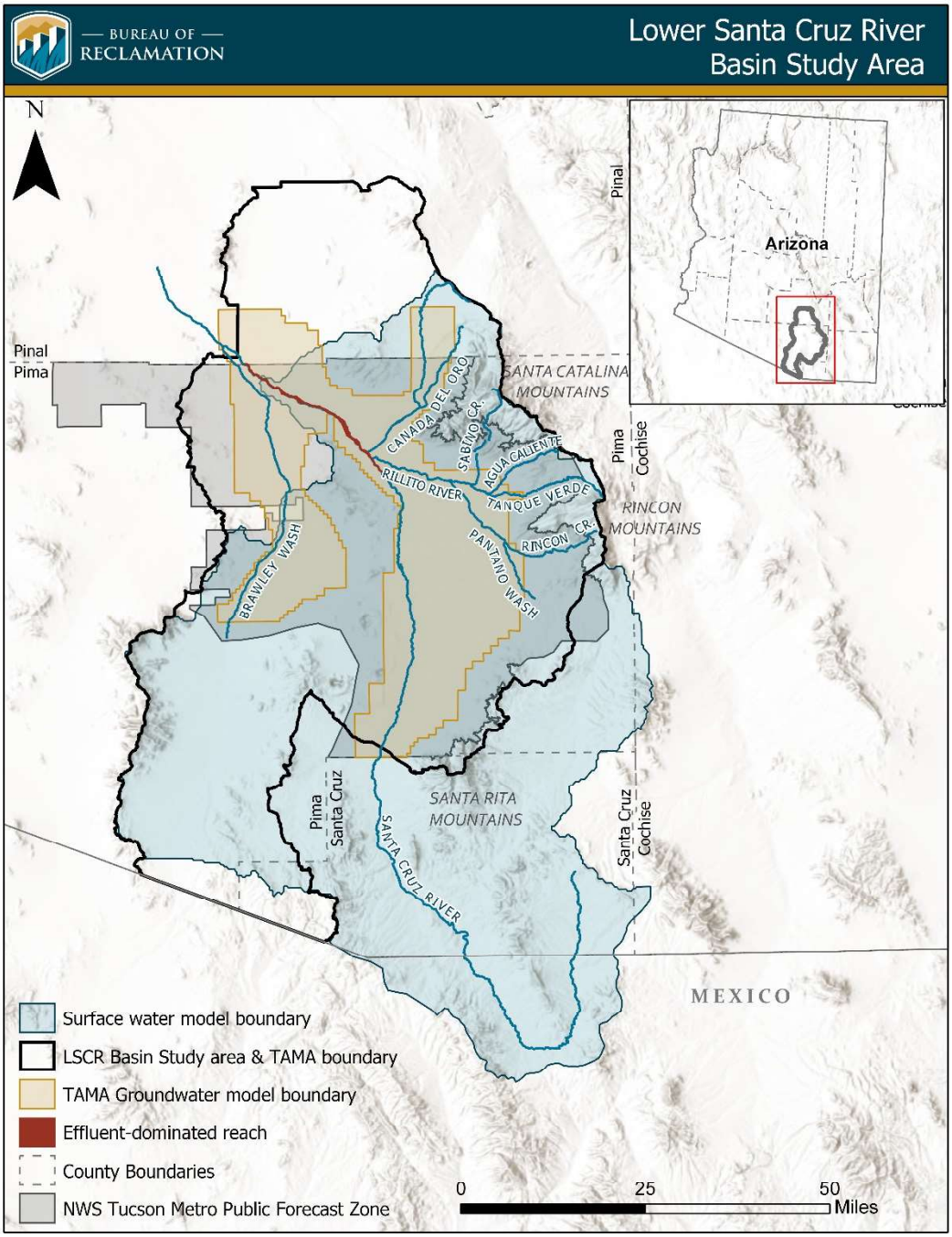


Figure ES-1. Lower Santa Cruz River Basin study area and modeling boundaries.

Downscaling

The output of Global Climate Models (GCM) is too coarse to use in an analysis of basin-scale hydrology. A process called "downscaling" must be applied to the GCM output to infer additional spatial detail. Statistical downscaling is a commonly used technique, and the statistically downscaled output of many GCMs, using a variety of emissions scenarios, are readily available to researchers. To date, all Reclamation Basin Studies have employed statistically downscaled climate projections.

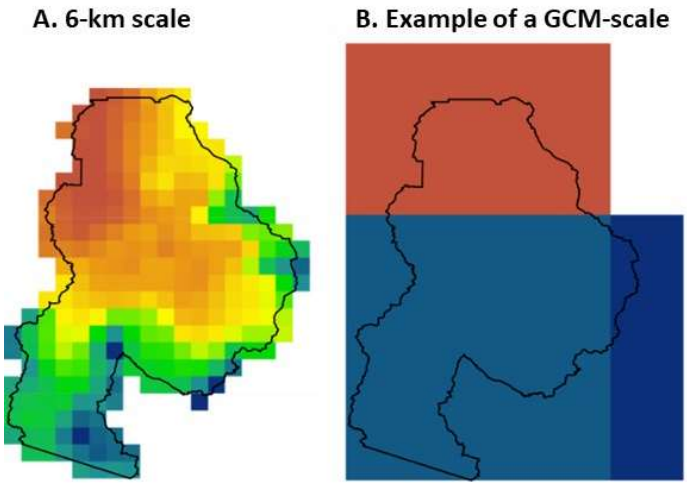


Figure ES-2. Example of resolutions from a downscaled projection (left) and a global climate model projection (right). These use the same data.

While statistically downscaled climate projections are computationally straightforward and readily available, they are constrained by their reliance on historical observations to project the future. In other words, this technique assumes that the range and distribution of hydrologic events that have occurred in the past will be maintained in the future. In fact, climate scientists have observed that the future variability of hydrologic processes may be fundamentally different from the past (Milly et al., 2008).

To account for this risk, the Project Team requested the inclusion of a climate projection that used a physically based method of downscaling, called dynamical downscaling. Dynamical downscaling uses the GCM output as the input to a Regional Climate Model (RCM) that simulates atmospheric processes that take place at a finer scale (in this case, 25 kilometers). Thus, it can project conditions outside of the historical climate record.

The southeastern Arizona climate is highly seasonal, with two distinct precipitation regimes. The monsoon season is characterized by short, intense, and highly local precipitation that occurs in the late summer and early fall. Precipitation events in the fall and winter are more sustained and widespread, but less intense. After the winter rains, the region experiences a period of low to no precipitation in the dry season before the start of the next monsoon season.

A review of available dynamically downscaled GCMs showed that the best simulated monsoon timing in the study area was from the low resolution (LR) Max-Planck-Institute Earth System Model (MPI-ESM-LR; Giorgetta et al., 2013), run downscaled using the Weather Research and Forecasting Model (WRF). We refer to this downscaled simulation as "WRF-MPI" throughout this report. From a local water resource manager's perspective, the onset date of the monsoon is a critical consideration. Only the higher emissions scenario was available for this GCM/RCM combination.

Without a WRF-MPI simulation available for the best-case climate scenario, the Study uses a statistically downscaled MPI-ESM medium resolution GCM output. This GCM is the same model used for the worse-case scenario, but using the run identified as mid resolution (MR). This projection predicts a future that is wetter and cooler than the worse-case scenario.

Due to the natural variability of the climate, it was necessary to compare time periods, rather than individual years, to detect changes in precipitation and temperature. The National Weather Service uses a period of thirty years to calculate a "climate normal." Similarly, this analysis compares simulations of a base historical period (1970- 1999), to a "near future" period of 2020-2049, also referred to as the "2030s", and a "far future" period of 2050-2079, or "2060s". While the groundwater modeling in the Study extends to 2060 to align with the conditions in Reclamation's Colorado River Basin Study, the hydroclimate analysis was not restricted by assumptions on Colorado River operations. See Table 1 for a summary of the emissions scenarios, downscaling techniques and model specifications used in this analysis.

Weather Generator

In addition to accounting for a range of risks, Project Team members supported an analysis that could simulate the considerable variability and seasonality characteristic of the southeastern Arizona climate. For this analysis, staff from Reclamation's Technical Service Center developed a three-season "weather generator." A weather generator is a computer program that produces large numbers (ensembles) of, in this case, precipitation and temperature time series. The distribution of values within the ensemble represents the variability of a system. This weather generator simulated the three distinct seasons: monsoon, winter wet, and dry. The weather-generated ensembles for the best- and worse-case scenarios were used as input to a surface hydrology model to estimate the future distribution of streamflows.

Summary: Temperature and Precipitation Change by Season

Table ES-1 summarizes the climate analysis. Analyses of changes to other key climate metrics, such as the onset and length of the monsoon and winter wet periods, are described in Section 2.4.3. Seasonality Results

Table ES-1. Summary of Projected Basin-Averaged Future Precipitation and Temperature Relative to its Respective Simulated Historical Period (1970 – 1999).

Geography	Statistic	Best- Case 2030s	Best- Case 2060s	Worse-Case 2030s	Worse-Case 2060s
Tucson Active Management Area	Change in Total Annual Precipitation	0.40″	-0.50″	-4.44″	-3.73″
Tucson Metro Public Forecast Zone	Change in Total Annual Precipitation	0.28″	-0.44″	-4.47″	-3.77″
Surface Water Model Boundary Area	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* compared to Historical: Best = 20.3%, Worse = 17.3%	21.6%	28.5%	18.9%	30.4%
Tucson Active Management Area	Change in Average Annual Temperature	2.92°F	3.81°F	3.36°F	5.07°F
Tucson Metro Public Forecast Zone	Change in Average Annual Temperature	2.88°F	3.77°F	3.34°F	5.05°F
Surface Water Model Boundary Area	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) is calculated by normalizing the standard deviation to the mean of the 30-year period and presented as a percentage.

Surface Hydrologic Modeling

Downscaled GCM output is the input to the weather generator, which produced separate ensembles of "best-case" and "worse-case" precipitation and temperature time series. These ensembles then serve as the input to a surface hydrology model called the Sacramento Soil Moisture Accounting Model (Sac-SMA). Sac-SMA simulates the processes of surface runoff, infiltration, and evapotranspiration. It is used by the National Weather Service's Colorado River Forecast Center to model floods in the Study area. The model was calibrated for the period of 1970-1999, aligning with the base historical period of the climate change analysis.

Use of the Sac-SMA model involved modeling several of the upstream basins outside of the Study area, especially to the south and east (Figure ES-1).

Surface Hydrology Results:

The best-case scenario projects overall streamflow increases in the monsoon and winter seasons through the 2030s and 2060s. The worse-case scenario features large streamflow decreases for the monsoon and winter seasons in the 2030s, which moderate in the 2060s. More detail is provided in Section 4.2. However, even under the best-case scenario, many streams may experience an increase in the number of dry days due to increased temperatures (see Appendix C) and changes in precipitation event characteristics. The worse-case scenario predicts an increase in the number of dry days for almost all streams in the Study area. Figure ES-3 illustrates this by using three charts:

- The number of dry days over the course of the year for each of the streams in the Sac-SMA model domain, for the historical period (1970 – 1999).
- The change in dry days by stream for the worse-case in 2030s, relative to the historical period.
- The change in dry days by stream for the worse-case in 2060s, relative to the historical period.
- Changes in soil moisture generally mirror changes in precipitation under future climate scenarios.

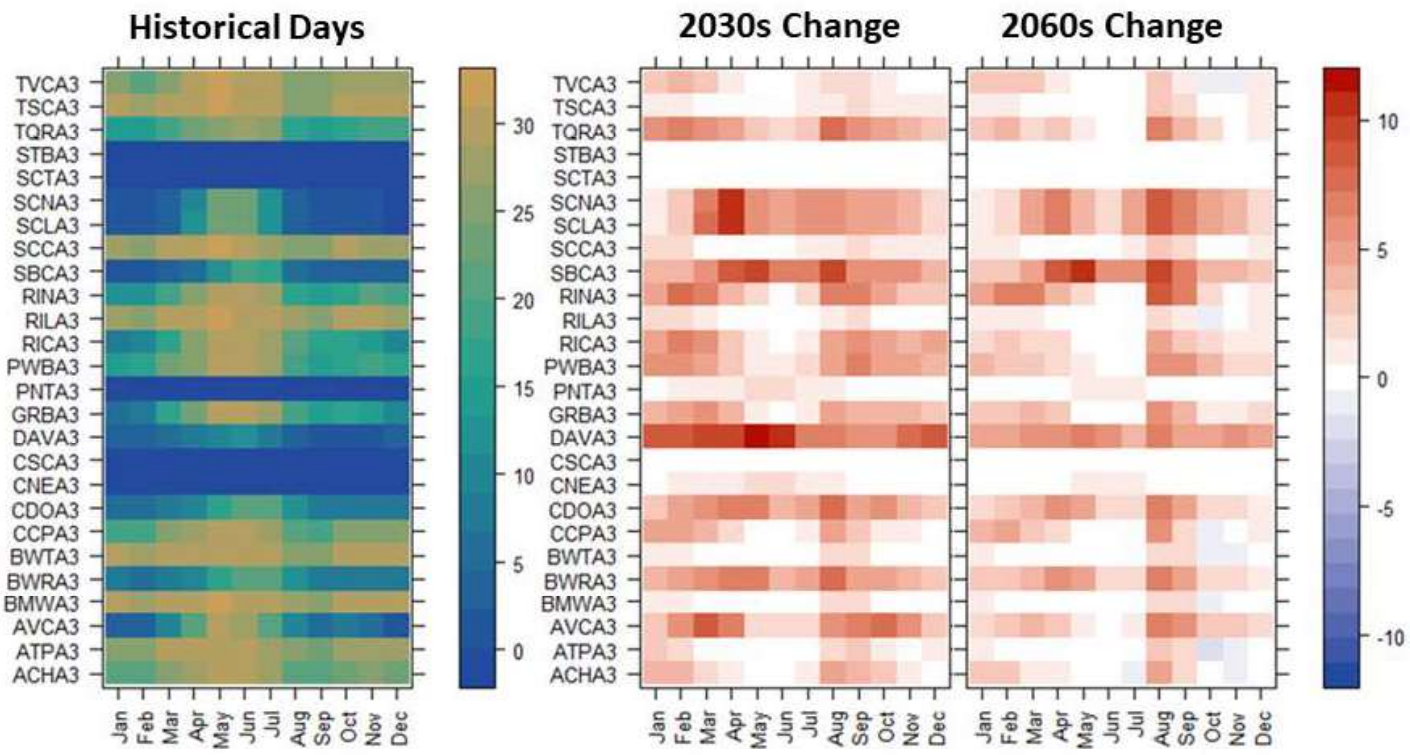


Figure ES-3. Dry days by stream in the simulated historical record and in projections for 2030s and 2060s for the worse-case scenario. See Figure 20 for definitions of the sub-basin abbreviations.

In summary, all models and climate scenarios consistently identify increases in temperature through time. Increases are larger under the worse-case scenario, which represents higher future emissions. Precipitation changes are more variable than temperature. The best-case scenario shows relatively minimal change in seasonal precipitation; in the worse-case scenario, total precipitation decreases in the monsoon and winter wet seasons.

Precipitation also becomes increasingly variable under projected future conditions. In either of these cases, it is likely that the number of dry days for streams will increase, especially in the summer months. The associated impacts include stress to vegetation and wildlife, as well as the potential for reductions in stream infiltration to the local groundwater aquifer, as addressed further in the next phase of the Study.

1. Introduction

The Santa Cruz River flows over 200 miles, originating in the San Rafael Valley in southeastern Arizona. The river crosses the US-Mexico border twice before flowing through Tucson, Arizona's second largest city. During flood events, the Santa Cruz drains to the Gila River, a tributary of the Colorado River. Portions of the main stem of the Santa Cruz River are effluent dependent, relying on the discharge of highly treated wastewater to maintain surface flows between precipitation events or wet seasons. In wet seasons, the river is also fed from tributaries such as the Cañada del Oro Wash and Rillito River, originating from the east of Tucson in the Santa Rita, Rincon, and Santa Catalina Mountains.

Arizona's 1980 Groundwater Code established Active Management Areas in areas of long-term groundwater decline to provide for long-term management and conservation of water supplies. Active Management Areas are primarily based on groundwater basin boundaries but take water use into account as well. The Lower Santa Cruz River (LSCR) Basin Study area is identical to the Tucson Active Management Area[1] (TAMA) within Pima and Pinal Counties, as seen in Figure 1. For the purpose of climate and surface water modeling, the LSCR Study hydroclimate analysis used a model boundary that extends to the south and east as shown in Figure 1. The northwest portion of TAMA was not included in the surface water model because those subbasins drain into the Gila watershed to the north. It is also sparsely populated compared to the rest of the TAMA.

Tucson and the surrounding area rely on groundwater, imported Colorado River water, and treated wastewater effluent to meet water supply needs. Key areas throughout the basin have experienced groundwater table declines, although the use and recharge of imported Colorado River water has helped to offset some of these storage losses. Changes in natural recharge, driven by shifts in precipitation and streamflow regimes, may further impact the local groundwater supply. Colorado River water is conveyed to the Tucson area via the Central Arizona Project (CAP), a 336-mile system of canals and pipelines. Arizona's CAP allocation has junior priority relative to other Colorado River rights holders. This introduces uncertainty to the reliability of the basin's water supply, particularly under projected warmer and potentially drier conditions in the Colorado River Basin (Reclamation 2012).

This report describes the analyses used to assess the impact of projected changes in precipitation and temperature on surface water supplies in the LSCR Basin. The basis of this approach is a pairing of dynamically and statistically downscaled climate projections over the surface water model boundary area, as detailed in Chapter 2 Climate Analysis. To account for the high degree of variability of the southeastern Arizona climate, a statistical "weather generator" was developed for the study, described in Chapter 3. The weather generator creates a large group, or ensemble, of plausible precipitation and temperature time series. Together, these time series simulate the inherent variability of the local climate. The resulting ensemble of climate

[1] https://new.azwater.gov/ama/management-plan/3

information is used with the Sacramento Soil Moisture Accounting (Sac-SMA; Burnash et al. 1973) model to propagate these projected climatic changes to the surface water system as described in Chapter 4. Surface Water Modeling. This study complements ongoing work by the LSCR Basin Study Project Team to evaluate climate change impacts on water supply and demand for agricultural, municipal, industrial, and environmental uses and provides details on the Sac-SMA modeling methodology and output analysis techniques.

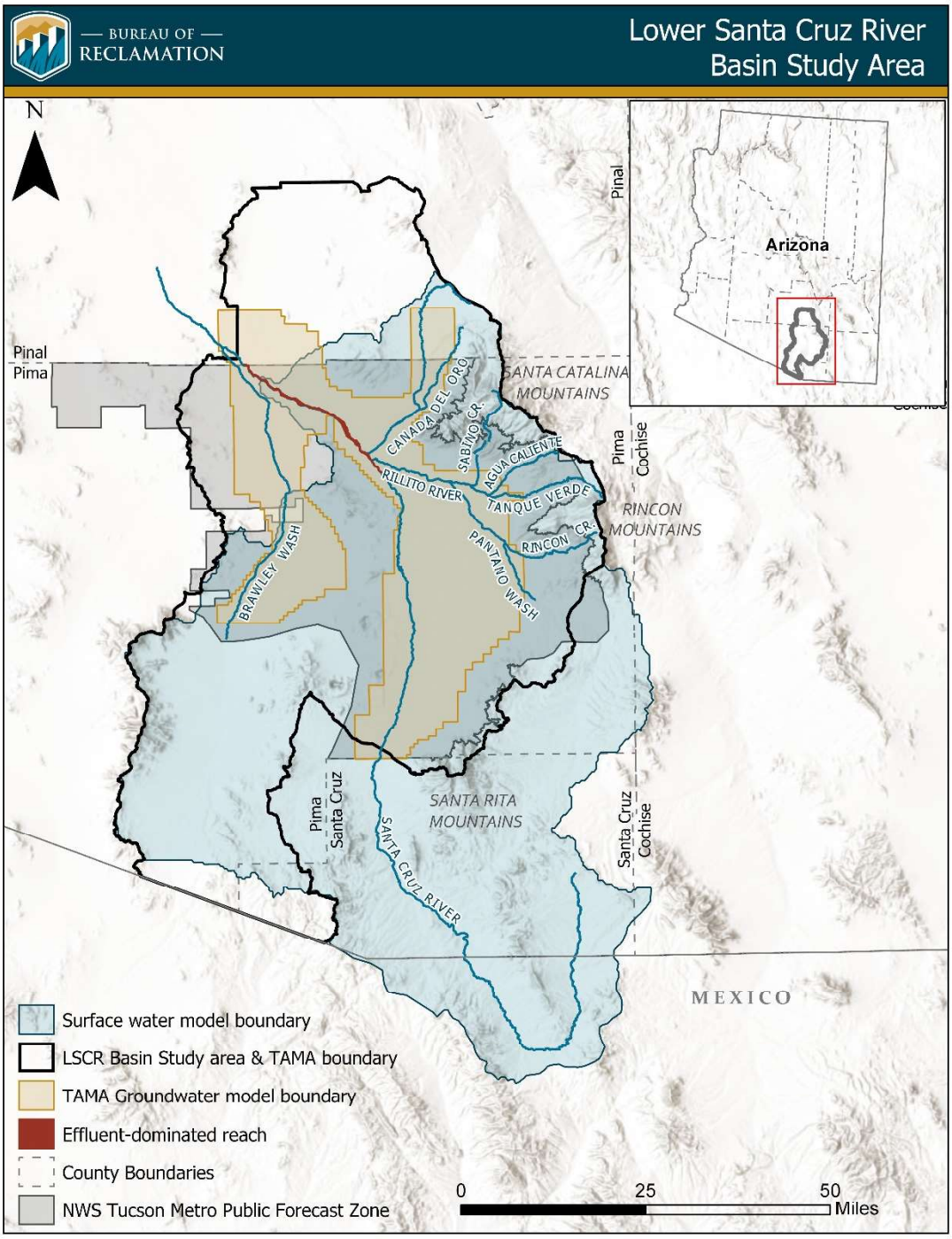


Figure 1 – Lower Santa Cruz River Basin study area and modeling boundaries.

2. Climate Analysis

2.1. Current Climate

This section provides an overview of the Tucson area's climate. Basic climate information is presented for the Tucson Active Management Area, with a focus on weather station data from the Tucson International Airport. Changes in annual temperature and precipitation are provided for the TAMA as well as the National Weather Service's Tucson Metro Area Public Forecast Zone, shown in Figure 1. Beginning in Section 2.2, analysis was performed using the geography of the surface water model boundary area, also shown in Figure 1.

Annual temperatures at the Tucson International Airport[2] average a minimum of 56 degrees Fahrenheit (°F) and a maximum of 83°F, with large seasonal and diurnal variability typical of mid-latitude steppe and desert climates. June and July have the hottest average monthly maximum temperatures (around 100°F), and December and January have the coolest minimum monthly temperature of approximately 40°F. The Tucson airport station (elevation 2560 feet; Figure 2) receives an average of 11.6 inches of precipitation per year. Precipitation is greater at higher elevations, averaging 33 inches per year in the Santa Catalina Mountains near Mount Lemmon[3] (station elevation 7690 feet), often with enough winter precipitation occurring as snow to accumulate snowpack on the ground.

Maximum monthly precipitation typically occurs in July (spatially distributed as shown in Figure 2) and August. Precipitation occurs over two distinct wet periods, one associated with the summer North American Monsoon (NAM) season (mid-June through September) and the other with cyclonic and low-pressure frontal systems in the fall and winter (approximately October-March). Summer monsoon precipitation is characterized by convective events that are typically short, intense, and highly localized. The highest maximum monthly temperatures occur in June and July (see Figure 2), with some cooling associated with the continued monsoon rains in August. Precipitation in the fall and winter produces more sustained and widespread but less intense precipitation events. Following the winter rains, the region experiences a period of low to no precipitation in the dry season preceding the start of the next monsoon season.

[2]COOP Station #028820 (NCDC 1981-2010 Monthly Normals) - https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?aztuap
[3]COOP Station #025732 (1981-2010 Monthly Climate Summary) - https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?az5732

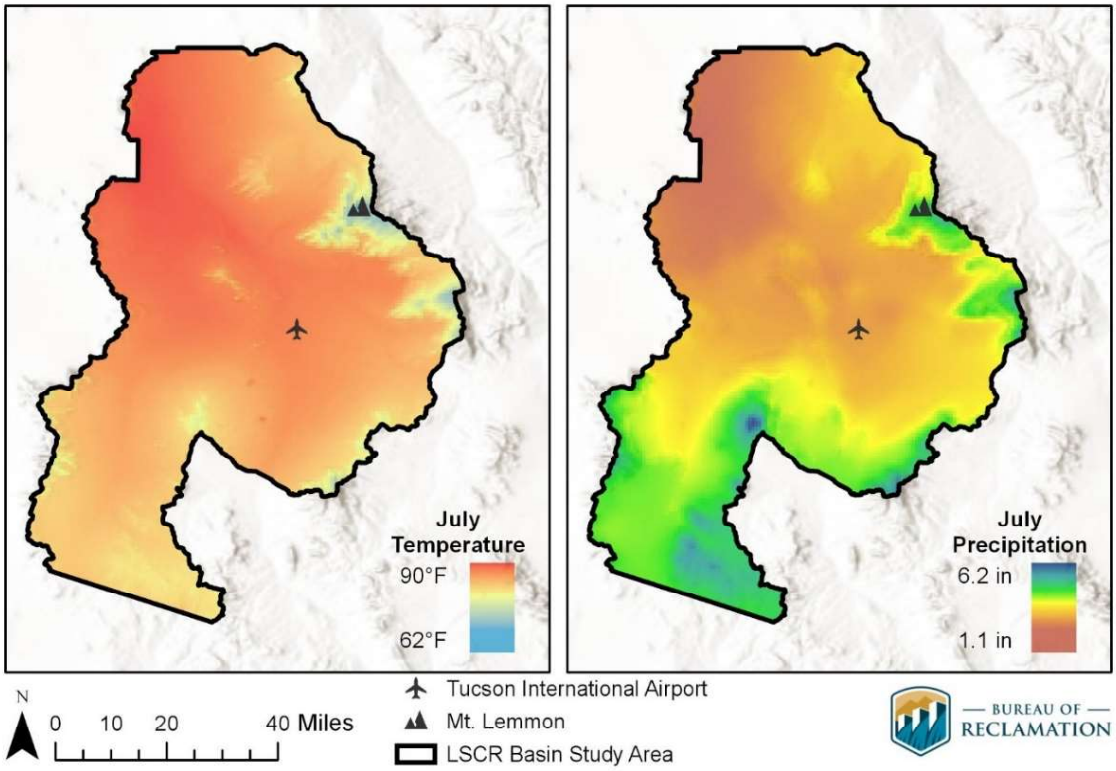


Figure 2 – July PRISM[4] temperature (left) and precipitation (right) 30-year (1981-2010) normals over the LSCR basin study area.

Precipitation is highly variable across the basin and across days, months, and years (Figure 3), with the variability on the same order of magnitude as the precipitation itself. Over the 30-year period from 1981 to 2010 depicted in Figure 3, some days of the year never received significant rainfall (e.g., June 10th). These consistently dry days tend to occur just before the onset of the monsoon in mid-June or early July (Figure 3, top). In addition to the day-to-day variability during the monsoon season, the start and end of the season can also vary greatly from year to year. The wide range of observed monthly precipitation totals during the monsoon months is depicted by the blue boxplots in the bottom of Figure 3. To represent the distinct seasonality of precipitation in the region, this study takes a dynamic approach to defining the dry, monsoon, and winter seasons, as described in Section 2.4.

[4] Parameter-elevation Regressions on Independent Slopes Model

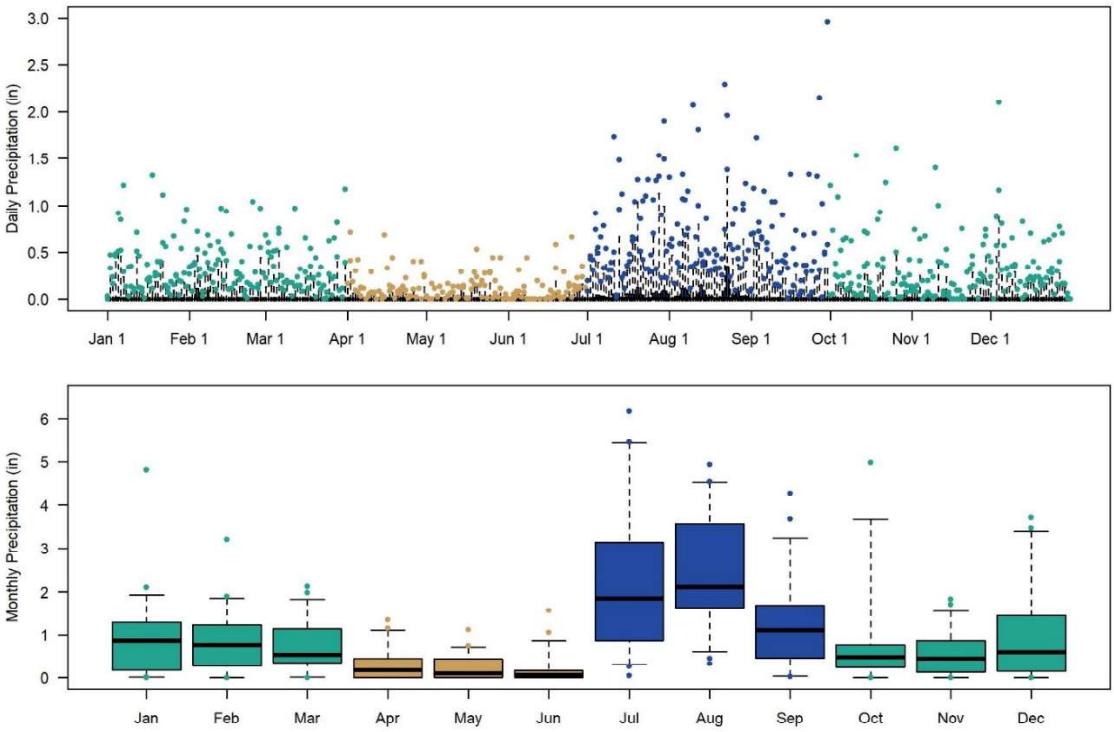


Figure 3 – Rainy day (top) and total monthly (bottom) precipitation at the Tucson Airport station from 1981-2010. Teal boxes indicate months that typically fall in the winter rainy season, tan indicates months that are typically in the dry season, and blue are months typically in the monsoon season. Whiskers represent 5th/95th percentile of interannual variability over the period.

2.2. Climate Scenarios

The formulation of climate scenarios begins by developing assumptions about how the key drivers that impact the Earth's climate will vary in the future. These factors include the emissions and concentrations of greenhouse gasses and certain aerosols, as well as land use and land cover conditions. While these sets of assumptions contain information besides levels of greenhouse gas emissions, they are commonly referred to as "emissions scenarios".

The Intergovernmental Panel on Climate Change (IPCC) sponsored the development of standardized emissions scenarios called Representative Concentration Pathways (RCPs) to, "encourage research that will characterize a broad range of possible future climate conditions, taking into account recent climate observations and new information about climate system processes" (Moss et al. 2010). This Study uses two RCPs from the IPCC 5th Assessment Report (AR5) (Taylor et al. 2012 and IPCC 2014) to define future climate outcomes: RCP 4.5 and RCP 8.5 as depicted in Figure 4.

The concept of radiative forcing is key to understanding climate change. National Oceanic and Atmospheric Administration's (NOAA) Climate.gov website provides a simple description of this process, which is excerpted here:

"In accordance with the basic laws of thermodynamics, as Earth absorbs energy from the sun, it must eventually emit an equal amount of energy to space. The difference between incoming and outgoing radiation is known as a planet's radiative forcing. In the same way as applying a pushing force to a physical object will cause it to become unbalanced and move, a climate forcing factor will change the climate system. When forcings result in incoming energy being greater than outgoing energy, the planet will warm (positive radiative forcing). Conversely, if outgoing energy is greater than incoming energy, the planet will cool."

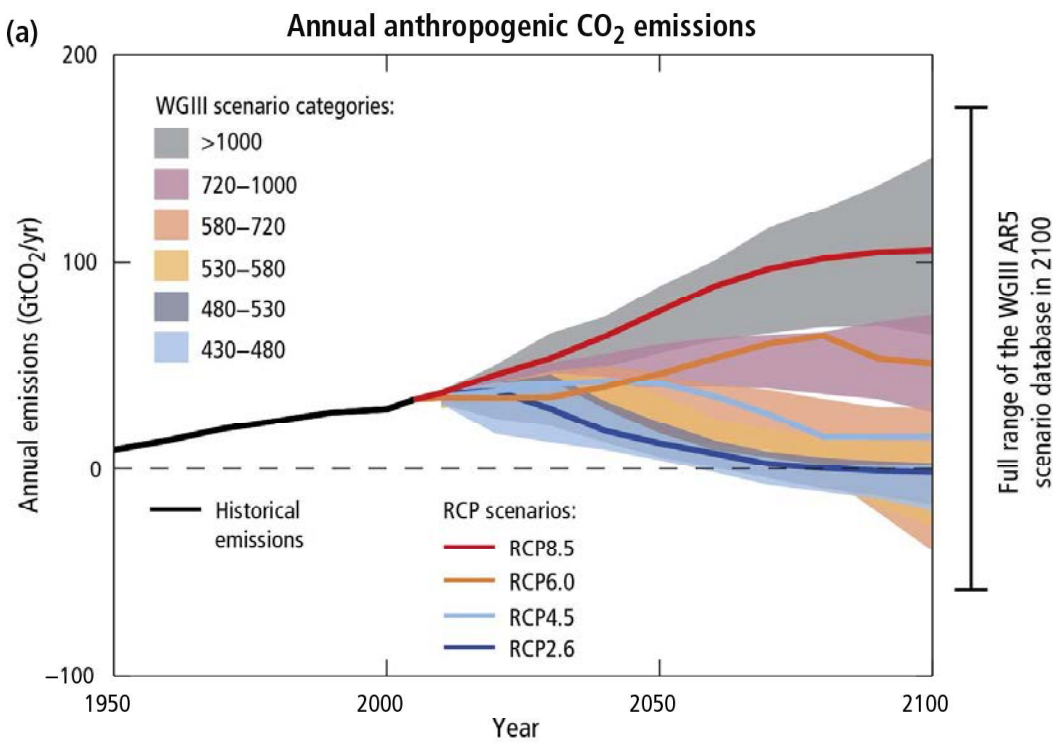


Figure 4 – Emissions of carbon dioxide (CO_2) alone in the RCPs (lines) and the associated scenario categories used in the IPCC Working Group III (WGIII; colored areas show 5 to 95% range). The WGIII scenario categories summarize the wide range of emission scenarios published in the scientific literature and are defined on the basis of CO_2-eq concentration levels (in ppm) in 2100. (Figure and caption from IPCC, 2014).

This Study used the following RCPs:

- **High Risk** (RCP 8.5; Riahi, 2011). Radiative forcing continues to rise through 2100, suggesting minimal improvements from adaptation strategies and continued increases in greenhouse gas emissions. This continued increase most closely reflects the current trajectory of emissions, lending this scenario the "business as usual" label.

- **Low Risk** (RCP 4.5; Thomson et al. 2011). Radiative forcing increases more slowly during the mid-21st century and stabilizes shortly after 2100 from moderate levels of

mitigation of greenhouse gas emissions. At the time of development, RCP 4.5 was considered a more realistically achievable scenario than the lowest RCP (RCP 2.6).

General Circulation Models, also referred to as Global Climate Models (GCM), use RCPs as input to simulate the Earth's response to changes in incoming and outgoing radiation. This Study uses long-term GCM simulation outputs driven by RCPs from the IPCC's standardized climate experiments known as the Coupled Model Intercomparison Project phase 5 (CMIP5). GCM outputs represent large-scale atmospheric and oceanic processes, with coarse model grid resolutions, typically on the order of 100 km laterally. Since "climate" refers to the typical weather of an area over a period, often 30 years, long-term simulations are needed to assess how climate may change in the future.

2.2.1. Downscaling Methods

The spatial scale of GCM simulations is typically too coarse to support the type of hydrologic modeling required for local water resource management. The coarse scale of GCMs typically does not capture climate processes such as orographic precipitation, snowfall, and convective storms—processes that are important for water resources planning.

GCM simulations must be spatially downscaled to be used in basin-scale hydrologic modeling. Spatial downscaling methods derive climate information at finer spatial resolution from coarser spatial resolution GCM output. The fundamental basis of spatial downscaling is the assumption that significant relationships exist between local and large-scale climate (USAID, 2014).

The importance of downscaling for basin-scale studies is illustrated in Figure 5, which shows Parameter-elevation Regressions on Independent Slopes Model (PRISM; PRISM Climate Group 2018) precipitation data on a 6 kilometer (km) by 6 km grid (left) versus a 100 km by 100 km grid resolution, typical of a GCM (right). Note how the spatial precipitation patterns are lost at the scale of the GCM. The entire LSCR Basin study area is covered with less than three GCM grid cells, while the 800 meter PRISM precipitation topographic patterns (shown in Figure 2) are still visible at the downscaled 6-km resolution.

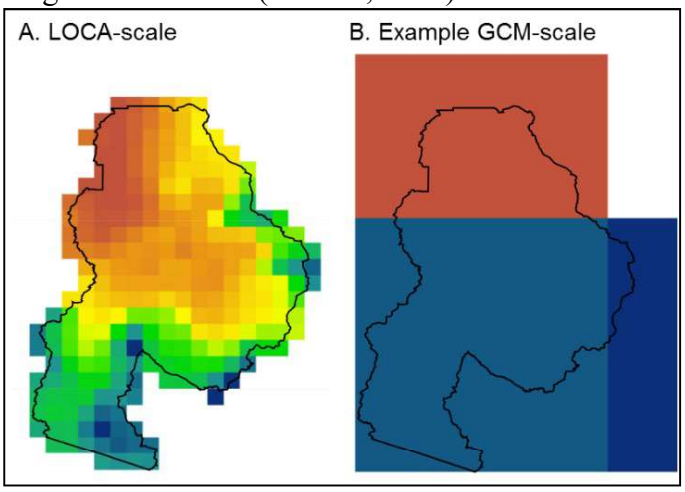


Figure 5 – PRISM gridded precipitation scaled to the approximate resolution of A) LOCA and B) a sample GCM. Both figures use the same data and color scale as Figure 2.

This study uses two approaches for downscaling GCM simulations: *statistical* and *dynamical* downscaling. Statistical downscaling relies on empirical relationships derived between projections and historical observations. This study uses the Localized Constructed Analogs (LOCA) method (Pierce et al. 2014) to downscale CMIP5 GCM simulations to a finer spatial resolution (1/16th degree, or approximately 6 km). The LOCA dataset provides 64 projections of daily precipitation and minimum/maximum temperature from 32 GCMs using two emissions scenarios: RCP 4.5 and RCP 8.5.

Statistical downscaling methods use observations to map global climate model outputs to a finer scale. LOCA uses the Livneh et al. (2015) gridded dataset over the period from 1950-2005 to select appropriate analog days from observations. While this method relies on the assumption that there is a historical day that captures future patterns, the observation dataset accounts for the systematic effects of local properties such as topography on precipitation and temperature. LOCA uses less temporal averaging than many other statistical downscaling methods to better preserve extreme events, such as hot days or heavy rains (Pierce et al. 2014). This makes it better suited for use in the desert southwest U.S. and for understanding variability in complex topography than other statistical downscaling methods.

Dynamical downscaling uses GCM outputs as input to a higher resolution regional climate model (RCM), such as the Weather Research and Forecasting (WRF) model used in this study. The benefit of this approach is that it simulates physical processes and does not rely on finding a suitable historical analog to provide local climate information. As decision-makers ask increasingly detailed questions regarding future changes in local climate, dynamical downscaling provides a method to look at changes in processes and patterns outside of the observed record.

The computational expense of running an RCM often limits the number of models and scenarios that can be evaluated. Therefore, this approach may not capture the uncertainty associated with model development choices or provide a range of RCPs to quantify uncertainty related to future emissions scenarios. As the available dynamically downscaled projections in this Study were based only on RCP 8.5, a statistically downscaled projection was used to include RCP 4.5 and the uncertainty surrounding the composition of the future atmosphere.

The consequence of downscaling methodology selection on projected water resources was recently evaluated in two Arizona basins by a Reclamation Science and Technology study (Shamir and Halper, 2019). This study concluded that the changes projected by the dynamically downscaled simulations are substantially larger than the statistically downscaled, for both projected wetter and drier future scenarios.

2.2.2. Future Climate Scenarios

The study's cost-share partners, represented by the Project Team, helped to shape the approach to the future climate analysis. Partners indicated that they wanted to model a range of risks to the area's water using sectors, from a "worse-case" scenario (severe but not impossible to adapt to) to a "best-case" scenario (one that would require a minimum amount of adaptation). These scenarios would "bookend" the range of impacts to water users and serve as a basis for future planning activities.

Study partners were aware of recent University of Arizona research that compared the impact of downscaling method on projected streamflows for three Colorado River catchments, the Upper Colorado River at Lees Ferry, the Salt River, and the Verde River (Mukherjee 2016). The study compared two ensembles of CMIP 3 GCMs, downscaled using either statistical or dynamical methods. For all three basins, the mean of the dynamically downscaled ensemble projected lower monsoon and winter precipitation compared to the mean of the statistically downscaled ensemble.

This finding led to a concern that omitting the use of a dynamically downscaled projection could lead to an underestimate of risks to water users. Partners requested that Reclamation work with researchers from the University of Arizona Hydrology and Atmospheric Sciences Department to develop a climate scenario using dynamically downscaled projections as part of the "worse-case" scenario. The limited number of dynamically downscaled datasets necessitated the selection of a statistically downscaled best-case scenario based on the lower risk RCP 4.5 as a counterpart to the high-risk RCP 8.5 dynamically downscaled worse-case scenario (Table 1).

Table 1 – Summary of Datasets Used to Define Climate Scenarios

Scenario	Downscaling	RCP	Downscaled Resolution	Date Range
Historical Best-Case	Statistical (LOCA)	-	6km	1970-1999
Historical Worse-Case	Dynamical (WRF)	-	25km	1970-1999
2030s Best-Case	Statistical (LOCA)	4.5	6km	2020-2049
2030s Worse-Case	Dynamical (WRF)	8.5	25km	2020-2049
2060s Best-Case	Statistical (LOCA)	4.5	6km	2050-2079
2060s Worse-Case	Dynamical (WRF)	8.5	25km	2050-2079

**Note that both the statistically and dynamically downscaled datasets include retrospective (historical) simulations to provide a baseline for evaluating model performance and relative change in climate. Historical years from the modeled dataset were selected to align with the surface water model calibration period.*

The worse-case scenario uses outputs from the low resolution (LR) Max-Planck-Institute Earth System Model (MPI-ESM-LR; Giorgetta et al. 2013) run downscaled using WRF (WRF-MPI) as part of the North American Coordinated Regional Downscaling Experiment (NA-CORDEX) archive. Only RCP 8.5 is currently available for this GCM/RCM combination. While other combinations of GCMs and downscaling models are available as part of NA-CORDEX, University of Arizona analysis determined that WRF-MPI best simulated monsoon timing in the study area (Chang 2018). From a local water resource manager's perspective, the onset date of the monsoon is a critical consideration. WRF-MPI simulations are available at 25 km lateral resolution and 6-hourly temporal resolution from 1950-2100. Additional details on WRF configuration are provided in Castro et al. (2017).

Without WRF-MPI simulations available for RCP 4.5 in the NA-CORDEX archive, the best-case scenario was created using the LOCA statistically downscaled MPI-ESM-MR GCM output for the RCP 4.5 emission scenario. The GCM for this scenario is the same model used for the worse-case scenario, but using the run identified as mid resolution (MR) to provide a scenario that is wetter and cooler than the worse-case (refer to Figure 8 in Section 2.3. Projected Changes in Annual Precipitation and Temperature Climatology).

As discussed in the introduction to Chapter 2, precipitation in the LSCR basin is extremely variable across a range of temporal scales from days to years. Partners requested an analysis that would preserve the variable nature of the southern Arizona climate, rather than one that focused on average changes. To accomplish this, the analysis describes two future periods that characterize the climatology of two 30-year intervals. The first interval is centered around the 2030s (2020-2049) and the second is centered around the 2060s (2050-2079). These periods are

also referred to as the "near future" and "far future" in this report. The 2060s time horizon was selected to align with the demands and external supply projections for the Lower Colorado River Basin. The historical period (calendar years 1970-1999) aligns with the surface water model calibration period.

We compared simulations of the historical period using the two GCM/downscaling method combinations with the observed data used to calibrate the Sac-SMA model. The Sac-SMA model calibration data over this historical period are derived from hourly gauges and radar data aggregated to elevation bands to drive the surface water model. The surface water model and forcing dataset are described further in Section 4.1 and used throughout this study as a historical dataset for comparison. Each historic period climate simulation (LOCA and WRF-MPI) provides retrospective results that are used as a baseline for comparisons and for bias correction.

2.2.2.1. Bias Correction

All model outputs contain biases, or systematic errors, related to the configuration of the model, downscaling method, or input data. To account for these biases, this study compares each future period to its respective historical period simulation with the same model configuration and inputs to identify projected changes. For example, the 2060s worse-case scenario was compared to the WRF dynamically downscaled historic period simulation, while the 2060s best-case scenario was compared to the LOCA statistically downscaled historic period simulation. In other words, to adjust for systematic errors, we present the changes between the simulation of the historic period and the future period using the same emissions scenario, climate model and downscaling method.

Bias correction is often used to account for systematic differences between modeled results and observations. Modeled temperatures are less uncertain than precipitation but required bias correction to ensure that realistic values for potential evapotranspiration calculations would be used in the Sac-SMA hydrology model. Bias correction requires historical observations. This study uses the observed dataset used to calibrate the Sac-SMA model for temperature bias correction. Future temperatures were adjusted (or bias corrected) based on the difference between the cumulative density functions of the observed and modeled historical temperatures within a 15-day window (Thrasher et al., 2012).

Similar correction methods were not applied to precipitation to maintain the important but uncertain nature of the extremes in the precipitation distribution. However, the WRF-MPI dataset developers extensively analyzed the raw WRF output for use in this study (Chang 2018). Modeled precipitation, averaged over the surface water model boundary area, was also reviewed to ensure realistic values, defined here as not exceeding 150% of the annual maximum historical daily averaged precipitation for the same area from the Sac-SMA calibration dataset (Figure 6). The best- and worse-case scenario future daily precipitation data were also subjected to this screening procedure (Table 2). No values (historical or future) exceeded this threshold, a constraint similar to those used in previous studies (Reclamation 2011, Payne et al. 2004, and Maurer et al. 2007).

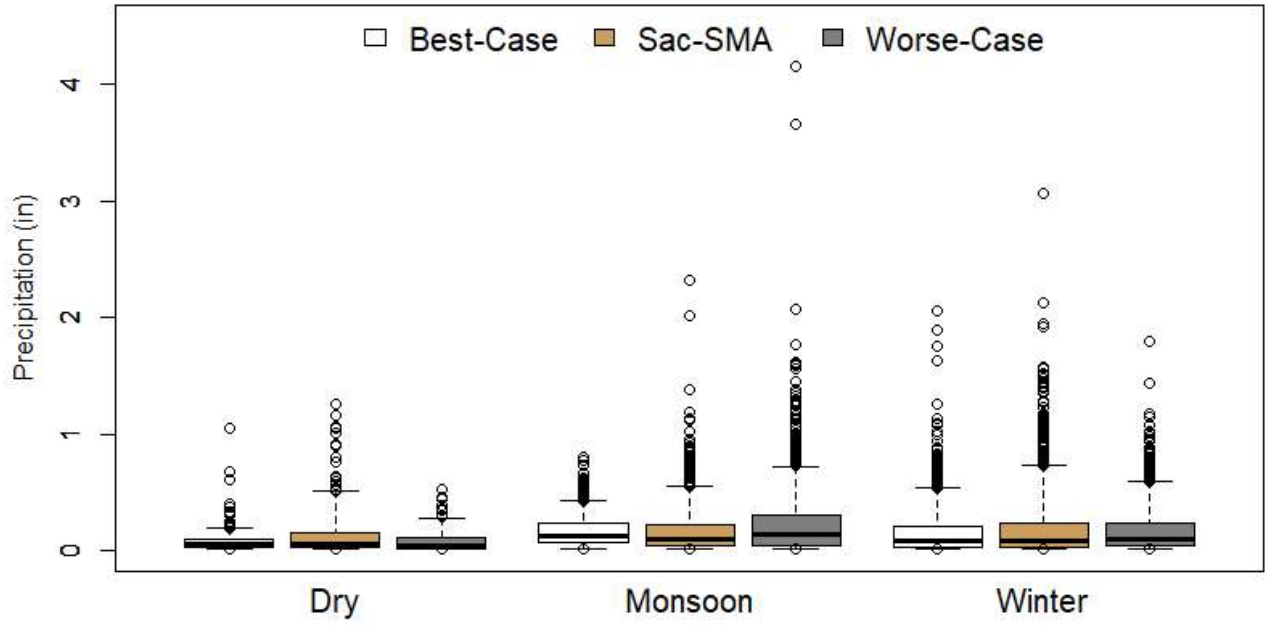


Figure 6 – Historical (1970-1999) daily rainy day precipitation averaged over the surface water model boundary area for the Sac-SMA calibration dataset (tan), best-case scenario simulation (white), and worse-case scenario simulation (gray), presented by season. Here, rainy days are defined as any day with greater than 0.01 inches of rain precipitation, a threshold selected after considering local climatology. Whiskers represent 5th/95th percentile of interannual variability over the historical period.

Table 2 – Statistics of Rainy-Day Precipitation by Season, Scenario, and Period, averaged across the surface water model boundary area.

		Precipitation (inches)						
		Sac-SMA	**Best-Case Simulation**			**Worse-Case Simulation**		
		Hist.	**Hist.**	**2030s**	**2060s**	**Hist.**	**2030s**	**2060s**
Dry	5th Percentile	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Mean	0.13	0.08	0.08	0.08	0.08	0.10	0.09
	Median	0.06	0.06	0.05	0.04	0.04	0.05	0.05
	95th Percentile	0.52	0.19	0.23	0.28	0.28	0.37	0.32
	Maximum	1.25	1.05	0.47	0.82	0.53	0.75	0.65
Monsoon	5th Percentile	0.01	0.02	0.01	0.01	0.01	0.02	0.01
	Mean	0.17	0.16	0.15	0.13	0.23	0.20	0.20
	Median	0.09	0.13	0.11	0.08	0.14	0.12	0.11
	95th Percentile	0.55	0.43	0.43	0.42	0.73	0.64	0.69
	Maximum	2.32	0.80	1.00	1.37	4.15	4.09	4.23
Winter	5th Percentile	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Mean	0.19	0.15	0.16	0.19	0.18	0.16	0.18
	Median	0.08	0.08	0.07	0.09	0.10	0.08	0.09
	95th Percentile	0.73	0.53	0.58	0.68	0.59	0.55	0.57
	Maximum	3.07	2.05	1.75	2.14	1.80	1.59	2.28

2.2.2.2. Model Limitations

The dynamically downscaled simulation uses a physically based approach that better captures the monsoon season dynamics important to this study. The LOCA simulation provides a complement to the dynamically downscaled projection and was selected to agree with the WRF-MPI scenario, consistent with the goal of illustrating a range of risks (i.e., best- and worse-case scenarios). The developers of LOCA and its user-community do not typically recommend using single projections for analysis. This is because a single LOCA projection does not reflect the physics of the atmospheric patterns in the same way that dynamical downscaling does. Also, selecting a GCM that is well performing for a region does not guarantee the processes for which it was selected are retained. Individual large extreme precipitation events are often not well represented in statistically downscaled data, which is reflected here in the absence of monsoon season precipitation extremes in the LOCA MPI-ESM dataset, as seen in Figure 6.

While the dynamically downscaled dataset was selected based on the GCM's ability to capture the monsoon season in the region (Chang, 2018), capturing remnant tropical cyclones that recurve into the Southwestern United States, typical of the late summer to early fall period (August – October), is a known weakness of these simulations. With these inherent limitations in mind, the best- and worse-case scenarios are still very useful for planning and adaptation strategy development and fit within the range of change seen from the larger ensemble of statistically downscaled models available from the LOCA dataset, as described in the next section.

2.3. Projected Changes in Annual Precipitation and Temperature Climatology

The statistics provided in this section cover the surface water model boundary area, which includes higher elevation areas that are cooler and rainier than the Study area. Projected changes in annual precipitation and temperature for the Tucson Active Management Area and the National Weather Service's Tucson Metro Forecast Zone are provided in Table 4.

Projected annually averaged temperature over the surface water model boundary area generally increases through time, (Figure 7), with larger increases under the worse-case scenario. Under the best-case scenario, the average annual change in precipitation increases by 0.32 inches in the 2030s and decreases by 0.85 inches in the 2060s, relative to the simulated historical period, which averages 15.8 inches. For the worse-case scenario, the future precipitation decreases more drastically in the near future (4.34 inches) and recovers slightly in the far future with a decrease of 3.90 inches, relative to the simulated historical average of 23.1 inches. The slight improvement in the far future may be caused by abnormally wet years in the far future (Figure 7).

Similar to projected precipitation changes, temperature changes are more severe in the worse-case scenario than in the best-case scenario, with temperatures consistently increasing more in the far future than in the near future. Near future average annual temperature increases range from 2.94°F in the best-case to 3.41°F in the worse-case scenario. Far future increases range from 3.83°F to 5.12°F for the best- and worse-case scenarios, respectively. The larger increase in

temperature in the far future under the worse-case scenario mirrors the continued increase in greenhouse gas emissions under RCP 8.5 relative to a reduction in emissions under RCP 4.5.

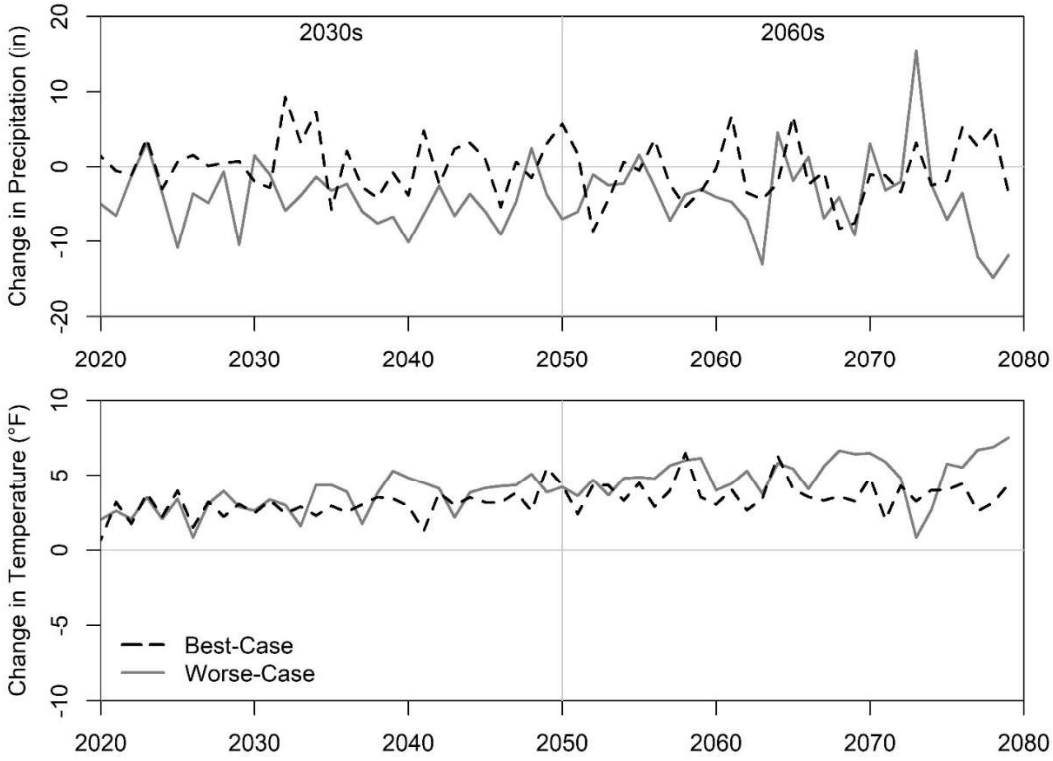


Figure 7 – Timeseries of the change in total annual precipitation (inches) and average annual temperature (°F) relative to the respective 30-year average of simulated historical values for the best- (dashed black line) and worse-case (solid gray line) climate scenarios. The gray vertical line represents the break between the near future (2030s) and far future (2060s). Values above the gray horizontal line at zero indicate future increases in precipitation or temperature and values below indicated decreases.

Figure 8 shows the changes in precipitation and temperature for the best- and worse-case scenarios, relative to the range of changes predicted by the 64 LOCA simulations, for the two future periods. These plots indicate where the selected cases fall within a larger portfolio of climate models. Note that the colors on the y-axis (temperature) go from lighter red at the bottom to darker red at the top. This is due to the fact all scenarios had increases in temperature. In contrast, some LOCA simulations had increases in precipitation while others had decreases, indicated by the transition from blue (wetter) to red (drier) on the x-axis.

In general, the best-case climate scenario (black square) has a wetter and cooler climatology over the two future periods used in this study (Figure 8), relative to the worse-case scenario (black triangle). Statistics of the full LOCA ensemble, reflected by the horizontal and vertical lines in Figure 8, provide context for the severity of the change relative to the range of uncertainty in the ensemble of 64 LOCA-downscaled CMIP5 models. This ensemble includes both RCP 4.5 and RCP 8.5 data, but does not include other emission scenarios, thus better reflecting uncertainty from model selection—not the full range of possible future emissions.

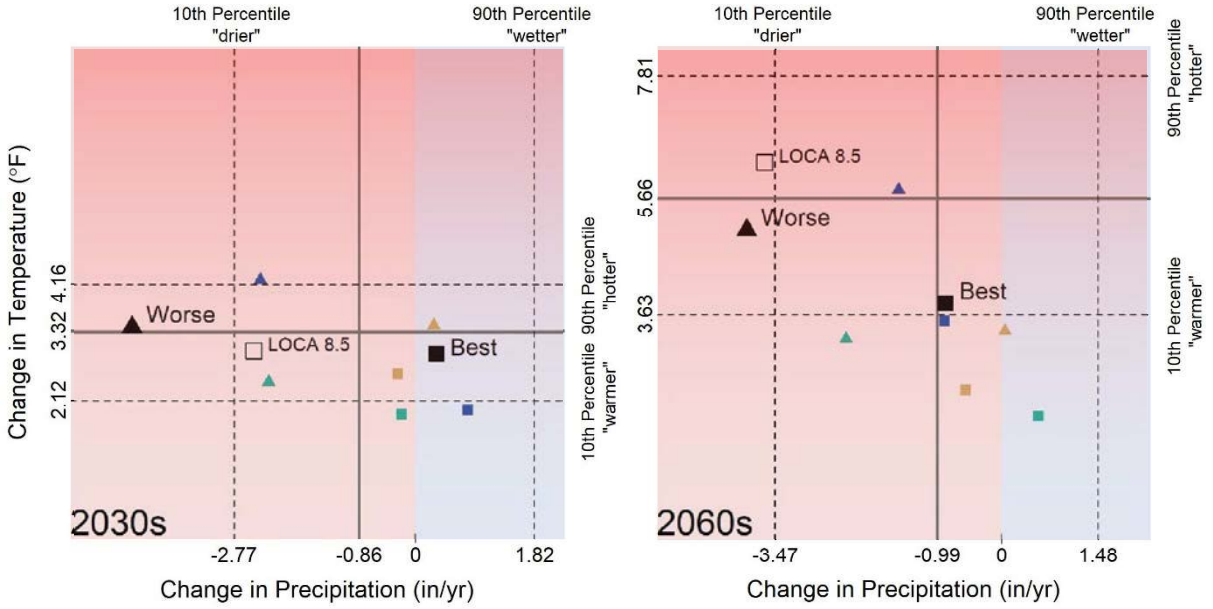


Figure 8 – Change in total annual precipitation averaged over the surface water model boundary area (inches per year) and average annual temperature (°F) for the best- (filled square) and worse-case (filled triangle) averaged over the case scenarios for the 2030s (left panel) and 2060s (right panel). Seasonal changes are also displayed as smaller shapes for the dry (tan), monsoon (blue), and winter (teal) seasons with change in precipitation in units of inches of precipitation per season. The open square is the RCP 8.5 equivalent of the LOCA-downscaled MPI-ESM-MR projection. Dashed lines are the 10th and 90th percentile change from the full LOCA ensemble and solid dark gray lines are the median change. Note the use of consistent scales in the 2030s and 2060s panel plots.

While only two projections were analyzed in detail in this study, these two scenarios fit well within the range of change seen in the larger LOCA model ensemble. Figure 8 includes the 10th, 50th (median), and 90th percentiles of change from the LOCA simulations averaged over the surface water model boundary area. Although the best- and worse- cases were selected based on additional analyses of model performance, in the 2030s the best- and worse-case scenarios also represent warmer/wetter and hotter/drier scenarios, respectively, relative to the range of the full set of LOCA simulations (32 GCMs, 2 RCPs). In the 2060s, the worse-case scenario continues to provide a scenario that is hotter and drier than the best-case. This provides confidence in suitability of the selected cases.

Figure 8 also plots the LOCA MPI-ESM-MR RCP 8.5 scenario as open squares, which is the same emission pathway and GCM used for the worse-case scenario. While downscaling influences the magnitude of annual change in precipitation and temperature, the direction of change is largely consistent between the WRF and LOCA RCP 4.5 datasets, suggesting the WRF-MPI dataset is a reasonable worse-case scenario relative to the best-case LOCA-MPI scenario.

Figure 8 investigates period-averaged annual changes to look at changes in climatology, however precipitation and temperature vary from year to year within these periods. Interannual variability in precipitation is larger than for temperature (Figure 7). Standard deviation provides a measure

of this variability, with low standard deviations indicating that values tend to be closer to the mean and high standard deviations indicating a larger spread of values around the mean. Here, the relative standard deviation (RSD), or coefficient of variation, normalizes the standard deviation to the mean of the 30-year period to indicate the deviation as a percentage of the mean and provide context for high and low variability. The RSD of the Sac-SMA calibration dataset precipitation is approximately 25% and temperature is less than 2%, illustrating that total precipitation varies much more than average temperature from year to year.

Interannual variability in precipitation and temperature across the surface water model boundary area increases into the future under both climate scenarios. These changes are summarized in Section 2.5. Under the best-case scenario, annual precipitation RSD increases slightly (by approximately 1% of the mean) in the near future (2030s) and more (by 8% of the mean) in the far future (2060s). The interannual variability of the worse-case precipitation scenario has even greater increases through time, with a rise of approximately 2% of the mean in the near future and a nearly 12% increase in the far future. The interannual variability in the temperature scenarios increases as well, but the RSD is small relative to that of precipitation.

The distinct seasonality of the LSCR basin necessitates a closer look at changes in sub-annual precipitation and temperature to describe changes in the climate system. Precipitation occurs over two distinct wet periods associated with the summer monsoon season (mid-June through September) and cyclonic and low-pressure frontal systems in the fall and winter (referred to here as the “winter” season). The remaining months are very dry with little to no rainfall. Additional description of these seasons follows in Section 2.4. Climate Metrics. Generally, projected temperature increases are greatest for the worse-case monsoon season (Figure 8). Projected decreases in precipitation are also greatest for the worse-case monsoon and winter seasons, suggesting decreases during important seasons for water supply, recharge, and environmental considerations. These seasonal changes are critical to stakeholder decision making in the basin and ultimately drove the development of the climate metrics used for the hydroclimate analysis.

2.4. Climate Metrics

Stakeholders requested detailed climate information to develop adaptation scenarios. As a result of discussions with the study cost-share partners, the Reclamation team developed three climate metrics of concern to local water users to quantify and analyze. These metrics include:

1. **Extreme events: temperature and precipitation, intensity, and frequency**
   Local stakeholders’ concerns related to the intensity of precipitation events extend beyond interest in available water. Flooding, groundwater recharge, and changes in the timing or intensity of extreme temperature (including heat waves and freezes) were of concern across the basin.

2. **Monsoon timing: onset and demise**
   The monsoon season in Southern Arizona marks the end of a prolonged dry season with little to no rain. Local water users therefore highly anticipate the start of the monsoon season, and any changes in the timing of onset are of great interest. The importance of

this timing is far reaching, also including supporting native vegetation and signaling the end of fire season.

3. **Dry period onset**
   The onset of the dry season marks the end of winter rains and the start of the dry season. Along with changes in end of the dry season (i.e., monsoon onset), this metric defines the length of the dry period. Changes in these metrics would require water users to develop adaptation strategies to prepare for the extended dry season.

2.4.1. Climate Metric 1: Changes in Intensity and Frequency of Future Precipitation and Temperature

Not only are changes in the amount of rainfall and magnitude of temperature of interest for planning future adaptation measures, but the timing between rain events is of concern. Prolonged dry periods could drive increases in water demand, even if complemented by equal amounts of precipitation during the season from larger intensity events. For a discussion of the changes in extreme temperature and precipitation, see Section 3.3. Weather Generator Results.

2.4.2. Climate Metrics 2 and 3: Changes in Seasonality

Southern Arizona has a desert climate with high evaporation rates and low total annual precipitation. Precipitation falls during the summer monsoon and winter seasons, resulting in three distinct seasons: monsoon, winter wet, and dry (Figure 9). The definition of these seasons is critical to incorporating these metrics in the weather generator development (Section 3). Metrics used to define these seasons require weather variables, either directly or derived, that are common to all three climate datasets (i.e., dynamically downscaled WRF-MPI, statistically downscaled LOCA-MPI and Sac-SMA historical calibration datasets).

Figure 9 – Conceptual diagram of seasonality in the LSCR basin.

2.4.2.1. Determination of Monsoon Onset

Multiple approaches exist to define the North American Monsoon onset timing (#1 in Figure 9) in the southwestern United States, including methods using dewpoint temperature, precipitation, and atmospheric dynamics. In Tucson, the National Weather Service (NWS) previously defined the onset of the monsoon season as the first of three consecutive days reported with a mean daily dewpoint temperature greater than 54°F (Ellis et al., 2004) or 53°F (Chang, 2018).

Since 2008, however, the NWS has defined the monsoon season as June 15 to September 30,[5] mainly for increasing public awareness and severe weather hazard preparation. The fixed monsoon definition avoids some of the challenges of the dewpoint-based metric, including occasional non-monsoon moisture events that temporarily increases the dewpoint temperature, incorrectly signaling the start of the monsoon season. However, using the June 15 to September 30 date limits the signal of early or late monsoon onset and does not account for monsoon season interannual variability.

[5] https://www.wrh.noaa.gov/twc/monsoon/monsoon.php

To account for possible future shifts in monsoon seasonality, the dewpoint-based metric was adopted to develop the weather generator seasonality. The daily average 53°F threshold was found to capture the start of monsoon precipitation better than 54°F and better match the observed historical monsoon-onset timing reported by Ellis et al. (2004).

Dewpoint temperature is a measure of humidity and reflects the temperature at which a parcel of air becomes saturated with water vapor. Dewpoint, or other humidity measures that could be used to calculate dewpoint directly, are not available for this model as part of the LOCA simulations or from the Sac-SMA calibration data, although it is available from the WRF dataset. Therefore, this study approximated dewpoint for LOCA and Sac-SMA data using the dewpoint depression approach. This approach assumes that the daily minimum temperature approaches the dewpoint temperature and is offset by a depression constant. For LOCA, this approach uses PRISM-based depression constants, consistent with previous applications of LOCA data (Reclamation, 2015) and minimum daily temperature, which is provided in the LOCA dataset.

The 6-hourly temperature data from the Sac-SMA calibration dataset was used alongside the Tucson Arizona Meteorological Network (AZMET[6]) station record to determine daily minimum temperature. AZMET stations began operating in 1987 and are designed to provide meteorological observations for primarily agricultural interests. Measurements include air and soil temperature, humidity, solar radiation, wind speed and direction, and precipitation. The relative humidity observations were needed here to calculate dewpoint temperature. The Tucson AZMET station record was also used to derive dewpoint depression constants for all subbasins in the Sac-SMA dataset. Using the dewpoint relationships at the AZMET station to extrapolate to all elevation zones was not reliable for determining the monsoon timing. Sac-SMA seasonality is provided for reference and was used in Weather Generator development.

Analysis of the WRF-modeled dewpoint temperature revealed an atmospheric dry bias in the dynamically downscaled data, requiring bias correction of the onset threshold. This correction used PRISM dewpoint data (PRISM Climate Group, 2018) for the cell over the local AZMET station to determine the percentile of 1981-2010 June and July dewpoint temperatures that corresponds to the daily average of 53°F. PRISM provided a gridded data product with the expected bimodal distribution of June/July dewpoint temperatures to capture the shift from dry to wet weather regimes. Applying the resulting percentile to the distribution of dynamically downscaled dewpoint temperatures resulted in a bias-corrected threshold of 50.3°F, for use only with the WRF-MPI data (Chang, 2018). That is, for the WRF-MPI data the onset of monsoon season was defined as the first day in a three-day average of mean daily dew point temperature above 50.3°F. For further details, see Appendix D, Dynamically Downscaled Climate Projections in the Lower Santa Cruz Basin Study, Final Report for Cooperative Agreement R17AC00061.

2.4.2.2. Determination of Monsoon Demise

The end of the monsoon season is less well defined beyond the NWS fixed date of September 30. For consistency with the onset metric and literature (Ellis et al., 2004), monsoon demise is defined here as the day after the last three consecutive days above the dewpoint temperature threshold. For LOCA simulations and Sac-SMA historical data used in the best-case scenario,

[6] https://cals.arizona.edu/AZMET/

monsoon demise is, therefore, the day after the last three consecutive days with dewpoint above 53°F. For WRF-MPI data used in the worse-case scenario, it is the day after the last three consecutive days above 50.3°F. The demise of the monsoon season is not always followed by immediate winter storms, as these could occur any time during the winter season. Here, the winter wet season is considered the period that stratiform rain events can occur, and thus does not experience sustained elevated humidity.

2.4.2.3. Determination of the Start of Dry Season

The dry season in the LSCR basin is characterized by prolonged periods with low to no rainfall. The transition to this season typically occurs between March and May and dry conditions persist until the start of the monsoon season. The NWS reports 1981-2010 averaged precipitation totaling less than 0.75" from April through June.[7] Over the historical period of this study (1970-1999), the observed average length of dry spells beginning in the months leading into the dry season (March, April, and May) is 15, 21, and 18 days, respectively. Here, a dry spell is defined as consecutive days with no precipitation greater than 0.01 in/day.

Figure 10 depicts these average lengths and number of dry spells grouped by the month in which the spell begins (the dry spell can extend into the next month and the length can therefore be longer than 30 days). The length and number of dry spells are highly dependent. Bars aligning closer to the left of the plot indicate more frequent but shorter dry spells, while bars aligning to the right of the plot indicate longer, less frequent dry spells but also suggest months that approach no rainy days.

The distribution of dry spells in March is skewed toward longer events (median length = 6 days, mean length =15 days) suggesting some transitions to the dry season occur in March, but that the transition more consistently occurs in April. January and February average 10-day dry spells, suggesting a 14-day period with no rain ($\leq$ 0.01 inch) is sufficient to capture the transition out of the winter rain patterns with shorter dry periods that dominate January and February. The onset of the dry period is therefore based on the first time there is a dry spell of 14 days or more that ends after May 1st and starts before June 15th, in order to constrain the trigger events to the dry fore-summer period.

[7] https://www.wrh.noaa.gov/twc/climate/tus.php

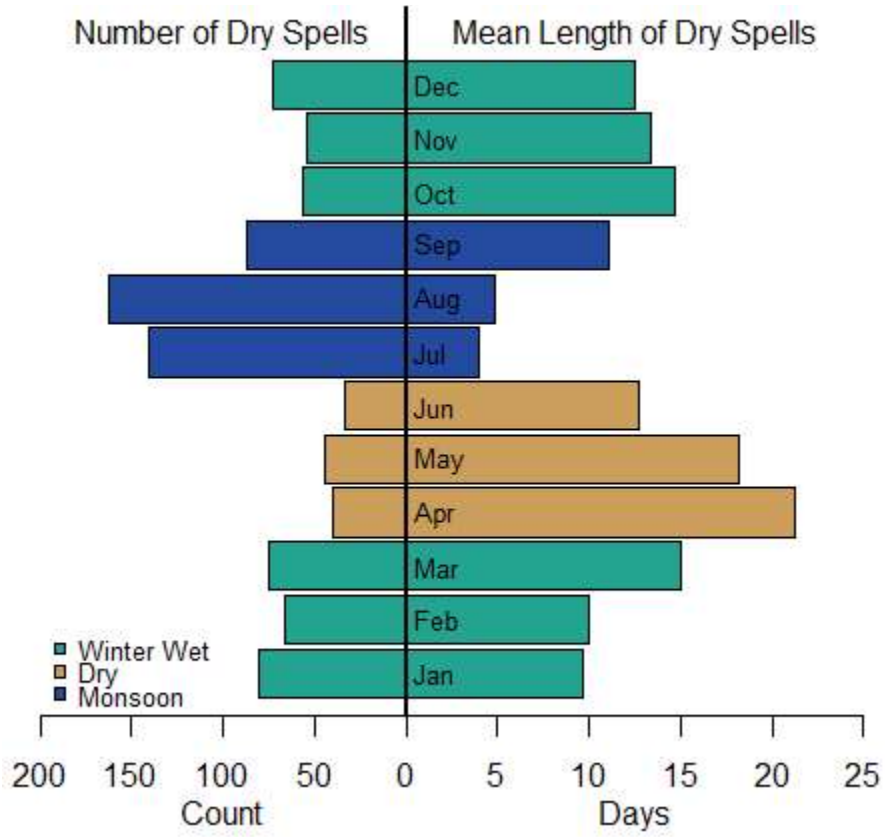


Figure 10 – Historical (1950-2009) dry spell statistics by month of start date from the Tucson Airport weather station compiled by M. Crimmins (personal communication 2018). Color indicates approximate season with teal = winter wet season, tan = dry season, and blue = monsoon season.

2.4.3. Seasonality Results

2.4.3.1. Historical Period

The Tucson NWS reports the median 1948-1997 monsoon onset date as July 3 (Table 3). The median day of monsoon onset for the historical period (1970-1999) simulated using LOCA-MPI (the same model as the best-case scenario) is July 5 (Table 3) and all years have monsoon onset dates within the fixed NWS monsoon period (i.e., onset after June 15) as seen by the position of the best-case monsoon distribution medians within the gray box in Figure 11. For the worse-case scenario based on WRF-MPI retrospective modeling, the simulated historical median onset date is June 22 (Table 3). The historical WRF-MPI simulation has a wider range of possible monsoon onset dates and exhibits more variability in monsoon timing (Figure 11), both onset and demise. This is likely due to the use of dynamical downscaling.

Both the best- and worse- cases have some years when the monsoon season ends after the last day of the NWS monsoon period (September 30). The median monsoon demise (or onset of the winter wet period) over the modeled historical period was September 7 for the best-case and October 2 for the worse-case, which fall on either side of the literature reported median of September 14 (Table 3). The simulated historical median onset of the dry season is April 24 for

the best-case scenario and May 6 for the worse-case scenario, both occurring later than the date calculated from observations at the Tucson Airport (April 15). The resulting length of the dry season, or the number of days between the dry season and monsoon season onset dates, reflects the larger variability of the worse-case seasonality results (Figure 14). The median historical dry season length for the best-case scenario was 80 days, while the worse-case scenario only had a median length of 49 days, but with more interannual variability. These modeled values provide a baseline to compare future values accounting for some of the inherent model biases.

Table 3 – Median Date of Seasonal Transition Defined by Climate Metrics

	Dry Season Onset	Monsoon Onset	Monsoon Demise
Literature	April 15[c]	July 3[a]	September 14[b]
Sac-SMA Calibration Dataset	April 19	July 7[d]	September 16[d]
Best-Case Model, Historical Period	April 24	July 5	September 7
Worse-Case Model, Historical Period	May 6	June 22	October 2

a. Tucson National Weather Service Forecast Office 1948-1997 Median (Ellis et al., 2004)
b. Phoenix National Weather Service Forecast Office 1948-1997 Median, Tucson unavailable (Ellis et al., 2004)
c. Median onset 1950-2009 from metric applied to Crimmins' (2018) dry day analysis at the Tucson airport weather station
d. Sac-SMA monsoon dates use dewpoint developed at the elevation zone over the Tucson AZMET station.

2.4.3.2. Future Periods

Future periods exhibit small changes in monsoon onset for the best-case scenario with median onset dates advancing by two days for each future period, to July 3 and July 1 for the 2030s and 2060s, respectively. Although small, the shift in the median and the tightening of the range of onset timing, particularly with respect to fewer late onset dates in the future periods, drive an earlier start to the best-case monsoon season (Figure 11). The worse-case scenario does not show a single trend in monsoon onset date for the future periods, with a later median onset date of June 29 in the near future and returning to a median date of June 22 in the far future. The worse-case climate scenario therefore does not provide earlier relief to the dry season, as in the best-case.

A weather typing study using GCM and dynamically downscaled data in New Mexico found a similar minimum in the frequency of monsoon weather types around the middle of the 21st century, followed by an increase in monsoon events after 2050 (Prein et al., 2019 and personal communication). Prein also identified an earlier shift in the start of monsoon events and an increased frequency of monsoonal precipitation events in July and September. Both the best- and worse-case results project a later end of the monsoon period, or onset of the winter wet period (Figure 11), suggesting a general lengthening of the monsoon season in the future periods, particularly in the far future (Figure 12). Figure 13 shows winter season lengths and Figure 14 dry season lengths.

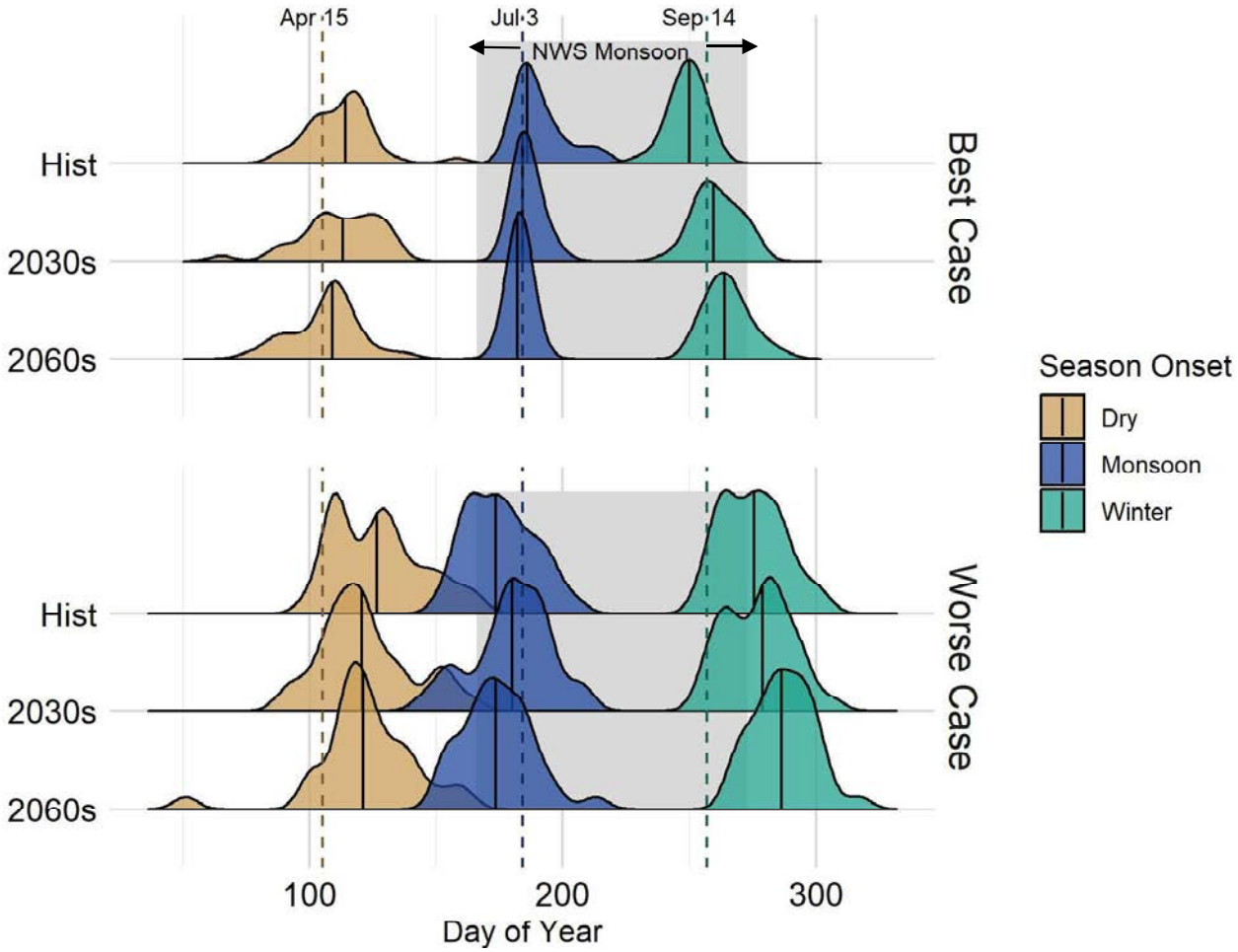
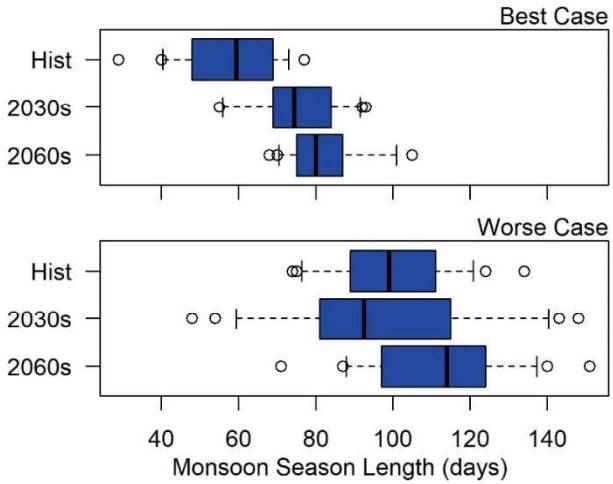


Figure 11 – Distribution of seasonal onset day of the year for the best- (top) and worse- (bottom) case scenarios. Black solid lines represent median onset day for each distribution and labeled, dashed lines represent select literature values given in Table 3. Gray shading indicates the NWS monsoon period of June 15 through September 30.

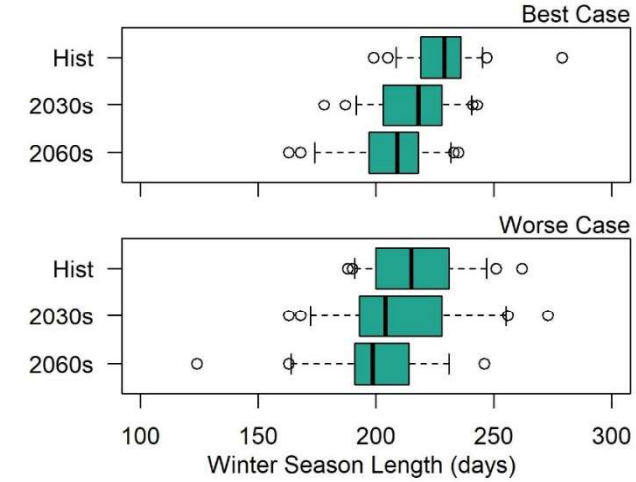
The lengthening of the monsoon season and changes in the dry season onset result in a consistent shift toward shorter winter wet periods under both scenarios (Figure 13). In both projected futures, the dry season begins slightly earlier in the year (Figure 11). In the best-case scenario, the median onset date of the dry season is one day earlier in the near future and five days earlier in the far future, relative to the historical period. The trend is less consistent in the worse-case scenario. Similar to the monsoon onset date, there is a larger advancement of the dry season onset in the near future (6 days) and a slight rebound to only a 5-day advancement in the far future. The combined changes in the starts of the dry and monsoon seasons result in both increases and decreases in the length of the dry season over time (Figure 14). Generally, the best-case scenario exhibits a shorter dry season in the future than the modeled historical period and the worse-case scenario projects an increase in dry season length.



	5th perc.	Median	95th perc.
Hist.	40	60	73
2030s	56	75	92
2060s	70	80	101

	5th perc.	Median	95th perc.
Hist.	76	99	121
2030s	59	93	140
2060s	88	114	137

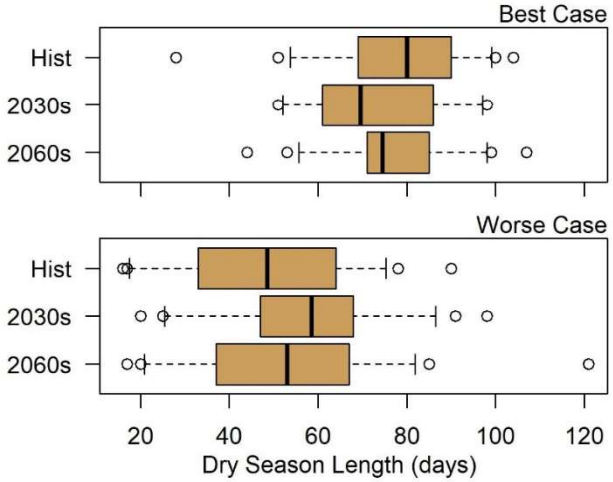
Figure 12 – Distribution and statistics of monsoon season lengths (in days) by period for the best-case (top) and worse-case (bottom) climate scenarios. Whiskers represent 5th/95th percentile of data.



	5th perc.	Median	95th perc.
Hist.	209	229	245
2030s	192	218	241
2060s	174	209	232

	5th perc.	Median	95th perc.
Hist.	191	215	247
2030s	172	204	255
2060s	164	198	231

Figure 13 – Same as Figure 12 but for the winter season lengths.



	5th perc.	Median	95th perc.
Hist.	54	80	99
2030s	52	70	97
2060s	56	75	98

	5th perc.	Median	95th perc.
Hist.	18	49	75
2030s	26	59	87
2060s	21	53	82

Figure 14 – Same as Figure 12 but for the dry season lengths.

In general, the worse-case scenario provides a greater range of seasonal lengths from year to year, representing a more variable future (Figure 15). The more variable nature of monsoon onset may be related to changes in the distribution of monsoon rainfall, with precipitation events becoming more intermittent, but more extreme. This change has been documented in the historical record by Luong et al. (2017) and DeMaria et al. (2019). More intense precipitation events are a result of increased moisture and atmospheric instability under future conditions. These events also contribute to increased variability of precipitation under future conditions.

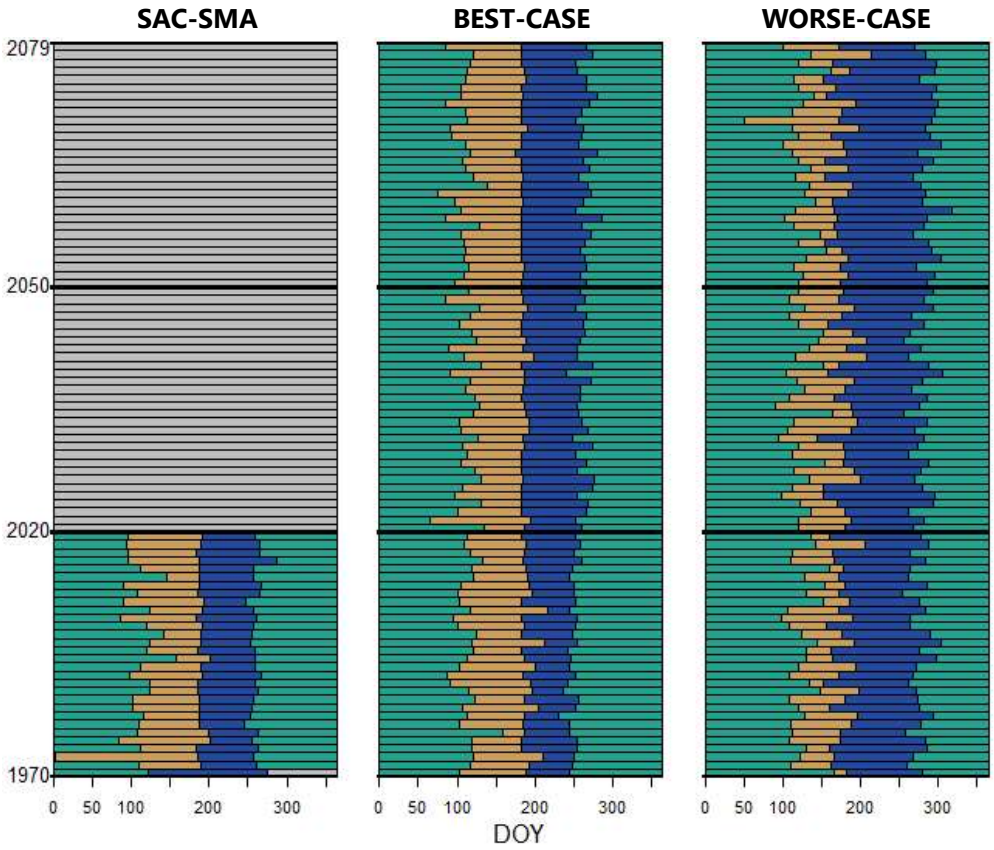


Figure 15 – Seasonality for each year of simulation for the Sac-SMA calibration dataset, and the best-case, and worse-case climate scenarios. Teal indicates days of the year (DOY) falling in the winter wet season, tan indicates days in the dry season, and blue indicates days in the monsoon season.

2.5. Climate Summary for Stakeholders

The historical climate in the Lower Santa Cruz River Basin varies greatly from year to year. Future projections under the scenarios developed here (Table 4) consistently identify increases in annual temperature, from the historical average of 63.3°F over the surface water model boundary area. Increases are larger in the worse-case scenario. The worse-case represents a future with no mitigation strategies to reduce greenhouse gas emissions while the best-case scenario represents a future with mitigation to curb emissions. The best-case scenario suggests relatively minimal change in seasonal precipitation. The worse-case scenario indicates decreases in total annual and seasonal precipitation. Interannual variability in precipitation increases for both scenarios.

Table 4 – Summary of Projected Basin-Averaged Future Precipitation and Temperature Relative to the its Respective Simulated Historical Period (1970 – 1999). All geographic areas are depicted in Figure 1.

Geography	Statistic	Best-Case 2030s	Best-Case 2060s	Worse-Case 2030s	Worse-Case 2060s
Tucson Active Management Area	Change in Total Annual Precipitation	0.40″	-0.50″	-4.44″	-3.73″
Tucson Metro Public Forecast Zone	Change in Total Annual Precipitation	0.28″	-0.44″	-4.47″	-3.77″
Surface Water Model Boundary Area	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* compared to Historical: Best = 20.3%, Worse = 17.3%	21.6%	28.5%	18.9%	30.4%
Tucson Active Management Area	Change in Average Annual Temperature	2.92°F	3.81°F	3.36°F	5.07°F
Tucson Metro Public Forecast Zone	Change in Average Annual Temperature	2.88°F	3.77°F	3.34°F	5.05°F
Surface Water Model Boundary Area	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) is calculated by normalizing the standard deviation to the mean of the 30-year period and presented as a percentage.

For additional climate figures, see Appendix A—Supporting Climate Figures.

3. Weather Generator

Precipitation is particularly variable in southern Arizona. While the best- and worse-case scenarios each provide one possible future precipitation and temperature sequence, there are other patterns of precipitation that are equally likely. To account for this uncertainty in daily patterns of precipitation and temperature, this study developed and applied a "weather generator" to introduce variability around the broader climate projection trends.

A weather generator is a numerical tool that resamples an input timeseries many times, while preserving observed or projected characteristics of importance, such as the statistics of the transition between wet and dry days. The resulting large group, or ensemble, of likely rainfall and temperature timeseries represents a range of possible amounts, daily patterns, and seasonality at a scale appropriate for driving the surface water model to produce a range of possible streamflows.

The weather generator is run using daily precipitation and temperature averaged over the surface water model boundary area, but the Sac-SMA surface hydrology model requires sub-daily information for each elevation zone in a subbasin. Therefore, the weather generator results are disaggregated both spatially and temporally, maintaining the patterns observed in the original climate simulations. From this point on, we use the best- and worse-case scenario to refer to the weather-generated ensembles of future temperature and precipitation. For additional details on the construction and performance of the weather generator, see Gangopadhyay et al., 2019.

3.1. Development and methodology

The weather generator takes in daily timeseries of precipitation, temperature, and season, averaged over the extent of the Sac-SMA basins depicted in Figure 1 in Section 1. Introduction. Three input sources were used for all available time periods: 1) the best-case climate scenario (from LOCA-MPI RCP 4.5); 2) the worse-case climate scenario (from WRF-MPI RCP 8.5); and 3) the Sac-SMA input dataset that was used for calibration of the surface water model. We used these three sets of inputs to generate an array of future weather conditions. Inputs for each of these weather generator runs include time series of the seasons developed using the metrics described in Section 2.4. Each day was numbered either: 1 = dry fore-summer, 2 = monsoon, 3 = winter wet. With these inputs, the weather generator performs the following calculations:

1. *Wet/Dry Day Transition Probabilities*: The probability of transitioning between wet and dry states was computed for each year on a seasonal basis over each study period. The time series of rainy days used to calculate these probabilities were derived from the daily timeseries of precipitation from the dynamically downscaled and statistically downscaled versions of the climate model, for each historical and future period, in order to capture any changes in precipitation frequency in the projections. A rainy day is defined as any day with 0.01 or more inches of rain.

2. *Weather Generation*: The weather generator process was repeated 100 times, running daily over 28-year-run lengths (used in the historic Sac-SMA runs) or 30 years for the future periods.

    i. *Initial conditions*: Each simulation begins in January, assuming it is the winter wet season. The antecedent wet/dry state is sampled from all January 1st conditions for a given input timeseries (Sac-SMA historical period or the four future periods).

    ii. *Wet/Dry State Transitions*: The occurrence of precipitation for a given day is based on the probability of transitioning out of the current state into the other for that season. For example, if the previous day was wet, and a given day in that season in the downscaled wet/dry time series transitioned from wet to dry 30% of the time, then approximately 30 of every 100 simulations results in a dry day and 70 in a wet day.

    iii. *Precipitation Simulation*: A nonparametric approach to precipitation simulation is taken, wherein non-zero daily precipitation is sampled uniformly from within a window of time from the date being simulated. More specifically, if precipitation occurs for a given day (i.e., it was determined to be a wet day in the previous step), a day is randomly selected from all rainy days in a seven-day window centered on that day of the year from all years in the 28- to 30-year period. The date of the sampled precipitation values is retained for spatial disaggregation.

    iv. *Temperature Simulation*: Temperature is less variable and simulated using a parametric approach. After determining if the simulated day is wet or dry, the temperature is calculated from an autoregressive linear equation with precipitation occurrence and mean monthly temperature as predictors. The equation includes lag-one persistence and adds variability using a random sample from a normal distribution centered on zero with a standard deviation equal to that of the residuals from the linear model for that month.

3. *Spatial disaggregation*: The outputs of precipitation and temperature averaged over the surface water model boundary area needed to be disaggregated to the elevation zones for surface water modeling. The pattern from the weather generator input timeseries for each scenario was remapped to the Sac-SMA elevation zones prior to averaging. For precipitation, the weather-generated area-wide value was multiplied by the ratios of elevation zone precipitation to the area average on the precipitation day sampled in step 2.iii. For temperature, the weather-generated area-wide value was added to the difference between the elevation zone temperature and the area-averaged temperature for the sampled day. For non-rainy days, the spatial temperature offsets were derived from that date in the Sac-SMA, LOCA, or WRF original inputs. This procedure results in a daily time series of precipitation and temperature at each elevation zone that is consistent with the best- and worse-case climate scenario spatial patterns.

4. *Temporal disaggregation:* Although the LOCA and WRF-MPI input simulations used here provide information for spatial disaggregation, they do not provide 1-hourly data needed for surface water modeling (see Table 1). The sub-daily patterns of precipitation (1-hourly) and temperature (6-hourly) for a given elevation zone are taken from the Sac-SMA historical calibration dataset. Out of the 28 years available in the Sac-SMA dataset, the day with the closest area-averaged precipitation value to the weather generated value for that day of the year was used to calculate the precipitation ratios and temperature offsets from the daily value to create sub-daily timeseries.

3.2. Validation

For additional details regarding the weather generator validation, see Appendix B.

3.3. Results

The resulting weather generated ensembles, depicted in Figure 16 and Table 5, indicate changes in seasonally averaged temperature and seasonal precipitation totals with respect to the historic period that are largely consistent with the changes in the input timeseries summarized in Table 4. Temperature consistently increases from the historical period to each future period. This increase is greater, as expected, for the worse-case scenario and into the far future (Figure 16, top row).

Extreme temperatures also increase in both scenarios, best depicted when looking at the most extreme temperatures (defined in Figure 17 as average daily temperatures that exceed the 99th percentile in that season, from all the years within a weather generated 30-year simulation). Extreme temperatures increase consistently in the future periods in every season, with the largest increases occurring in the dry and monsoon seasons (Figure 17), which are the spring and summer months when extreme temperatures pose the largest public health risk.

In the best-case scenario, the mean of the distribution of extreme dry season temperatures increases by 4.9°F in the 2030s and 4.5°F in the 2060s, relative to the historic period. The mean monsoon extreme temperature increases 3.5°F in the 2030s and 5.0°F in the 2060s. The increases in extreme temperatures are even larger under the worse-case scenario, with the dry season mean increasing by 5.3°F in the 2030s and 6.6°F in the 2060s. Mean monsoon season extreme temperatures increased 4.5°F in the 2030s and 7.1°F in the 2060s. The larger increases in the far future extreme temperatures reflect the emission scenario (RCP 8.5) underlying the worse-case climate, which does not include future emissions mitigation as the best-case does.

Seasonal precipitation changes in the best-case scenario, shown in the lower left panel of Figure 16, are relatively small and consistent in the dry season, when precipitation decreases through both future periods. Monsoon and winter season precipitation show opposite trends, with monsoon-season precipitation increasing in the near future but decreasing in the far future and winter season precipitation decreasing slightly in the near future but increasing slightly in the far future (Figure 16 bottom left).

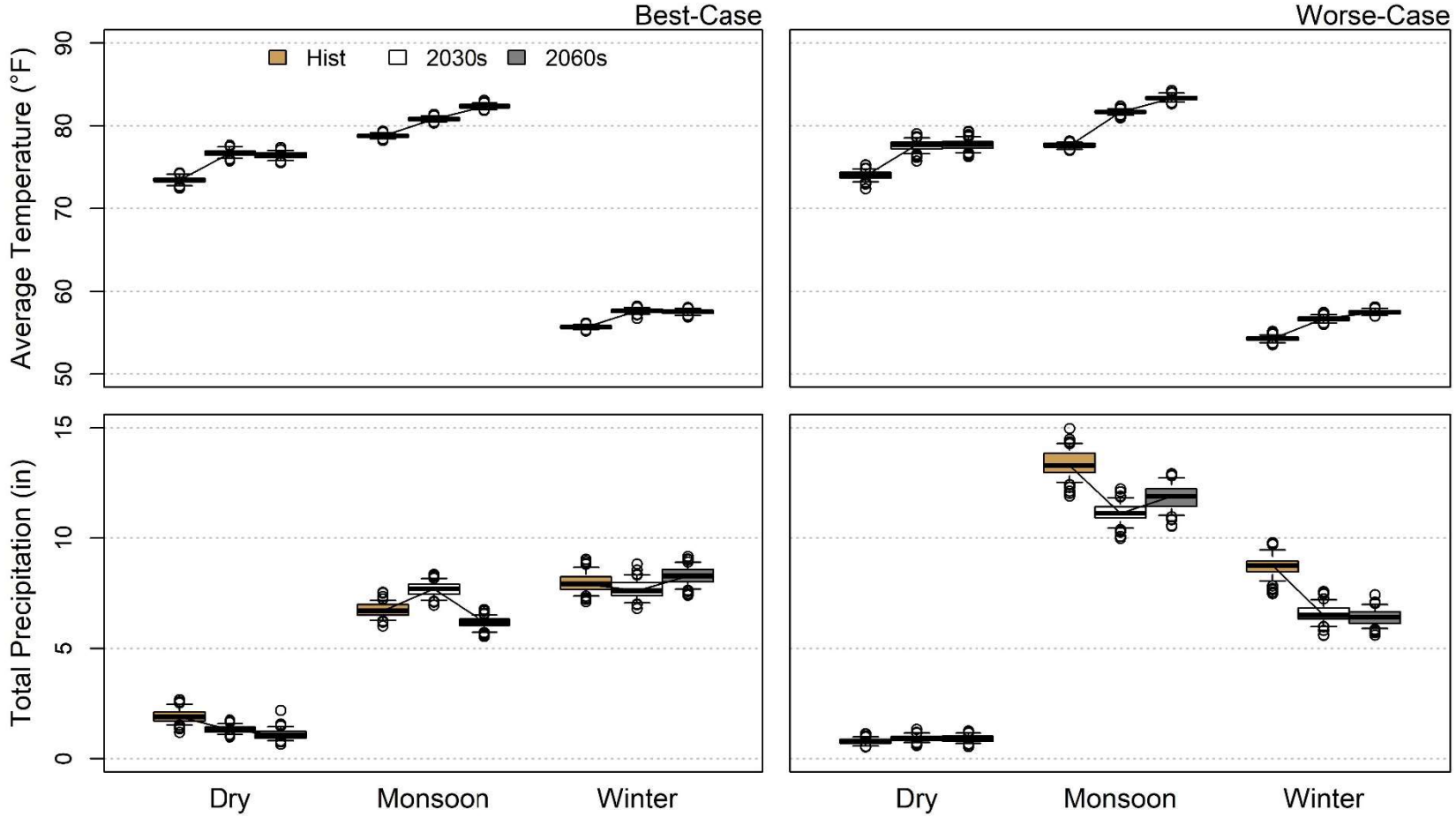


Figure 16 – Model simulated temperature averaged over the surface water model boundary area (top row) presented as a 30-year averaged seasonal mean and averaged precipitation for the same area presented as a 30-year averaged seasonal total (bottom row) for each period (colors), season (x-axis), and climate scenario (column). Boxplot distributions reflect the variability in the weather generator results from an ensemble that includes 100 sequences of 30 years each. The whiskers representing the 5th and 95th percentile of the ensemble.

Table 5 – Statistics of the Weather Generated Ensemble of Averaged Temperature for the surface water model boundary area. Top presents a 30-year averaged seasonal mean and basin-averaged precipitation. Bottom presents a 30-year averaged seasonal total for each period, season, and climate scenario.

Mean Temperature (°F)

		Best-Case Simulation			Worse-Case Simulation		
		Hist.	**2030s**	**2060s**	**Hist.**	**2030s**	**2060s**
Dry	5th Percentile	72.8	76.1	75.8	73.2	76.6	76.8
	Mean	73.4	76.7	76.4	74.0	77.6	77.7
	Median	73.4	76.7	76.4	74.0	77.7	77.8
	Mode	72.5	75.8	75.6	72.4	75.8	76.3
	95th Percentile	74.2	77.5	77.0	74.8	78.5	78.7
Monsoon	5th Percentile	78.5	80.5	82.0	77.2	81.3	82.9
	Mean	78.8	80.8	82.4	77.6	81.7	83.4
	Median	78.8	80.8	82.4	77.6	81.7	83.3
	Mode	78.3	80.4	81.9	77.0	81.0	82.7
	95th Percentile	79.2	81.2	82.8	78.0	82.1	84.0
Winter	5th Percentile	55.4	57.2	57.1	53.8	56.2	57.1
	Mean	55.7	57.6	57.5	54.3	56.7	57.5
	Median	55.7	57.6	57.5	54.3	56.7	57.5
	Mode	55.2	56.7	56.9	53.5	56.0	57.0
	95th Percentile	56.0	58.0	57.9	54.7	57.2	57.9

Total Precipitation (inches)

		Best-Case Simulation			Worse-Case Simulation		
		Hist.	**2030s**	**2060s**	**Hist.**	**2030s**	**2060s**
Dry	5th Percentile	1.54	1.11	0.81	0.57	0.74	0.70
	Mean	1.92	1.33	1.09	0.79	0.93	0.92
	Median	1.89	1.31	1.05	0.77	0.92	0.91
	Mode	1.20	0.98	0.67	0.54	0.59	0.55
	95th Percentile	2.46	1.59	1.44	0.99	1.17	1.16
Monsoon	5th Percentile	6.28	7.19	5.73	12.5	10.5	11.0
	Mean	6.73	7.69	6.17	13.4	11.2	11.8
	Median	6.71	7.70	6.18	13.3	11.1	11.9
	Mode	6.02	6.96	5.55	11.9	10.0	10.5
	95th Percentile	7.18	8.17	6.52	14.3	11.8	12.7
Winter	5th Percentile	7.38	7.07	7.69	8.05	5.99	5.91
	Mean	7.95	7.67	8.29	8.72	6.57	6.41
	Median	7.92	7.62	8.28	8.75	6.51	6.42
	Mode	7.13	6.81	7.42	7.49	5.59	5.61
	95th Percentile	8.67	8.33	8.91	9.46	7.20	6.99

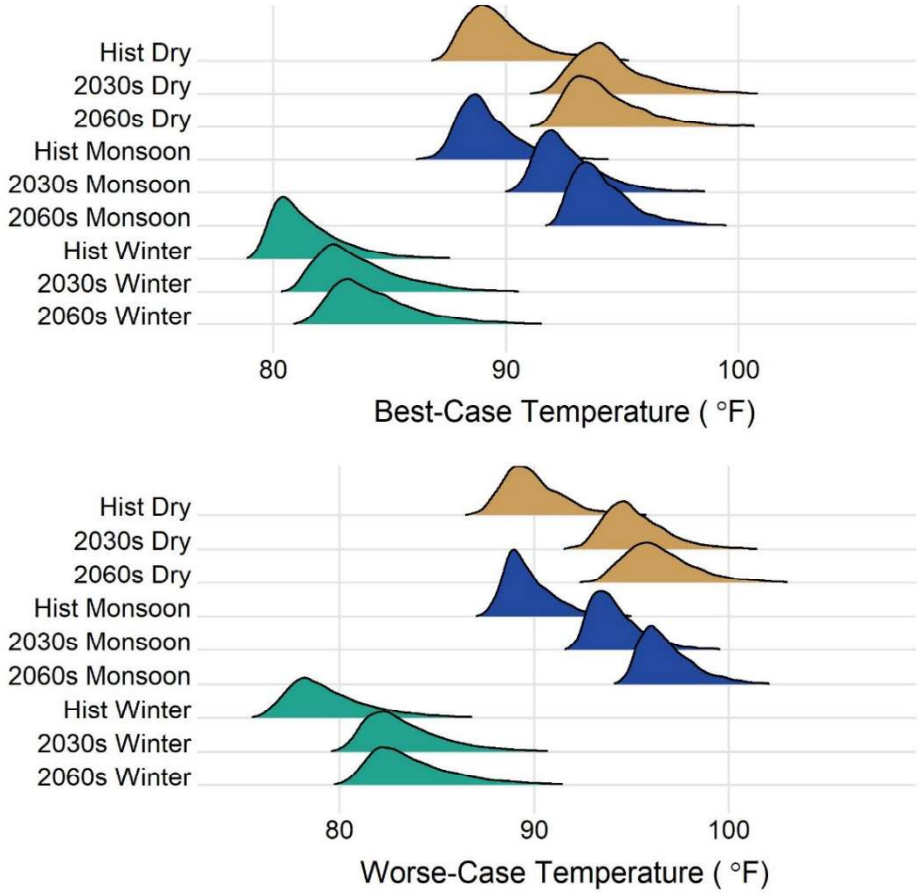


Figure 17 – Distributions of extreme daily temperatures, averaged over the surface water model boundary area, by period and season.

The weather generator was built around the assumption that the GCM and downscaling procedures adequately capture the seasonal and synoptic events. Here, the weather generator magnifies LOCA-MPI's lack of larger monsoon events to sample from in the best-case. In contrast, the worse-case scenario, derived from WRF-MPI, contains high precipitation days (see Table 2) that may be larger than previously observed and provides a wider range for the weather generator to sample over.

For example, future precipitation in the worse-case scenario generally decreases in the monsoon and winter seasons and shows little change in the dry season (Figure 16 bottom right). The slight rebound in far future monsoon precipitation relative to the near future may reflect longer monsoon seasons in the far future or larger individual extreme events, indicated by the upward extension of the 2060s distribution in Figure 18. Greater variability in worse-case weather generated seasonal totals mirrors the greater variability in worse-case season lengths (see Figure 15).

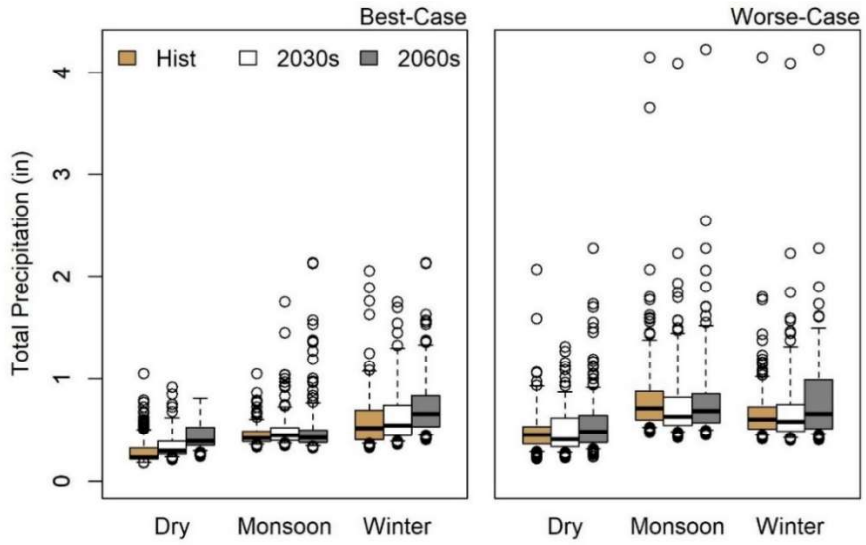


Figure 18 – Boxplot of extreme daily precipitation by season, period, and climate scenario.

Detection of changes in extreme precipitation events from daily, gridded modeled outputs is challenging because monsoon events are often short but intense, occur over small areas, and are highly variable in time and space. Rainfall observations in southeastern Arizona indicate an intensification of monsoon precipitation starting in the mid-1970s (Demaria et al., 2019), suggesting the historical period for this study has already experienced changes in climate processes.

Retrospective modeling using WRF at a convective permitting scale (about 3 km) since the 1990s also identified increased precipitable water and atmospheric instability typical of extreme monsoon events (Luong et al., 2017). This intensification is muted and the model processes simplified at the scale of the daily-averaged 25 km worse-case input data, similar to the smoothing noted at the Sac-SMA subbasin scale noted in Shamir et al. (2019). Limited observations or interpolation may also affect the intensification in the statistically downscaled simulations, although an increase in the largest monsoon events is apparent (Figure 18) but not necessarily tied to local physical properties.

Despite these limitations, both the weather generated best- and worse-case scenarios include changes in extreme precipitation events. Here, extreme precipitation is defined as daily rainy-day precipitation that exceeds the 90th percentile in that season, from all the years within a weather generated 30-year simulation. Statistics of the 30-year simulation represent shifts in climatology and the weather generated ensembles provide additional uncertainty in extreme precipitation between scenarios (Table 6).

Table 6 – Statistics of Extreme Precipitation from the Weather Generator Ensemble

		Extreme Precipitation (inches)					
		Best-Case Simulation			Worse-Case Simulation		
		Hist.	2030s	2060s	Hist.	2030s	2060s
Dry	5th Percentile	0.19	0.24	0.30	0.29	0.28	0.31
	Mean	0.28	0.34	0.44	0.50	0.49	0.53
	Median	0.23	0.30	0.39	0.45	0.41	0.49
	Mode	0.22	0.24	0.39	0.46	0.64	0.55
	95th Percentile	0.51	0.62	0.82	0.94	0.88	0.92
Monsoon	5th Percentile	0.36	0.37	0.34	0.53	0.48	0.50
	Mean	0.45	0.48	0.47	0.82	0.76	0.81
	Median	0.42	0.45	0.43	0.72	0.63	0.69
	Mode	0.40	0.41	0.51	1.56	0.67	1.90
	95th Percentile	0.60	0.73	0.77	1.38	1.45	1.52
Winter	5th Percentile	0.37	0.39	0.46	0.45	0.43	0.46
	Mean	0.60	0.66	0.74	0.66	0.67	0.80
	Median	0.52	0.55	0.66	0.61	0.59	0.66
	Mode	0.38	1.05	0.49	0.67	0.51	1.46
	95th Percentile	1.08	1.30	1.34	1.02	1.32	1.50

Changes in the central tendency across the ensembles of extreme precipitation are not consistent, although increases in extreme winter precipitation are suggested by both the mean and the median statistics. The more severe ensemble extremes (that is, the 95th percentile) consistently increase through time in the both the monsoon and winter seasons. Maximum values represent less than 1% of extremes and can exceed 4 inches per hour in the worse-case scenario.

Figure 18 portrays these changes by illustrating the distribution of the precipitation values in the top 10 percent of each 30-year simulation. Changes in extremes are depicted by either a shift in the box and whiskers or by an upward spread of the box. A shift in the box is equivalent to changes in the central tendency of the data. For example, the winter season shifts upward under both cases, indicating a general increase in the magnitude of daily precipitation extremes. A spread upward indicates more isolated extreme events of greater magnitude, similar to the increase in monsoon and winter season events in the 95th percentile shown in Table 6 and Figure 19.

Increases in the general magnitude of extreme events is more apparent in the best-case scenario while the increase in larger individual events, particularly in the winter season, is more apparent in the worse-case scenario. This is consistent with the nature of the LOCA downscaling procedure, which may not be able to capture changes in individual events as well as the physically-based dynamically downscaled procedure used for the worse-case scenario.

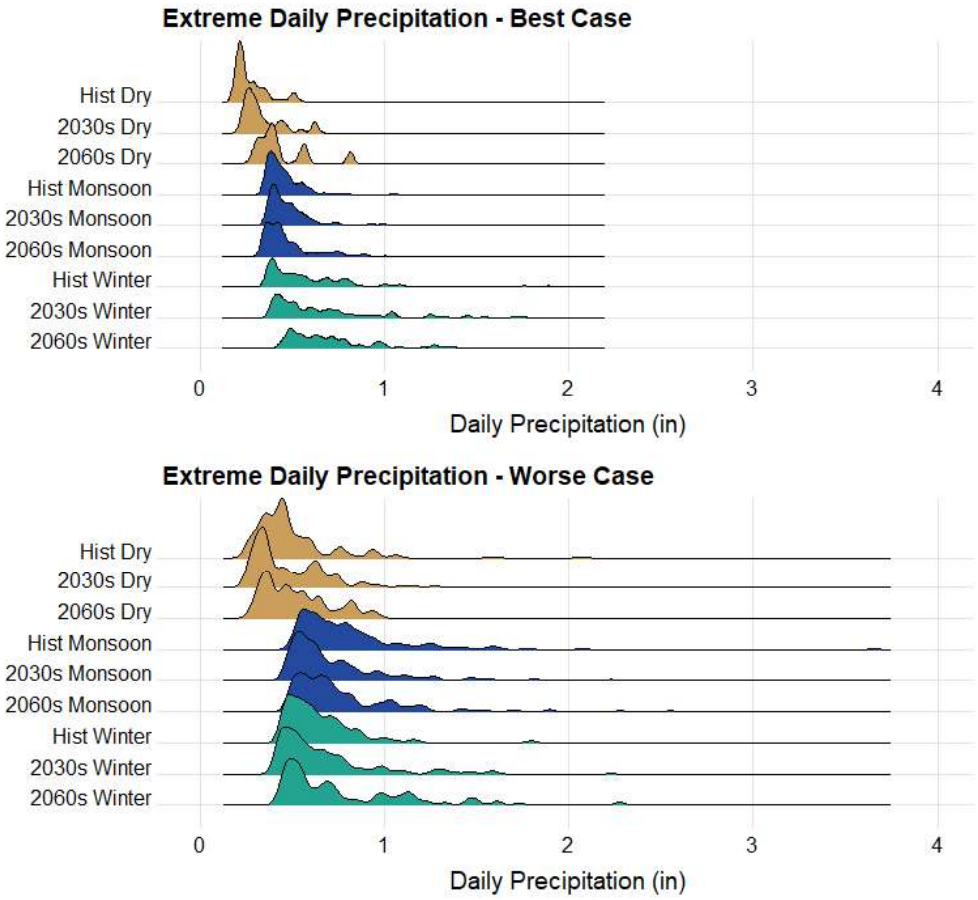


Figure 19 – Distribution of extreme daily precipitation by season, period, and climate scenario.

4. Surface Water Modeling

4.1. Sac-SMA Model

4.1.1. Description

The 100-projection ensembles of future temperature and precipitation created by the weather generator were used as input in a surface water model to derive a range of streamflows. Potential evapotranspiration (PET) is also needed for the Sacramento Soil Moisture Accounting surface water model. The method for estimating PET is described in Section 4.1.2.

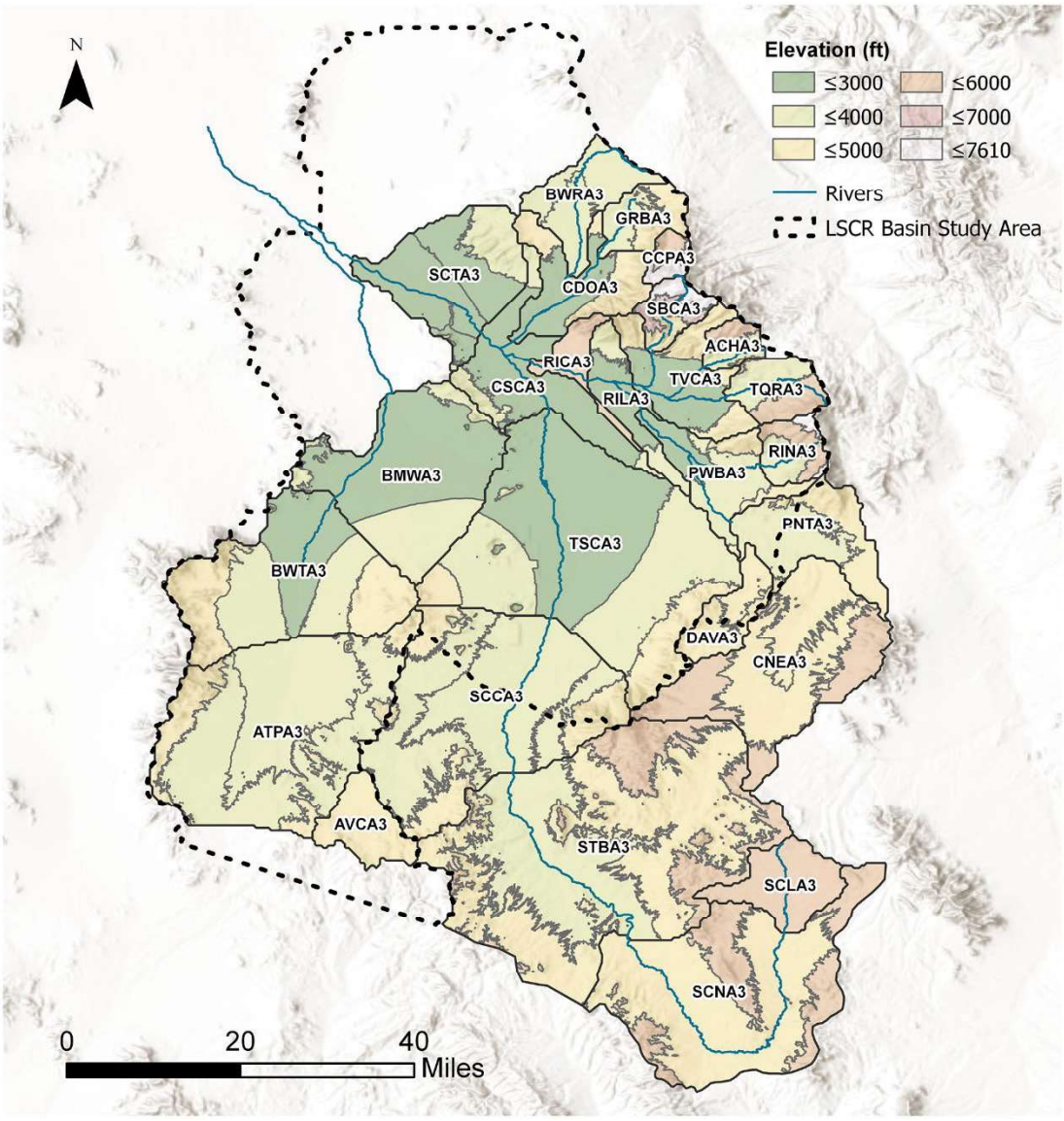
The hydrologic simulation for this study uses the National Weather Service's Colorado Basin River Forecast Center's (CBRFC)[8] calibrated Sac-SMA model of the Lower Santa Cruz River Basin and contributing watersheds, including the SNOW-17 model in elevation zones where snowfall is important. This model is part of the CBRFC's operational streamflow modeling system, with a focus on simulating the antecedent soil conditions that drive the runoff response. The CBRFC calibrates the model by adjusting parameters for each subarea to match the daily-averaged observed streamflow at the basins' outlets. The model available at the time of this study was calibrated from 1970-1999.

The Sac-SMA model simulates mechanisms that drive water movement through the soil column (surface runoff, infiltration, interflow, percolation, storage, evapotranspiration, and baseflow) while preserving the water balance. Additional information on how Sac-SMA calculates soil moisture and a diagram of the soil storage compartments and fluxes are provided in Section 4.3.

The Sac-SMA hydrologic model used by the CBRFC is run in a lumped framework, meaning parameters are averaged over elevation zones within the subbasins that make up a watershed. Each subbasin may include up to three elevation zones (Figure 20), depending on the topography, vegetation, and snowpack patterns in the basin. The surface water model boundary area used in this study has 26 subbasins divided into a total of 59 elevation zones, where the average size of an elevation zone is 79 square miles. Many subbasins are delineated to align outlets with available streamflow observations. Modeled streamflow for each subbasin is reported at the outlet where the river or stream leaves the subbasin.

The use of constant areal-averaged parameters—and perhaps more importantly, areal-averaged precipitation may limit a model's ability to capture diverse streamflow responses. Areal averaging may dampen the response to intense local storms, characteristic of convective summer rainfall events in the region (Shamir et al., 2019). However, this is true of most hydrologic models that can be run operationally in this region, and the model used here has the added benefit of years of CBRFC development.

[8] https://www.cbrfc.noaa.gov/



ID	DESCRIPTION
ACHA3	AGUA CALIENTE WASH - HOUGHTON RD
ATPA3	ALTAR WASH - NR THREE POINTS AZ
AVCA3	ARIVACA CK AT ARIVACA AZ
BMWA3	BRAWLEY WASH - AT MILEWIDE RD
BWRA3	BIG WASH - CAÑADA DEL ORO
BWTA3	BRAWLEY WASH - THREE POINTS
CCPA3	CAÑADA DEL ORO - CORONADO CAMP
CDOA3	CAÑADA DEL ORO - BLO INA RD NR TUCSON
CNEA3	CIENEGA CK - NR SONOITA
CSCA3	SANTA CRUZ - AT CORTARO
DAVA3	DAVIDSON CANYON
GRBA3	CAÑADA DEL ORO - GOLDER ROAD BRIDGE
PNTA3	PANTANO WASH - NR VAIL

ID	DESCRIPTION
PWBA3	PANTANO WASH - BROADWAY BLVD.
RICA3	RILLITO CREEK - LA CHOLLA BLVD AT
RILA3	RILLITO CREEK - TUCSON AT DODGE BLVD.
RINA3	RINCON CREEK - NR TUCSON
SBCA3	SABINO CREEK - NR TUCSON
SCCA3	SANTA CRUZ - CONTINENTAL
SCLA3	SANTA CRUZ - NR LOCHIEL
SCNA3	SANTA CRUZ - NR NOGALES
SCTA3	SANTA CRUZ - TRICO RD AT MARANA NR
STBA3	SANTA CRUZ RIVER - AT TUBAC AZ
TQRA3	TANQUE VERDE - GUEST RANCH
TSCA3	SANTA CRUZ - AT TUCSON
TVCA3	TANQUE VERDE - TUCSON

Figure 20 – Sac-SMA elevations by elevation zone for each labeled subbasin. The LSCR Basin Study area is shown using a thick black outline with subbasins outlined with a thinner gray line. Elevation zones are not always continuous across a subbasin.

4.1.2. Input Development

In addition to calibrated model parameters obtained from the CBRFC, the model requires subdaily mean areal precipitation (MAP at 1-hour time resolution), mean areal temperature (MAT at 6-hour time resolution), and mean areal monthly PET. The weather generator process with the space-time disaggregation described in Section 3.3 produces MAP and MAT files at the spatial (elevation zone) and temporal (subdaily) scale required to run Sac-SMA.

To account for the effect of warmer future temperatures on PET, future scenarios scale the existing monthly PET in the calibrated model by the ratio of the temperature-based PET calculated with the Hamon method (Hamon, 1963), using calibrated Sac-SMA and weather-generated temperatures. Temperature averaged over the surface water model boundary area is used for these PET calculations and the subbasin scalars used in the calibrated model are retained to provide consistent spatial variability in PET.

4.2. Future Surface Water Discharge

4.2.1. Change in Seasonal Streamflow

Changes in seasonal streamflow, presented as a fraction of the simulated historical period flow, are presented in Figures 21 – 23. Note that these figures have scales tailored to the range of model results. This has been done to highlight the detail within each season's range of values.

Historically, most surface water subbasins in the study area experience no flow conditions in the dry season, particularly those in the valley bottom (Figure 21, left panel). Long periods without rainfall continue to characterize the dry season under future scenarios. Thus, small changes in streamflow result in numerically large fractional increases and decreases in streamflow that are not particularly meaningful to water supply and water resources planning (Figure 21).

Changes in the total monsoon seasonal streamflow result from changes in the length of the season, intensity, and frequency of storms. In the near future, the best-case scenario has a consistently longer monsoon season (see Figure 12) resulting in more total flow over this season. Streamflow decreases in some subbasins in the far future, particularly in subbasins that experience larger increases in no flow days, as discussed in Section 4.2.2.

Under the worse-case scenario, the near future appears to be a transition time, with generally shorter, but highly variable monsoon season length. The changes in monsoon seasonality result in decreased ensemble median streamflow (Figure 22), but high variability in seasonal totals from year to year.

In the far future, the longer monsoon season results in an apparent recovery of streamflow; however, streamflow events are less frequent (Section 4.2.2) and likely more extreme, consistent with the increase in individual large precipitation events under this scenario (see Figure 18 and Table 6). Larger precipitation events can have a disproportionate change on streamflow, since proportionally less water can infiltrate under the SAC-SMA model configuration. Thus, small increases in seasonal precipitation may result in large modeled increases in seasonal streamflow when large runoff events occur.

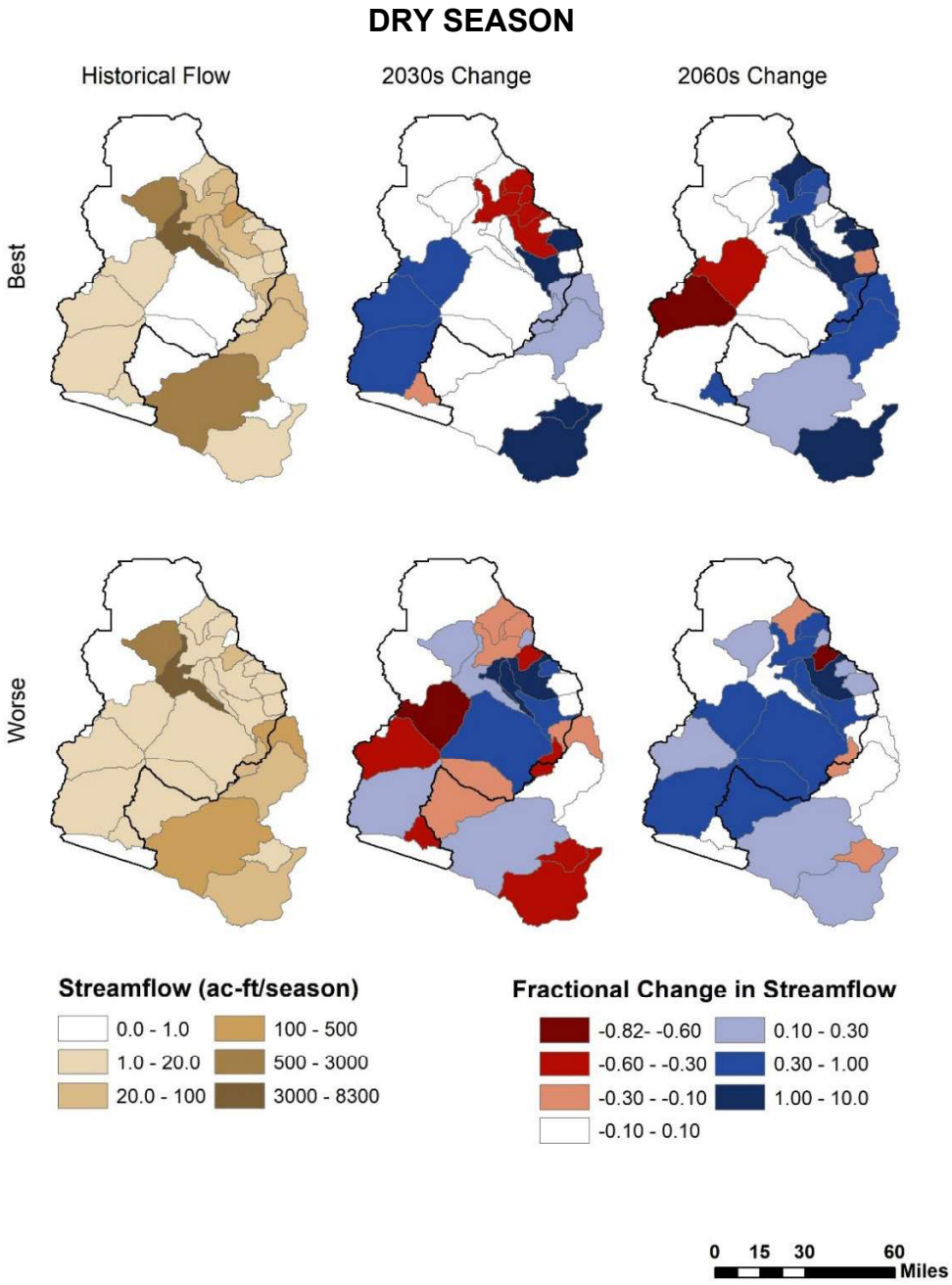


Figure 21 – Median of the ensemble 30-year average dry season total streamflow from the modeled historical period (tan) for each scenario, and projected change from historical (red for negative and blue for positive change respectively) in streamflow for the best- and worse-case climate scenarios. Note coverage is only over the areas identified as subbasins in Figure 20.

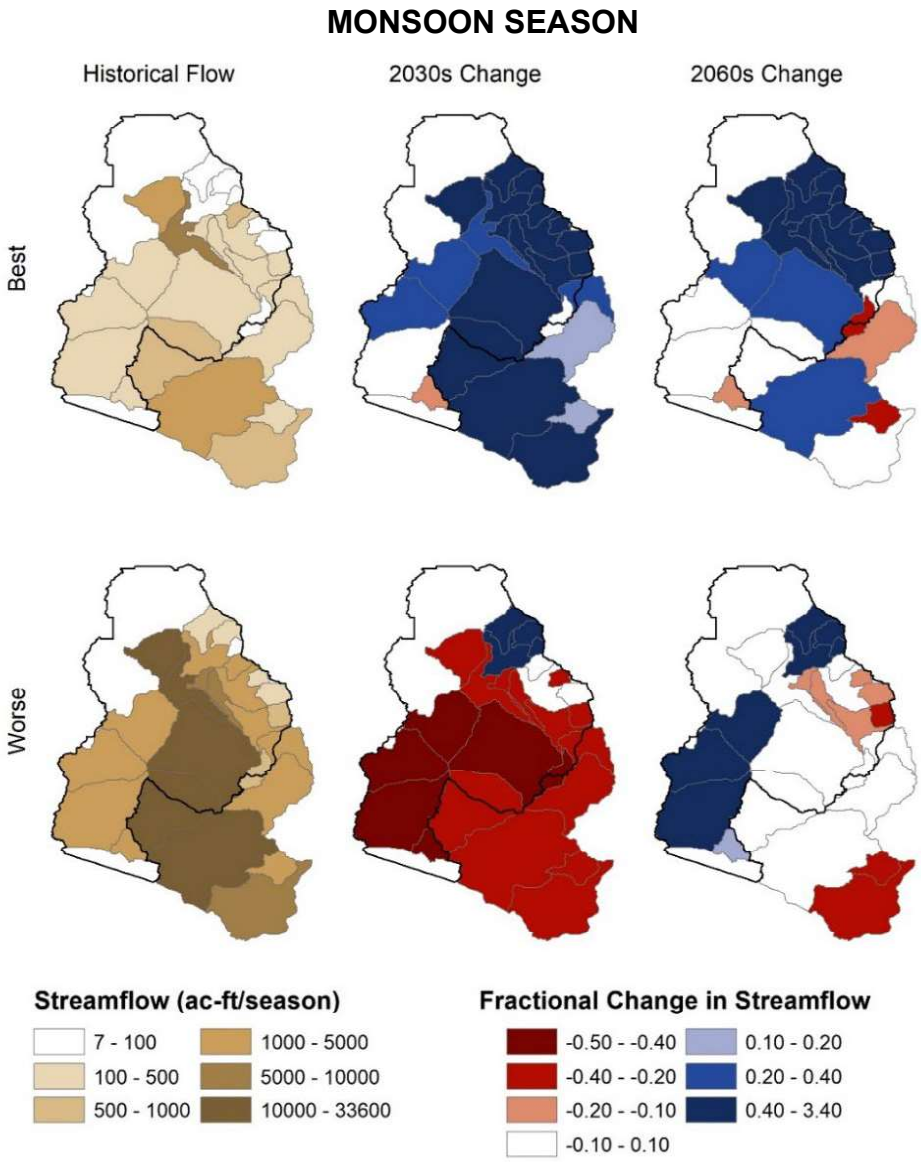


Figure 22 – Similar to Figure 21 but for the monsoon season.

The winter season shortens into the future under both scenarios. In the best-case scenario, the large events get consistently larger into the future (Figure 23), which compensates for the shortening of the season. In the worse-case scenario, total winter precipitation is consistently less under both future periods and this change in precipitation is reflected in reduced streamflow. Large precipitation events do not increase in the near future, resulting in little compensation for the shortening of the season; however, in the far future, more extreme precipitation likely results in some streamflow recovery.

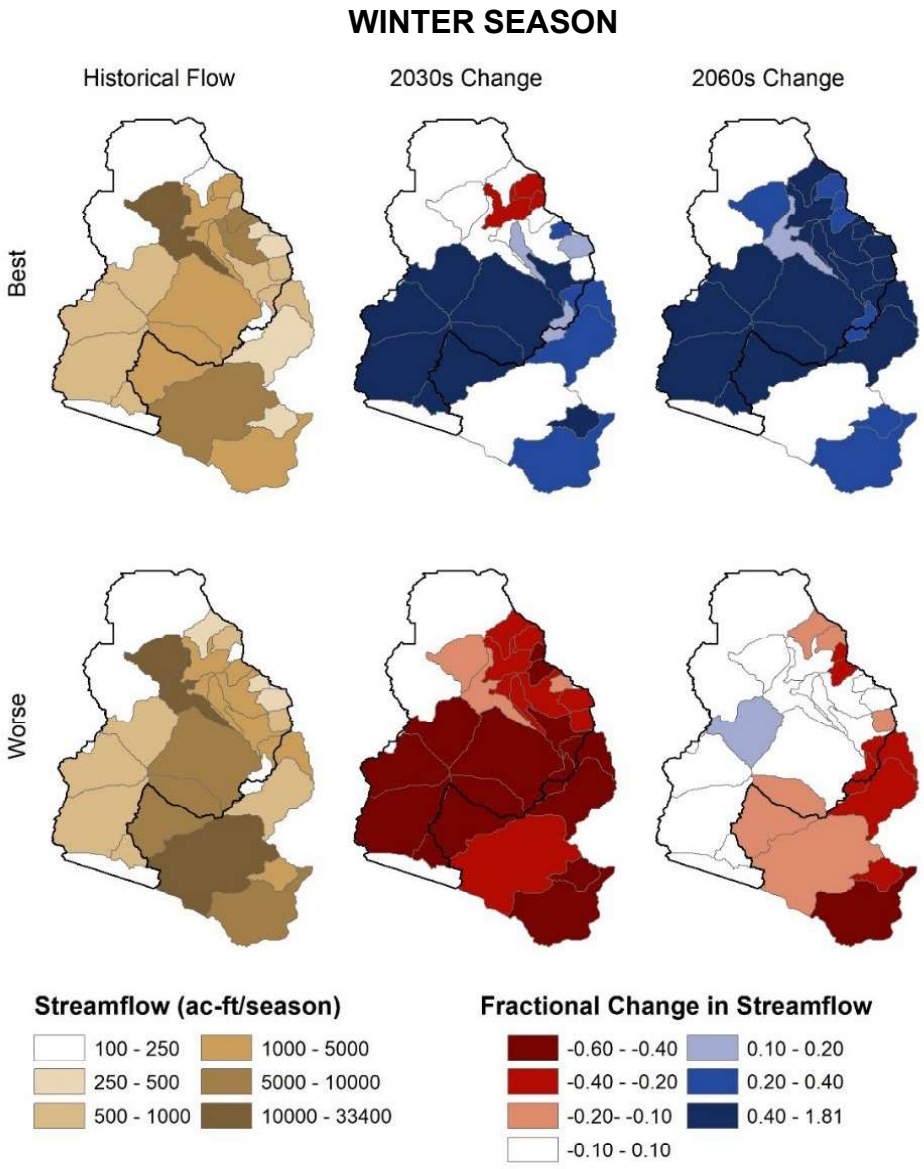


Figure 23 – Similar to Figure 21 but for the winter season.

Table 7 summarizes the ensemble statistics of historical streamflow and future change for select subbasins. The subbasins were selected to span a range of modeled flow regimes, ranging from year-round, or perennial, flow at Upper Cienega Creek (CNEA3), to streams that only flow in response to precipitation events during the dry season (ephemeral streams), to seasonal, or intermittent, flow that dries up in the spring at Rillito Creek at La Cholla (RICA3).

Note that the percent change under future scenarios is the change in that ensemble statistic. For example, Table 7 presents the change in the ensemble's 95th percentile for the 30-year averaged seasonal total streamflow, not the 95th percentile of the change. CBRFC's Sac-SMA modeled flows are also provided and represent the 30-year average of total acre-feet per season. The historical winter season is consistently higher and likely skewed by the 1983 flood that occurred during this period. This event may not have been well-captured in the LOCA and WRF historical period simulations.

Table 7 – Statistics of Period-Averaged Seasonal Total Streamflow Ensembles for Each Scenario, Period, Season, and Selected Subbasins. Historical flows are in ac-ft/season and future periods are presented as the percent change from historical in the ensemble statistic.

Upper Cienega Creek (CNEA3)		**Sac-SMA**	**Best-Case Simulation**			**Worse-Case Simulation**		
		Hist	**Hist**	**2030s**	**2060s**	**Hist**	**2030s**	**2060s**
Dry	5th Percentile	217	11.2	35%	72%	44.8	0.6%	-5.4%
	Mean		24.7	10%	46%	67.8	-6.2%	-2.3%
	Median		22.6	15%	54%	60.4	-3.8%	1.0%
	95th Percentile		45.5	-12%	26%	147	-35%	-40%
Monsoon	5th Percentile	1698	103	17%	-16%	1276	-43%	-12%
	Mean		163	13%	-17%	2183	-34%	7.8%
	Median		159	13%	-18%	2125	-32%	1.4%
	95th Percentile		238	13%	-16%	3192	-25%	36%
Winter	5th Percentile	2569	181	34%	60%	554	-37%	-27%
	Mean		282	37%	51%	887	-46%	-5.0%
	Median		268	39%	57%	869	-45%	-25%
	95th Percentile		456	22%	24%	1319	-52%	35%

Rillito Creek-La Cholla (RICA3)		**Sac-SMA**	**Best-Case Simulation**			**Worse-Case Simulation**		
		Hist	**Hist**	**2030s**	**2060s**	**Hist**	**2030s**	**2060s**
Dry	5th Percentile	537	1.20	-55%	-33%	0.09	69%	895%
	Mean		36.4	37%	97%	25.7	159%	24%
	Median		21.2	-10%	112%	6.90	214%	44%
	95th Percentile		117	51%	106%	118	137%	23%
Monsoon	5th Percentile	5812	161	248%	350%	3057	-50%	-8.8%
	Mean		451	165%	248%	8192	-29%	-12%
	Median		372	208%	286%	7540	-24%	-17%
	95th Percentile		946	166%	194%	14846	-27%	-7.0%
Winter	5th Percentile	18129	2640	12%	138%	2118	-29%	-8.7%
	Mean		5096	10%	101%	5129	-36%	3.1%
	Median		4539	9.1%	118%	4457	-31%	-2.1%
	95th Percentile		9667	2.5%	50%	9493	-31%	3.8%

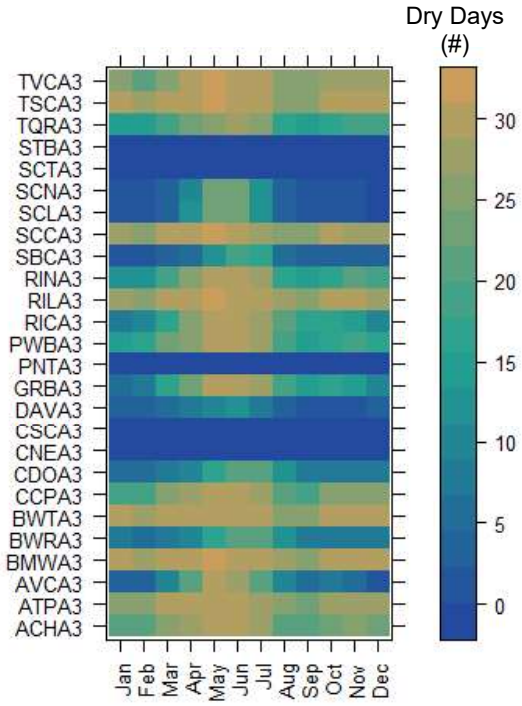
Sabino Creek-Nr Tucson (SBCA3)		Sac-SMA	Best-Case Simulation			Worse-Case Simulation		
		Hist	Hist	2030s	2060s	Hist	2030s	2060s
Dry	5th Percentile	838	217	-32%	-6.6%	23.2	-65%	-74%
	Mean		388	-28%	-2.0%	48.0	-33%	-46%
	Median		368	-35%	-6.0%	42.4	-56%	-60%
	95th Percentile		576	-4.2%	18%	86.5	57%	-6.4%
Monsoon	5th Percentile	2281	379	66%	22%	667	-33%	-23%
	Mean		549	75%	44%	1067	-8.9%	-5.1%
	Median		528	73%	52%	1015	-6.0%	-2.9%
	95th Percentile		732	114%	62%	1608	1.1%	-0.1%
Winter	5th Percentile	10005	4581	-16%	44%	1362	-46%	-45%
	Mean		6435	-8.4%	32%	2070	-43%	-32%
	Median		6145	-5.5%	39%	2024	-45%	-34%
	95th Percentile		8660	-6.1%	24%	2990	-43%	-23%

4.2.2. Change in Dry Days

Historically, the surface water systems in the surface water model boundary area are overwhelmingly ephemeral or intermittent, meaning that few locations in the area have streamflow all year long. A dry day is defined as any day with no flow modeled at the subbasin outlet. Figure 24 illustrates the ephemeral nature of the area, displaying the number of dry days at gaged concentration points calculated as average of the ensemble median over 30-year periods for the worse-case scenario. Thus, year-round flow, as seen for the Cienega Creek (CNEA3), may be a very small amount of modeled flow. It is also important to note that locations downstream of the wastewater treatment plants (CSCA3 and SCTA3) receive continuous recycled water contributions and thus also flow year-round.

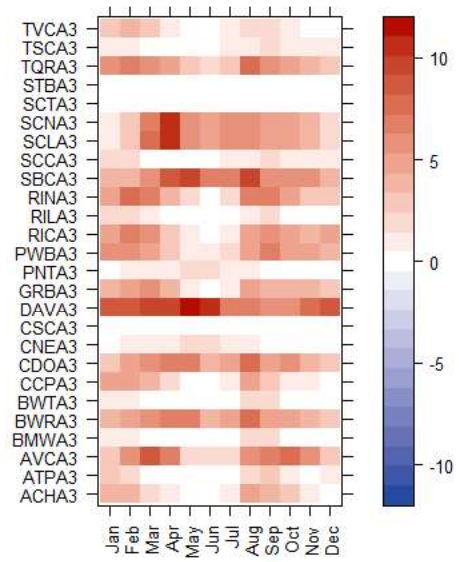
The change in the number of streamflow dry days between the historical period and modeled future periods under the worse-case scenario are presented in Figure 25 for the 2030s and Figure 26 for the 2060s. The largest increases in no-flow days consistently occur in headwaters subbasins, such as the Sabino Creek and the Santa Cruz near Nogales. These increases tend to be largest where the modeled subbasins are not fully perennial streams but have at least some flowing days every month. This change suggests that these transitional basins may experience longer no-flow periods in the future. Larger increases consistently occur in the spring during the transition to the dry season, but also occur in August during the monsoon season. The later onset of the monsoon season in the 2030s relative to the 2060s is likely the reason why there are more dry days in these transition months in the near future.

The worse-case is provided here, showing larger changes as determined by this modeling effort. The corresponding best-case figures are provided in Appendix C.



TVCA3	Tanque Verde - Tucson
TSCA3	Santa Cruz - At Tucson
TQRA3	Tanque Verde - Guest Ranch
STBA3	Santa Cruz River - At Tubac, AZ
SCTA3	Santa Cruz - Trico Rd At Marana
SCNA3	Santa Cruz - Nr Nogales
SCLA3	Santa Cruz - Nr Lochiel
SCCA3	Santa Cruz - Continental
SBCA3	Sabino Creek - Nr Tucson
RINA3	Rincon Creek - Nr Tucson
RILA3	Rillito Creek - Tucson At Dodge Blvd.
RICA3	Rillito Creek - La Cholla Blvd.
PWBA3	Pantano Wash - Broadway Blvd.
PNTA3	Pantano Wash - Nr Vail
GRBA3	Cañada Del Oro - Golder Road Bridge
DAVA3	Davidson Canyon
CSCA3	Santa Cruz - At Cortaro
CNEA3	Cienega Ck - Nr Sonoita
CDOA3	Cañada Del Oro - Blo Ina Rd Nr Tucson
CCPA3	Cañada Del Oro - Coronado Camp
BWTA3	Brawley Wash - Three Points
BWRA3	Big Wash - Cañada Del Oro
BMWA3	Brawley Wash - At Milewide Rd
AVCA3	Arivaca Ck At Arivaca, AZ
ATPA3	Altar Wash - Nr Three Points, AZ
ACHA3	Agua Caliente Wash - Houghton Rd

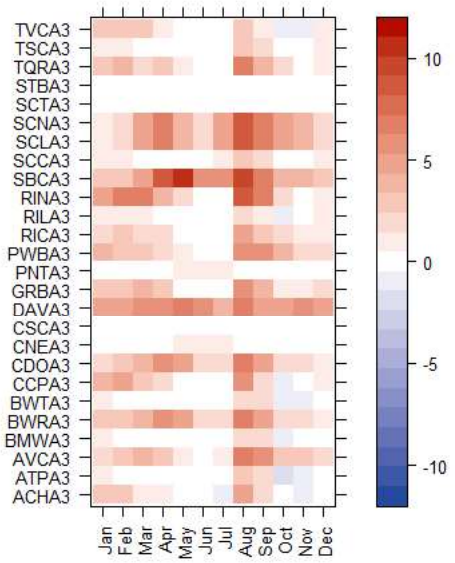
Figure 24 – The number of modeled historical dry days per month under the worse-case scenario for each Sac-SMA subbasin, abbreviated in the plot but defined on the right. Tan colors indicate months when the stream is dry the entire month, while the dark blue represents streams that flow the whole month.



2030s - Top 5 increases in dry days

month	# days
Davidson Canyon (DAVA3)	May	12
Davidson Canyon (DAVA3)	June	11
Santa Cruz near Nogales (SCNA3)	April	10
Santa Cruz near Lochiel (SCLA3)	April	10
Sabino Creek (SBCA3)	May	10

Figure 25 – Change in the number of dry days per month in the near future for each subbasin under the worse-case climate scenario. The table to the right provides details on the subbasins and months with the top five increases in dry days under near future conditions.



2060s - Top 5 increases in dry days month		# days
Sabino Creek (SBCA3)	May	10
Sabino Creek (SBCA3)	August	10
Sabino Creek (SBCA3)	April	9
Santa Cruz near Lochiel (SCLA3)	August	9
Santa Cruz near Nogales (SCNA3)	August	9

Figure 26 – Change in the number of dry days per month in the far future for each subbasin under the worse-case scenario. The table to the right provides details on the subbasins and months with the top five increases in dry days under far future conditions.

4.3. Soil Moisture

In addition to its role in streamflow generation, soil moisture supports upland vegetation communities and determines the amount of water needed for irrigation. Sac-SMA calculates sub-daily soil moisture for each elevation zone. Calculations include two soil layers: a fast-responding upper layer (about 20 centimeters) and a deeper (lower) layer that can extend to 60 inches, depending on the soil depth. Each layer is broken into tension and free water.

Free water is water controlled by gravity and can percolate to deeper soil layers. From the soil, it can return to the stream either as interflow from shallow layers or as baseflow from deeper layers. Tension water is held tightly in the soil by tension processes and can only be removed through evapotranspiration or diffusion. Storage and subsequent drainage from the deeper layer indicate a basin's antecedent conditions between runoff events. Deep storage is partitioned into fast (sub-daily to weeks) and slow (weeks to seasonally) draining reservoirs (Figure 27).

Changes in soil moisture generally mirror changes in precipitation under future climate scenarios. For the best-case scenario, soil moisture generally increases in the fall and winter, particularly in the far future, and decreases in the far future monsoon season months of July and August (see Appendix C, and for an example, Figure C2 for the Lower Cienega Creek subbasin).

The worse-case scenario is drier, with nearly all soil water zones indicating decreases in soil moisture in both the near and far future as exemplified by tension water in Figure 27. Model results indicate that more water is stored as tension water than free water; for an example see the moisture partitioning between free and tension water in both the upper and lower soil moisture layers in the Lower Cienega Creek subbasin depicted in Figure 27. This is consistent with the Arizona Department of Water Resources (ADWR) TAMA groundwater model inputs, which do

not include distributed recharge (from free drainage) but assume all soil water is lost through evapotranspiration.

The exceptions are the transitions to the dry season in May and the fall months in the far future, which suggest wetter soils during these periods. These soil moisture increases tend to occur in the lower-elevation, drier, portions of the area where large percentages of change may represent small increases in moisture. The higher elevation and wetter subbasins in the Santa Catalina and Rincon Mountains still decrease in soil moisture throughout the year. These high elevation subbasins are not located within the TAMA but contribute recharge to the basin through the lateral transfer of water through the mountain block to the basin boundaries, or via local return flow to streams. The subsequent changes in these mountain recharge processes warrant additional consideration and study, although existing studies of the nearby San Pedro watershed suggest mountain system recharge will decrease (summarized in Meixner et al., 2016).

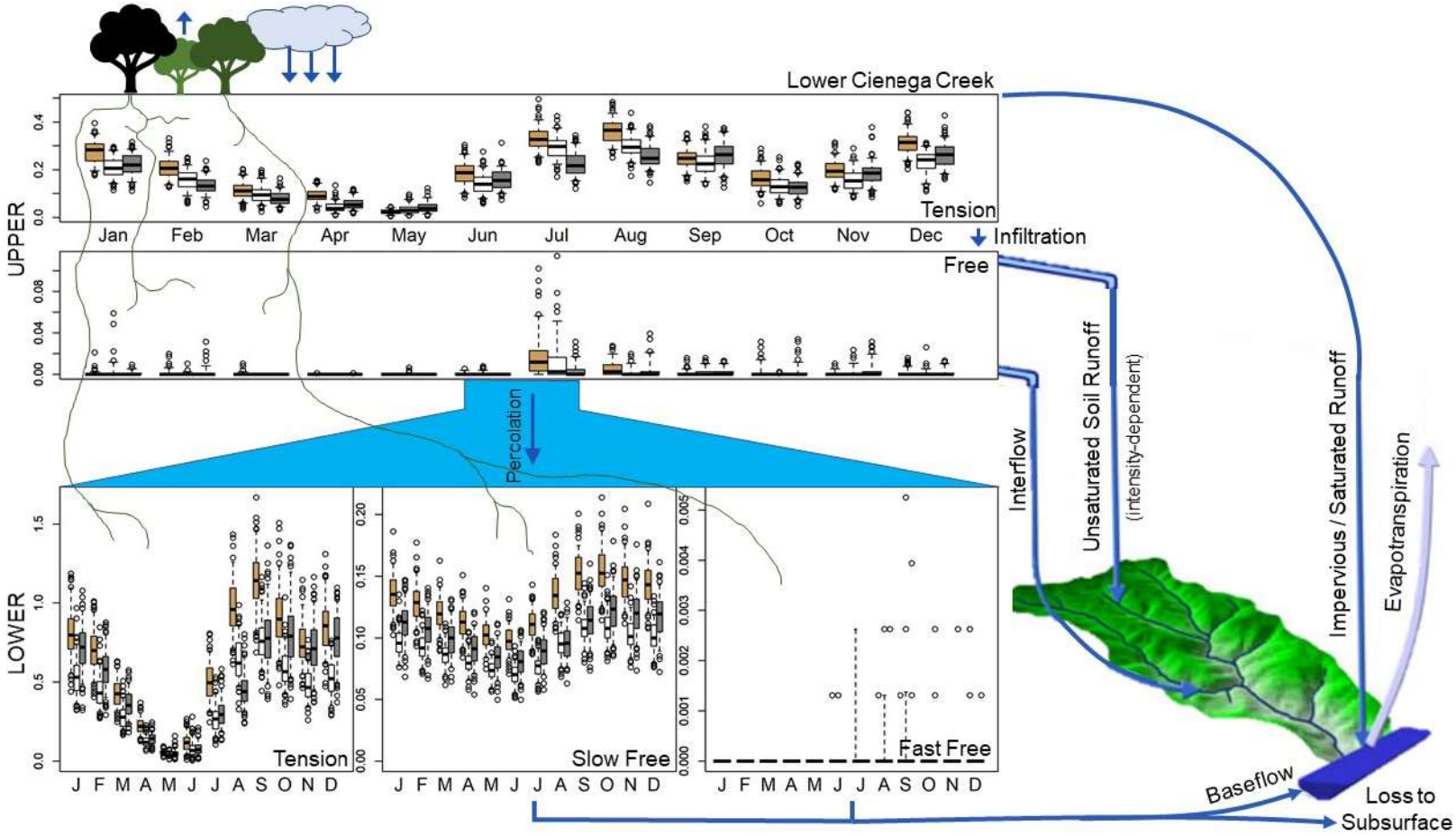


Figure 27 – Monthly averaged worse-case scenario soil moisture (inches) in each compartment of the Sac-SMA Cienega Creek lower elevation zone. Tan boxes are modeled historical distributions spanning the range of uncertainty from the weather generator simulations, white is near future, and gray is far future. Compartments include two in the upper layer (tension water and free water) and three in the deeper lower layer (tension water, and fast and slow draining free water). Graphics modified from https://www.cbrfc.noaa.gov/wsup/sac_sm/cbrfc_sacsma_101_20140731.pdf.

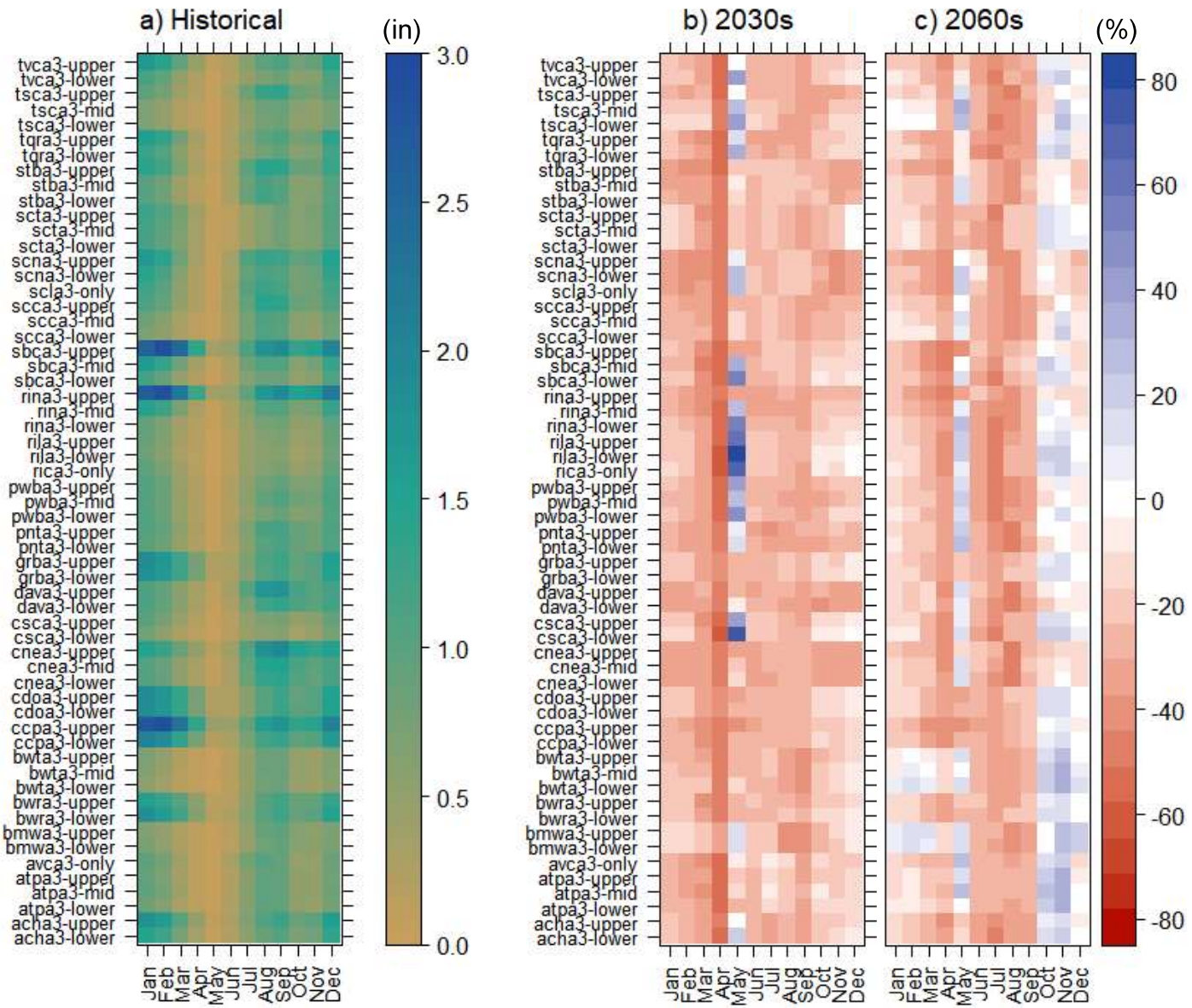


Figure 28 – Ensemble median, monthly average of the total tension water (sum of upper and lower soil zones) under the worse-case climate scenario for: a) modeled historical tension water in inches, b) near future change, and c) far future change as a percent relative to the historical period.

For soil moisture change, blue indicates an increase and red indicates a decrease. Results are presented for each elevation zone.

4.4. Evapotranspiration

Evapotranspiration (ET) is the movement of water from the ground, water surface, or vegetation to the air through evaporation or plant transpiration. In the LSCR basin, precipitation across the landscape rarely percolates deep enough to recharge the regional groundwater system before it is evaporated. The ADWR TAMA groundwater model, for example, does not include recharge from precipitation distributed across the landscape, assuming that the contribution is negligible relative to other sources of recharge (streamflow, mountain front, artificial recharge, etc.). Evapotranspiration is also expected to play a larger role in the water budget of the larger Colorado River system as the climate warms (e.g., Udall and Overpeck 2017).

Sac-SMA calculates actual ET by limiting PET to the amount of available water. Actual ET therefore reflects both changes in temperature (through adjusted PET) and changes in precipitation. Overall, the amount of water lost to the atmosphere through ET decreases in both the near and the far future (Figure 28). This trend follows the decreasing trend in soil moisture (Figure 27) which is consistent with the water-limited nature of southern Arizona.

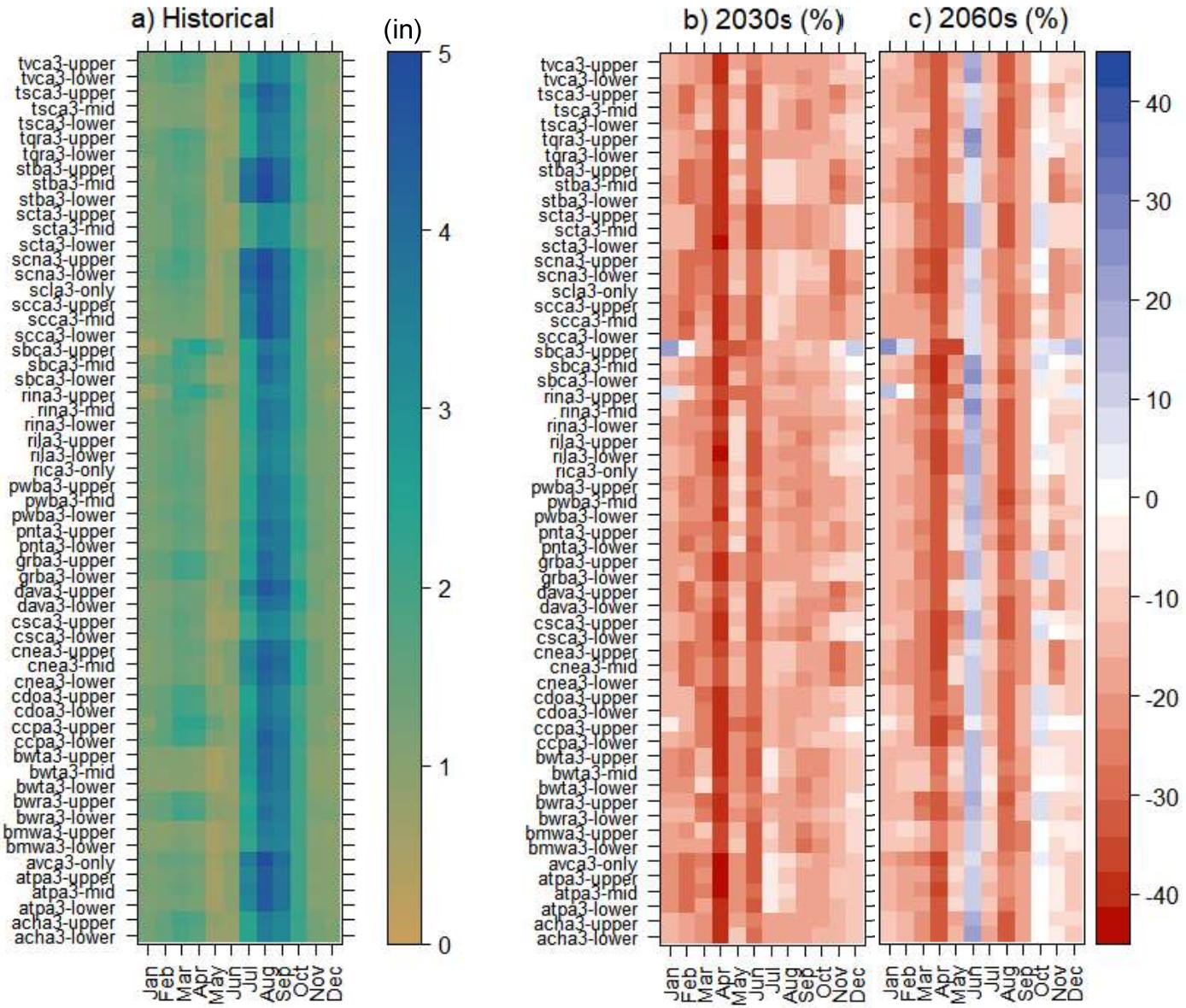


Figure 29 – Evapotranspiration (ET) under the worse-case climate scenario for a) modeled historical ET in inches, b) near future change, and c) far future change in ET as a percentage.

Blue indicates an increase and red indicates a decrease in ET.

5. Summary

This study investigated the potential range of climate and hydrologic changes in the SAC-SMA basins contributing to the Tucson Active Management Area, also referred to as the surface water model boundary area. It specifically examined changes in temperature, precipitation, streamflow, soil moisture and evapotranspiration for two thirty periods: 2020-2049 and 2050-2079. Reclamation and local stakeholders identified a "best-case", lower emissions scenario (RCP 4.5) and a "worse-" (not "worst") case emissions scenario (RCP 8.5).

To ensure that the study would fully reflect the impacts of climate change to the semi-arid climate, stakeholders selected a dynamically downscaled climate projection to represent the "worse-case": the low-resolution Max-Planck-Institute Earth System Model MPI-ESM run downscaled using the Weather Research and Forecasting Model. A corresponding climate model, the medium resolution MPI-ESM-MR Global Climate Model, run with RCP 4.5 and downscaled using the statistical Localized Constructed Analogs (LOCA) method was selected for the "best-case".

Changes over these thirty-year periods were evaluated for average annual area-wide temperature and precipitation and for the dry, monsoon and winter wet seasons. To reproduce the variability of the southeastern Arizona climate, a seasonal weather generator was used to produce an ensemble of 100 temperature and precipitation time-series for each case and future period.

These ensembles were then used as input to a surface hydrological model (the Sacramento Soil Moisture Accounting Model). This model was selected because it is part of the National Weather Service's Colorado Basin River Forecast Center's operational streamflow modeling system. The model available at the time of this study was calibrated over the water years 1971-1999.

This 1970-1999 Sac-SMA calibration set was used to provide a historical reference for model simulations of the same period. To identify projected changes while accounting for model biases, this study compares each simulated future period to a simulation of the period 1970-1999 using the same model configuration and inputs.

5.1. Results

Climate: Precipitation and Temperature by Season
All models and climate scenarios consistently identify increases in temperature through time. Increases are larger under the worse-case scenario, which represents higher future emissions. Seasonally, temperature increases in the monsoon and dry period were larger than in the winter wet season. Otherwise, seasonal temperature increases varied by scenario and time period.

Precipitation changes are more variable than temperature. The best-case provides a scenario with relatively minimal change in seasonal precipitation; in the worse-case scenario, total

precipitation decreases significantly in the monsoon and winter wet seasons. Precipitation also becomes increasingly variable under projected future conditions. Projected changes for the two future periods, relative to the simulated 1970-1999 historical period, are summarized in Table 4 in Section 2.5 as well as the executive summary.

5.1.1. Seasonal Length and Timing

The best-case scenario exhibited a slight advance in the date of monsoon onset, two days for each future period, to July 3 and July 1 for the 2030s and 2060s, respectively. The worse-case scenario does not show a single trend in monsoon onset date for the future periods, with a later median onset date of June 29 in the near future and returning to a median date of June 22 in the far future. This may be related to changes in the distribution of monsoon rainfall, with precipitation events becoming more intermittent, but more extreme, as documented in the historical record by Luong et al. (2017) and DeMaria et al. (2019). The worse-case climate scenario therefore does not provide earlier relief to the dry season, as in the best-case.

The best-case consistently shows a lengthening of the monsoon period and shortening of the winter wet period, but inconsistent changes in the length of the dry period. The worse-case has inconsistent trends over time for the monsoon and dry season, but does show a consistent trend toward a shorter winter season. In general, the worse-case scenario provides a greater range of seasonal lengths from year to year, representing a more variable future.

Extremes in both temperature and precipitation increased into the future. Increases in extreme temperature were consistently largest in the dry and monsoon season, when high heat is most dangerous for human health. Extreme temperatures increase over 7°F under the worse-case scenario in the far future, reflecting the largest change under unchecked emissions through the 2060s and beyond.

5.1.2. Surface Hydrology—Changes in 30-year Median Streamflow by Subbasin, Season, and Time Period

For the best-case monsoon season, a lengthening monsoon season and a slight increase in monsoon precipitation in the 2030s result in generally increasing streamflows for this period. In the 2060s, a slight decrease in monsoon precipitation negates some of these effects. Under the worse-case scenario, a decrease in monsoon rainfall by an average of 2.38 inches leads to decreased streamflow on the order of 20-50% for most of the sub-basins in the near future, but this trend is mostly reversed in the far future.

For the winter wet period, the best-case also predicts increases in streamflow over time. As the length of the winter season is predicted to shorten, this may be due to changes in storm size. The worse-case scenario predicts near future decreases in streamflow that are even more widespread than for the monsoon season, again moderating to some extent in the far future.

Other notable trends include:

- The number of no-flow days per month consistently increases in the worse-case, especially in April, May, and August.
- Soil moisture decreases are most pronounced in the months preceding the dry season, particularly in the worse-case scenario.

- In both future scenarios, evapotranspiration decreases due to soil moisture limitation despite rising temperatures that drive increases in the potential for evapotranspiration.

5.2. Conclusion

The goal of the Study is to identify where physical water resources are needed to mitigate supply-demand imbalances and to develop a strategy to improve water reliability for the municipal, industrial, agricultural, and environmental sectors. This memorandum delineates a range of potential changes in future temperature, precipitation, streamflow, soil moisture and evapotranspiration rates.

In southern Arizona, where the climate is already highly variable across space and time, the combination of these findings suggests a range of risks to the sustainability of groundwater, infrastructure, and environmental systems. In particular, projected changes may reduce the natural groundwater recharge that supports much of the municipal, industrial, agricultural, and environmental water use within the basin. In addition, alterations in the onset and length of the monsoon and winter wet seasons may require adaptation by water providers to maintain reliable deliveries throughout the year. Also of note are the projected changes in extreme temperature and precipitation and their implications for environmental and human health, as well as public safety and infrastructure investments.

The information and analysis in this report will be used as input to a groundwater model for the study area to identify water supply-demand imbalances for six growth/climate scenarios. The outcomes of these analyses will then be used to develop adaptation strategies for specific local sectors including municipal and industrial water supply, agriculture, and the environment.

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Appendix A—Supporting Climate Figures

Combined time series and box plots of the best-case (left) and worse-case (right) climate scenario precipitation (Figure A1) and temperature (Figure A2), used as input to the weather generator. Bold timeseries lines are basin averages while the gray lines are subbasin values of seasonal totals (for precipitation) or averages (for temperature). Boxplots (located within the violin plots to the right of the time-series') are basin-averages with the whiskers representing the $5^{th}/95^{th}$ percentile of daily values and the remaining values indicated as points. The violin plots are subbasin values with the shaded area extending to the maximum and minimum daily values. Daily precipitation boxplots are for rainy days only, defined as precipitation values greater than 0.01 in/day.

Figure A3 depicts the annual total precipitation (top) and average temperature (bottom) for the three climate scenarios across three periods. Note the effects of bias correction in annual temperatures, which aligns the historical temperatures from the three scenarios.

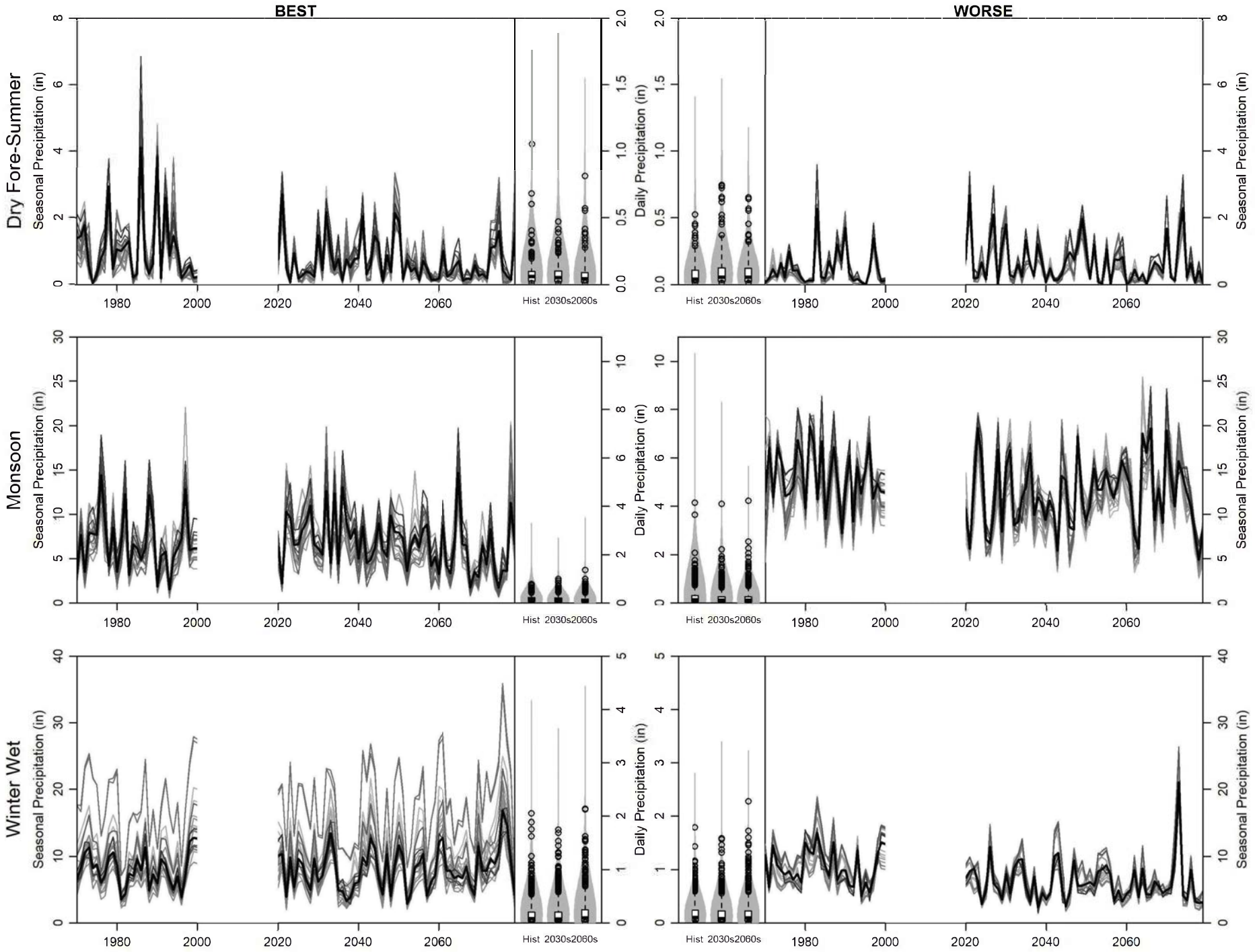


Figure A1 - Combined plot of climate scenario precipitation.

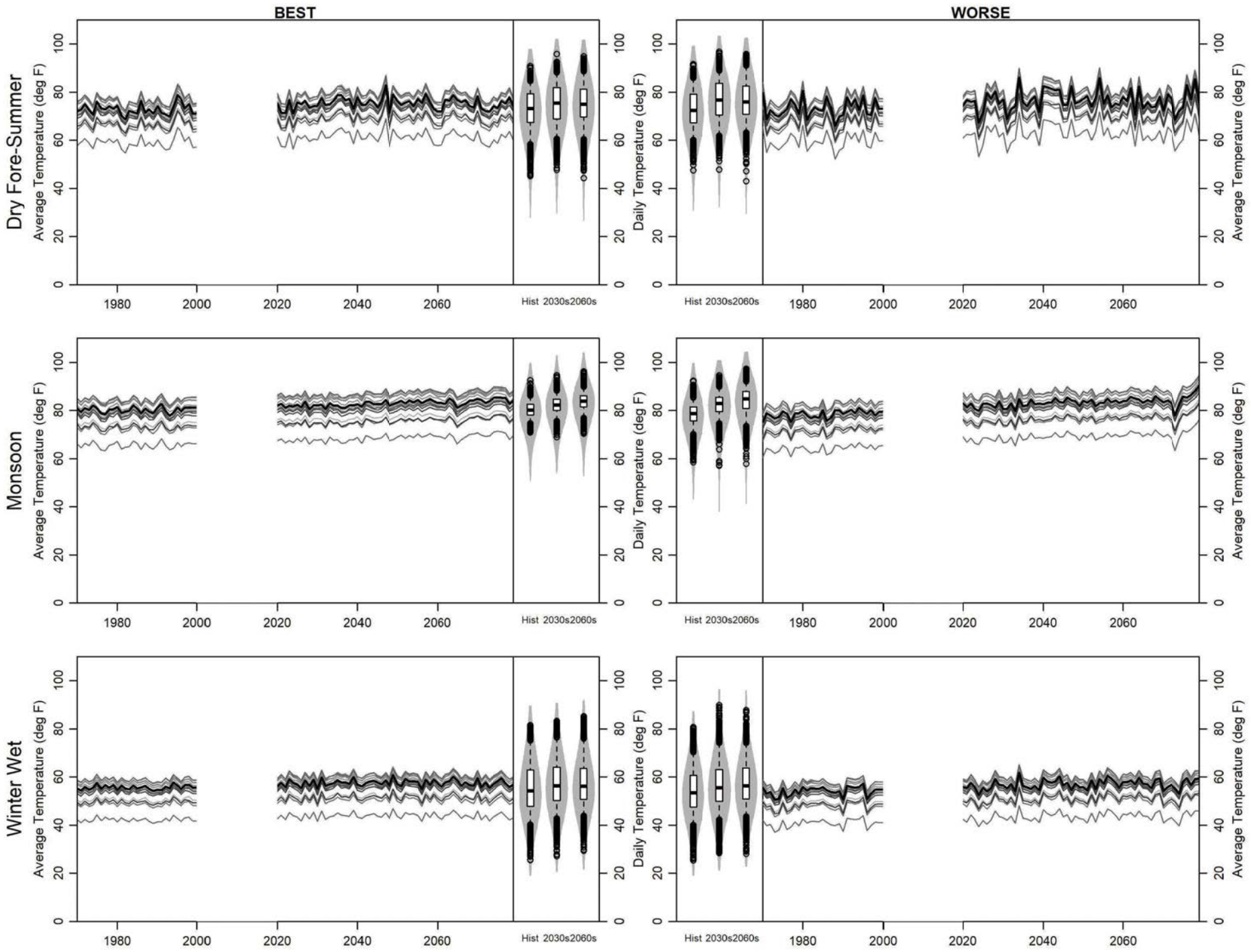


Figure A2 - Combined plot of climate scenario temperature.

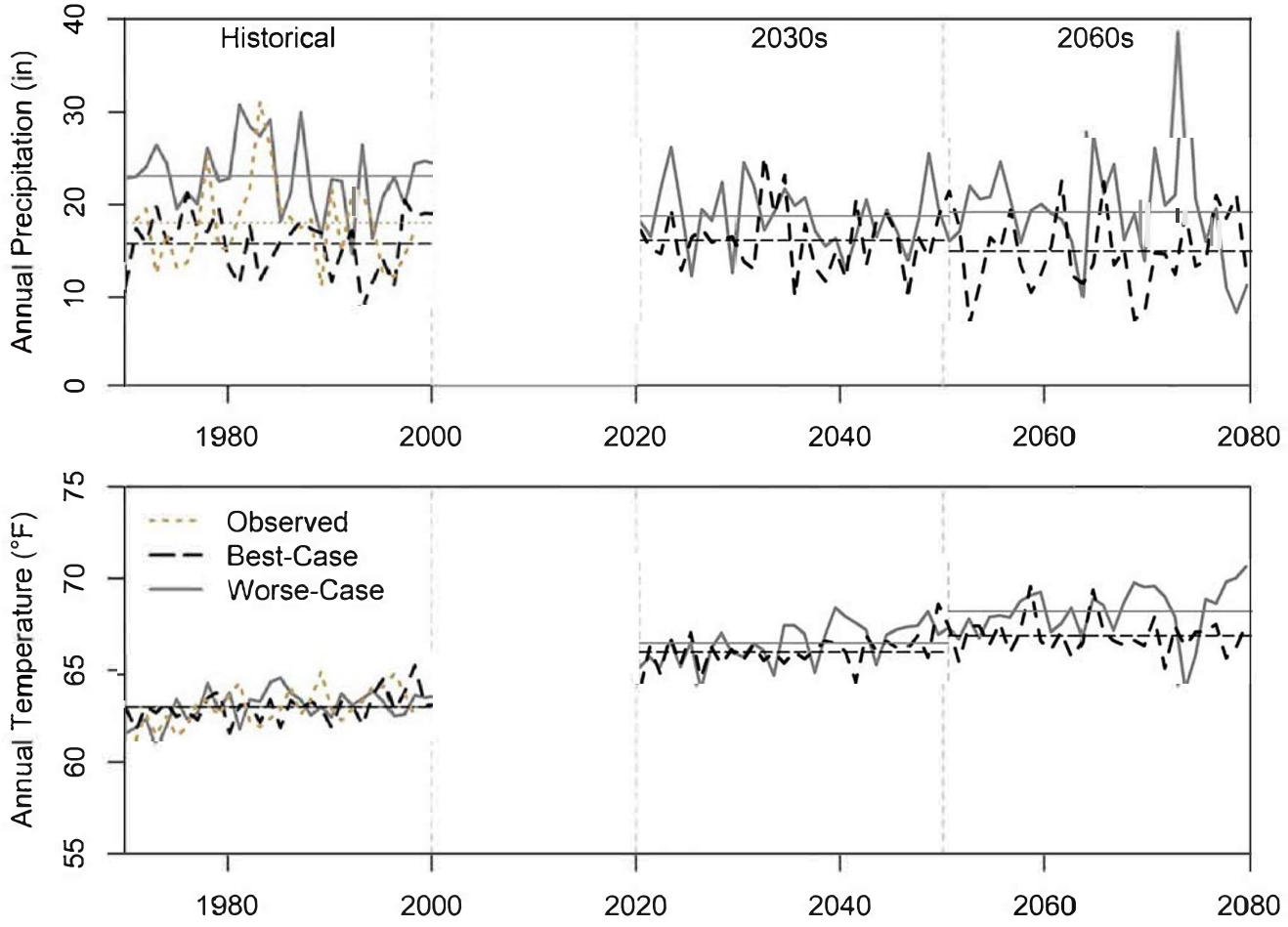


Figure A3 - Annual total precipitation (top) and average temperature (bottom) for the three climate scenarios across three periods.

Appendix B—Weather Generator Validation Figures

Statistics of basin-averaged weather generator outputs relative to inputs (or the training dataset).

Figure B1 – Validation of daily statistics of weather generator-derived precipitation.

Figure B2 – Validation of daily statistics of weather generator-derived temperature.

Figure B3 – Validation of monthly statistics of weather generator-derived dry spell length. Red lines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Month 1 is January.

Figure B4 – Validation of monthly statistics of weather generator-derived precipitation. Red lines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Month 1 is January.

Figure B5 – Validation of monthly statistics of weather generator-derived temperature. Red lines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Month 1 is January.

Figure B6 – Validation of seasonal statistics of weather generator-derived precipitation. Red lines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Season 1 is the dry season, 2 is the monsoon season, and 3 is the winter.

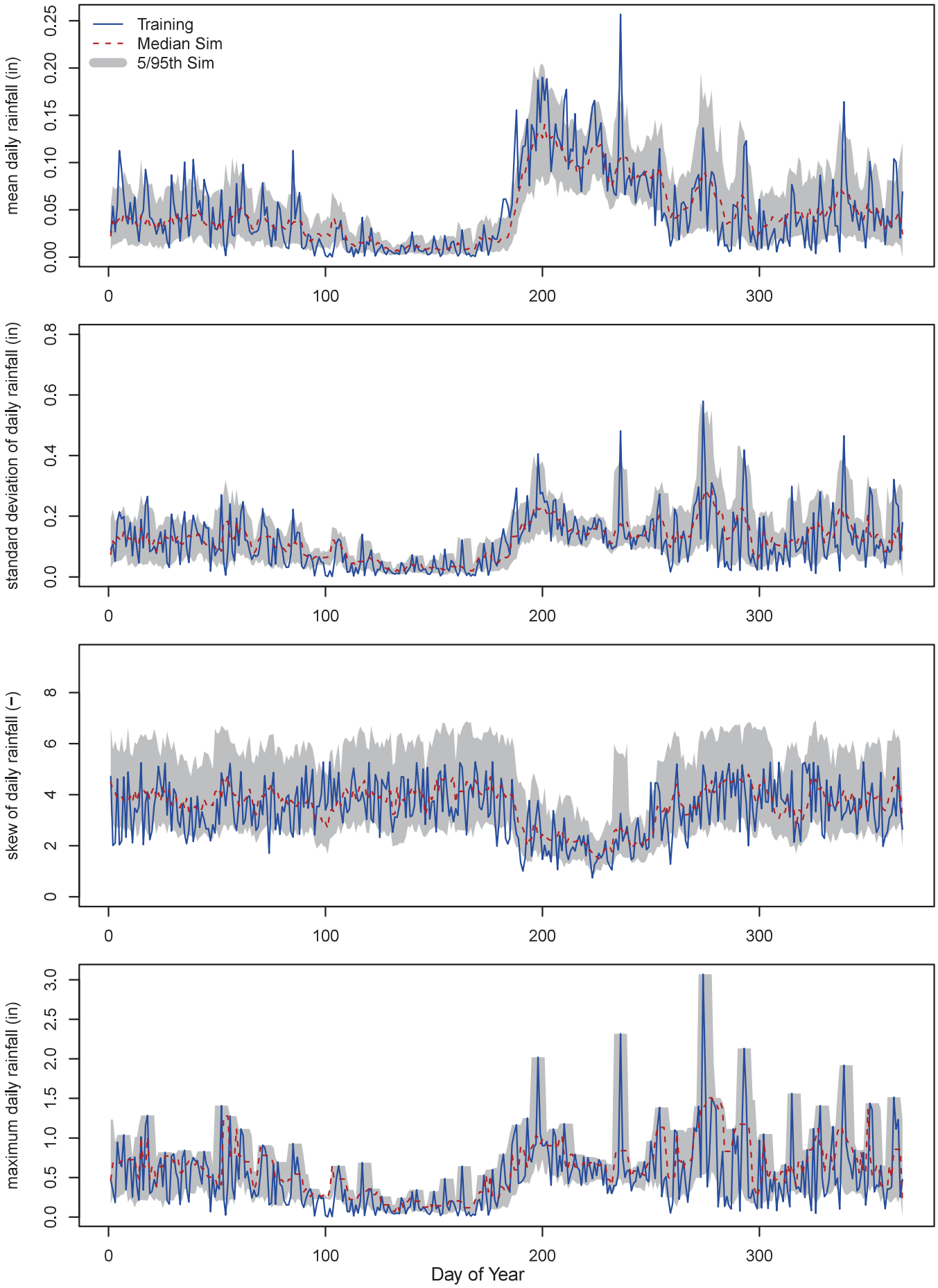


Figure B1 - Validation of daily statistics of weather generator-derived precipitation.

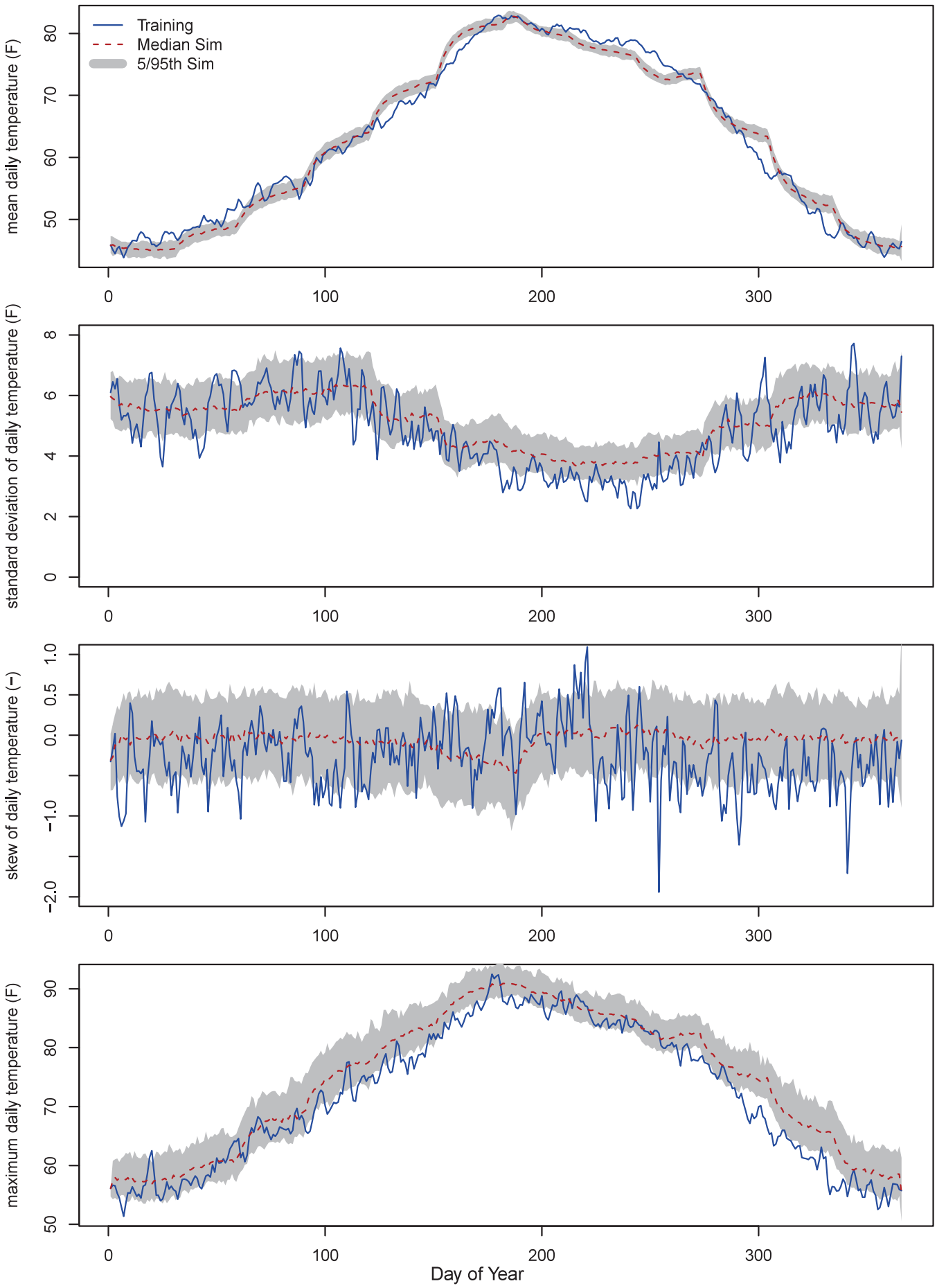


Figure B2 - Validation of daily statistics of weather generator-derived temperature.

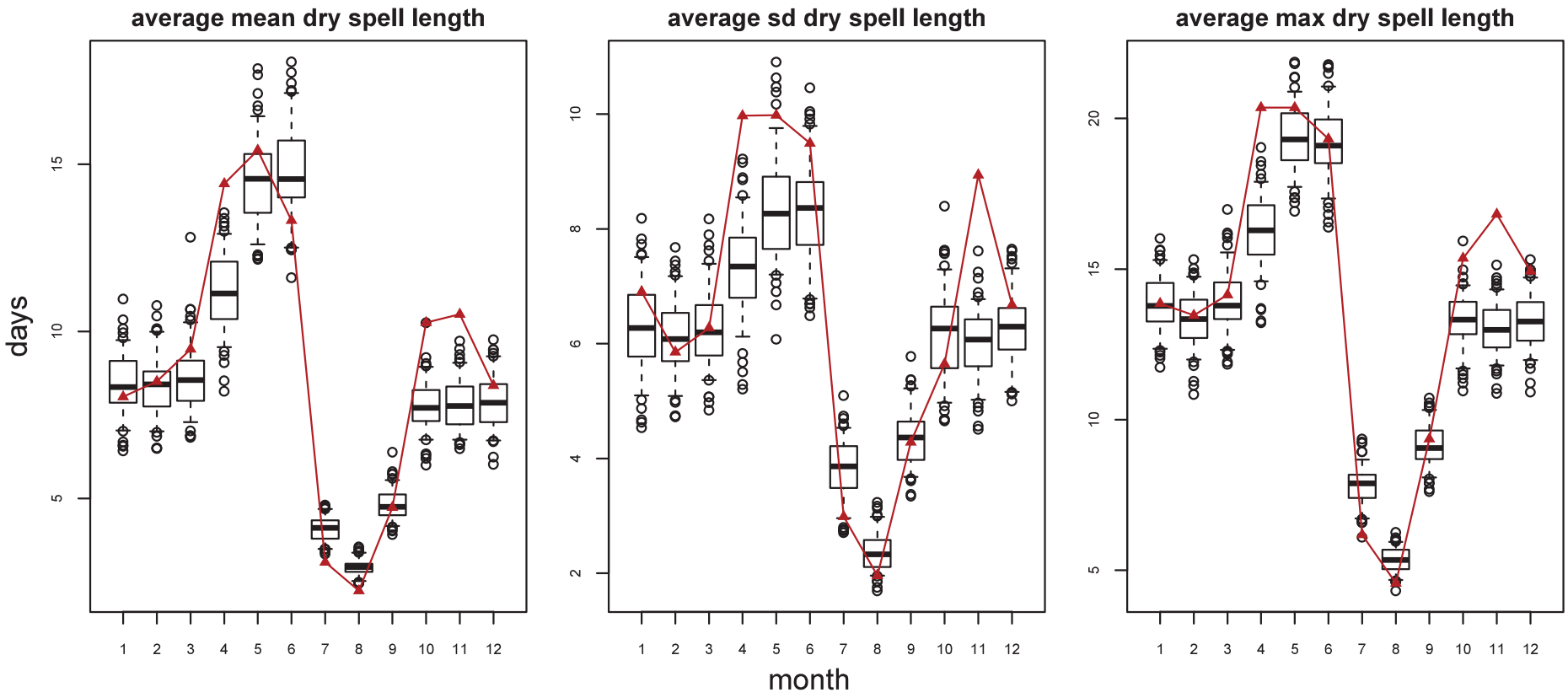


Figure B3 - Validation of monthly statistics of weather generator-derived dry spell length. Redlines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Month 1 is January.

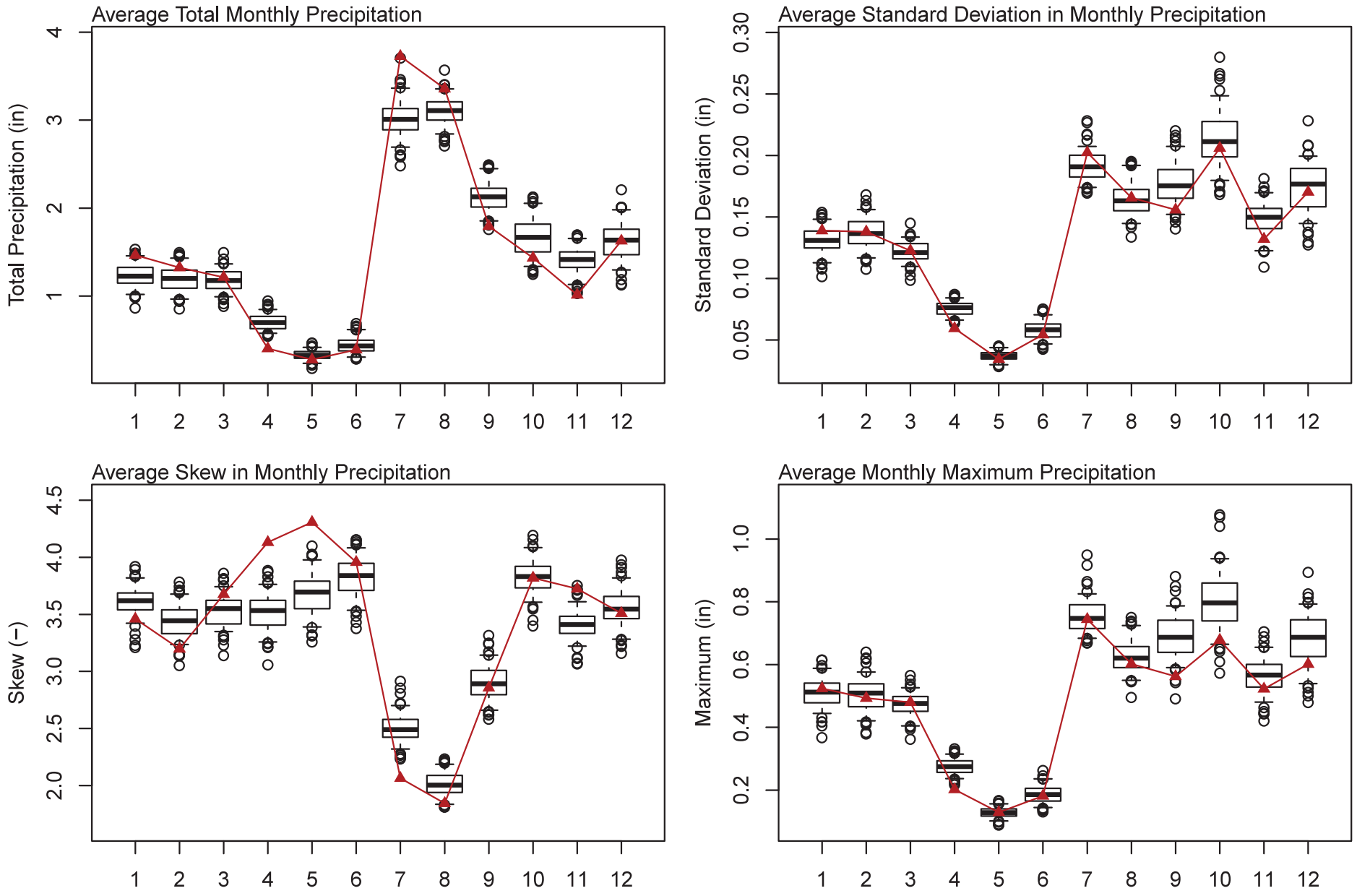


Figure B4 - Validation of monthly statistics of weather generator-derived precipitation. Redlines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Month 1 is January.

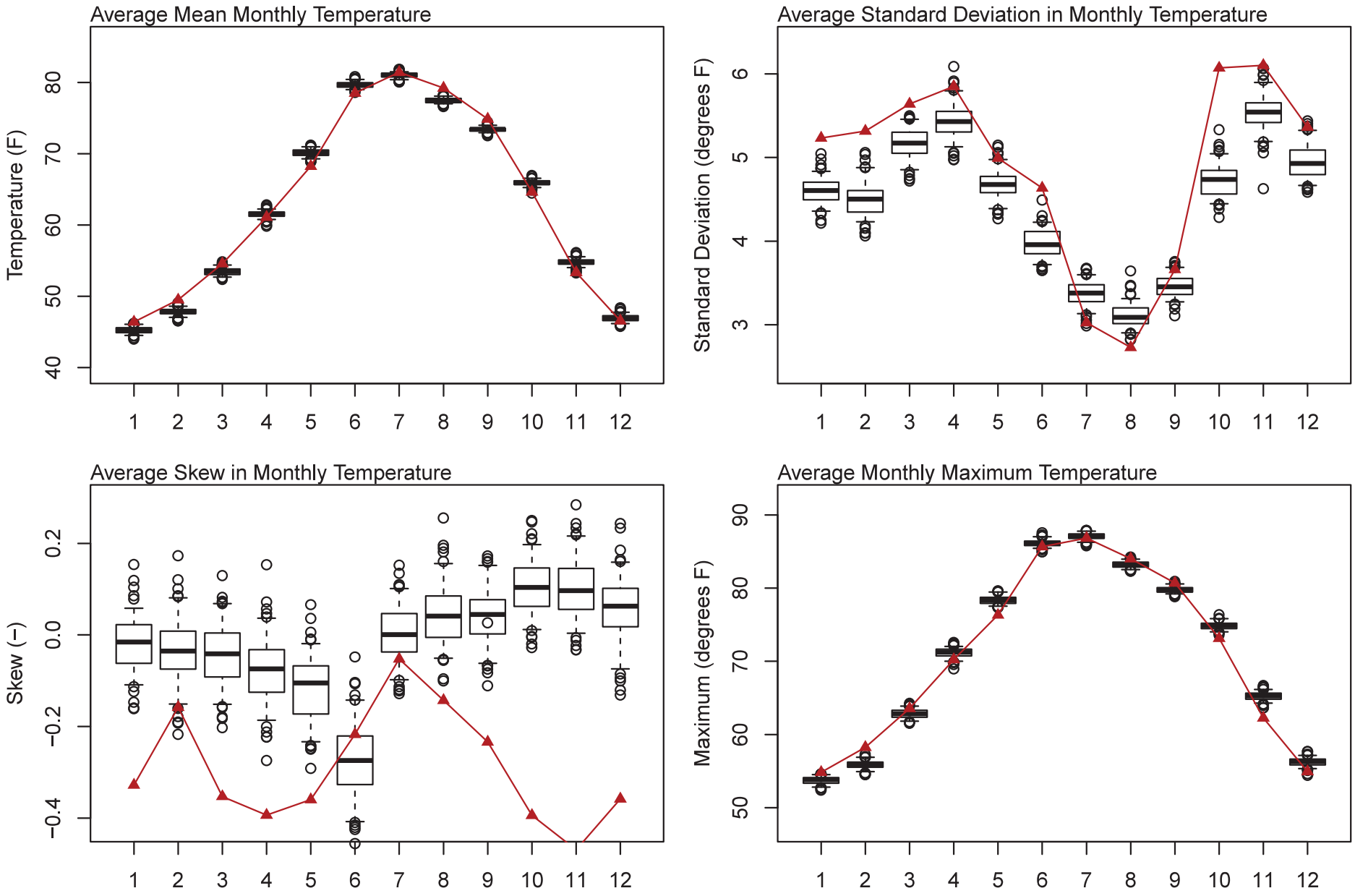


Figure B5 - Validation of monthly statistics of weather generator-derived temperature. Redlines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Month 1 is January.

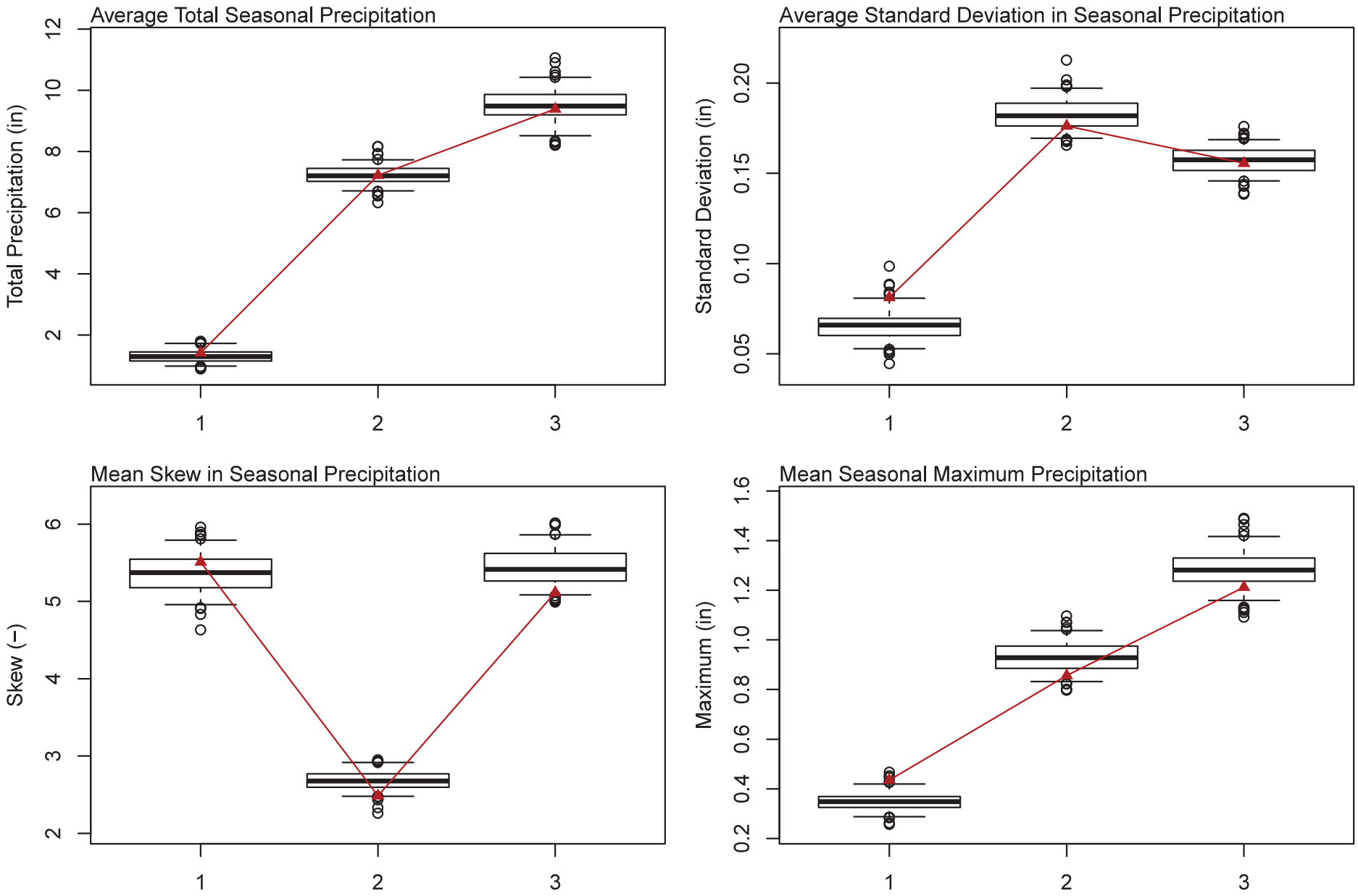


Figure B6 - Validation of seasonal statistics of weather generator-derived precipitation. Redlines are the statistics of the inputs dataset while the boxplots represent statistics from the weather generated ensemble. Season 1 is the dry season, 2 is the monsoon season, and 3 is the winter.

Appendix C—Supporting Surface Water Modeling Figures

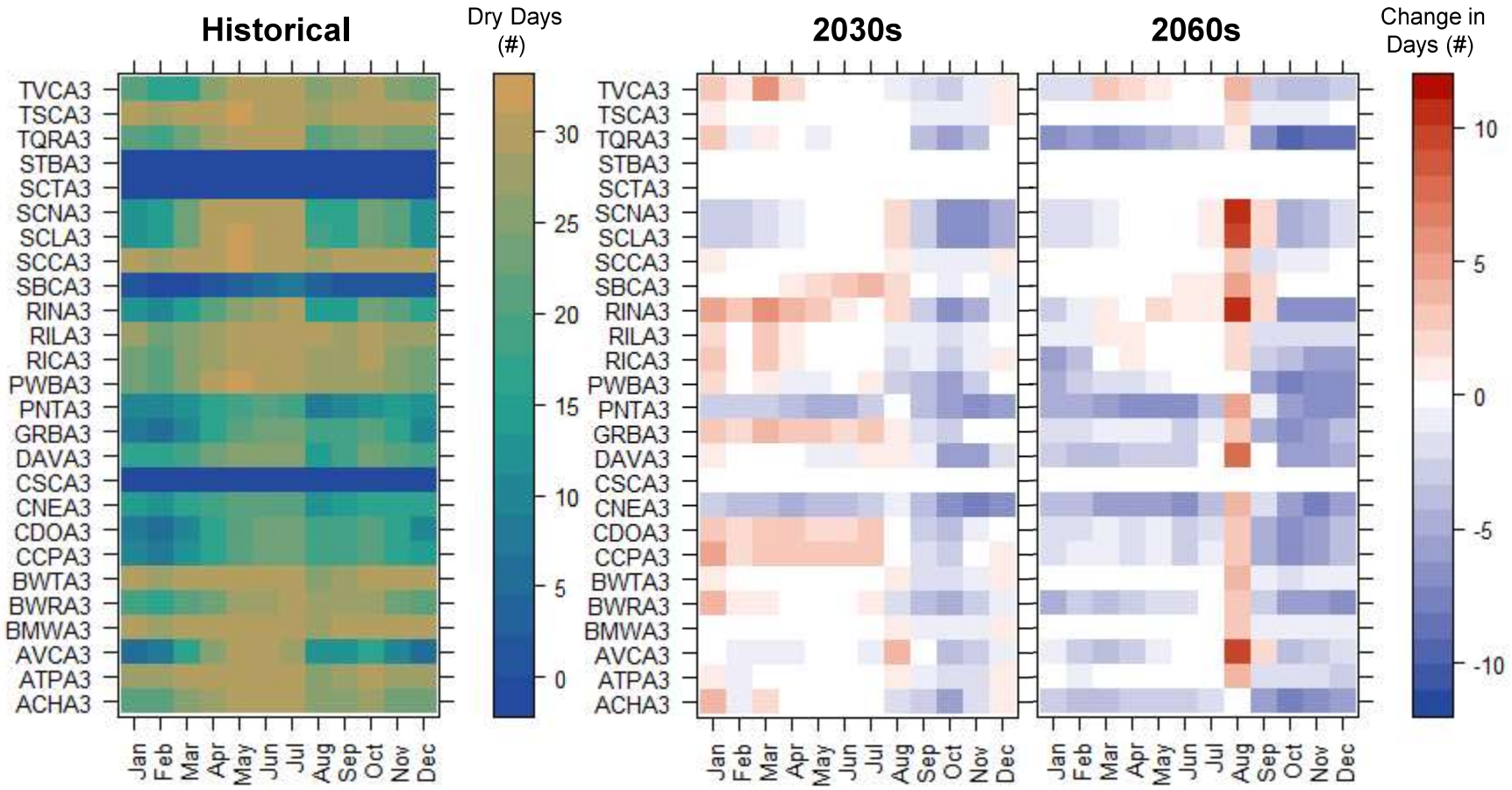
Additional figures of surface water modeling outputs for the best-case scenario.

Figure C1 – Best-case scenario model results for each Sac-SMA subbasin, including a) modeled historical dry days per month where tan colors indicate months when the stream is dry the entire month and dark blue represents streams that flow the whole month and change in the number of dry days per month in the b) near future and c) far future.

Figure C2 – Best-case scenario soil moisture (inches) in each compartment of the Sac-SMA Lower Cienega Creek elevation zone. Tan boxes are modeled historical distributions spanning the range of uncertainty from the weather generator simulations, white is near future, and gray is far future. Compartments include two in the upper layer (tension water and free water) and three in the deeper lower layer (tension water, and fast and slow draining free water).

Figure C3 – Ensemble median, monthly average of the total tension water (sum of upper and lower soil zones) under the best-case climate scenario for a) modeled historical tension water in inches and b) near future change and c) far future change as a percent relative to the historical period. For soil moisture change, blue indicates an increase and red indicates a decrease. Results presented for each elevation zone.

Figure C4 – Evapotranspiration (ET) under the best-case climate scenario for a) modeled historical ET in inches, b) near future change and c) far future change in ET as a percent. Blue indicates an increase and red indicates a decrease in ET.



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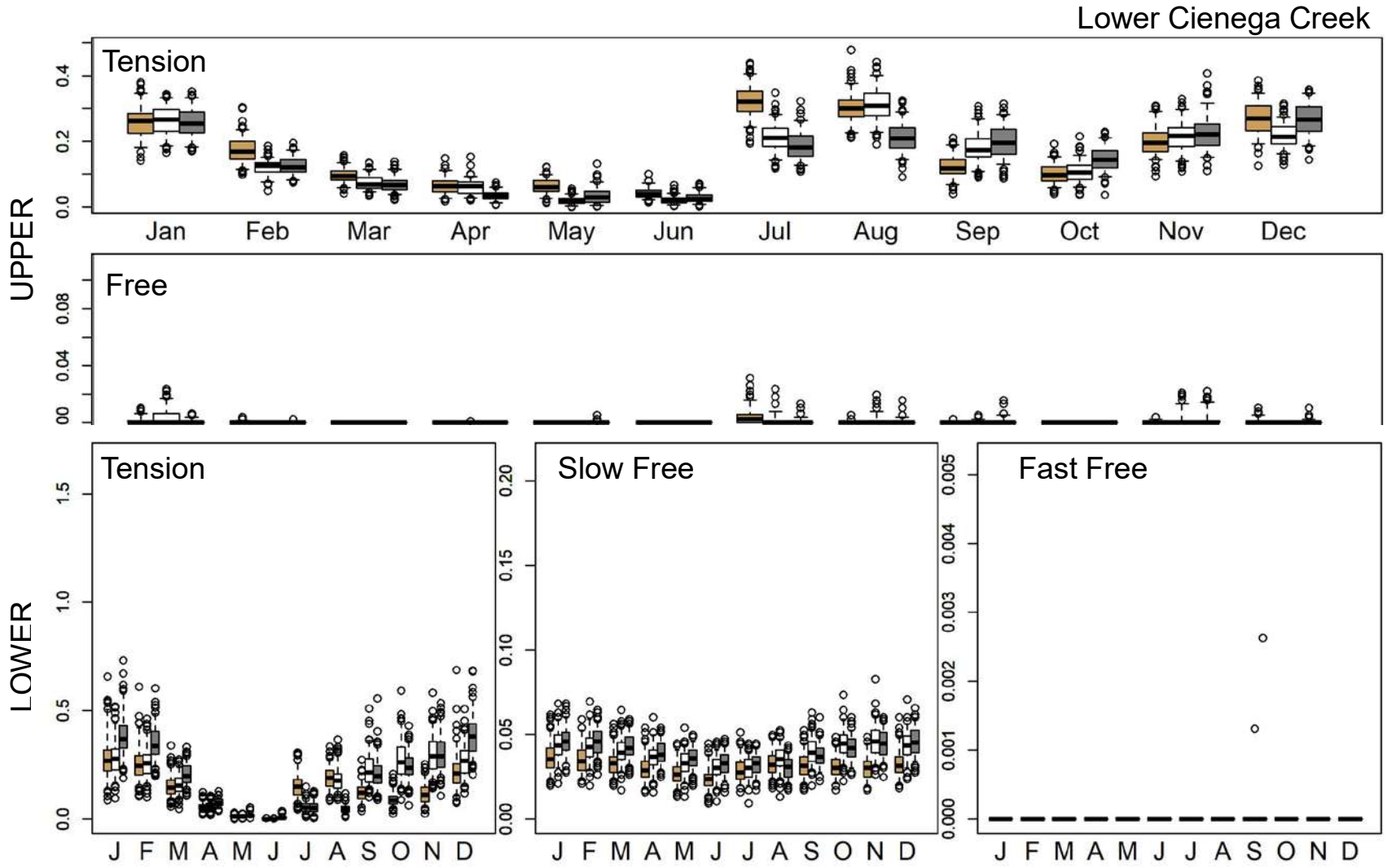

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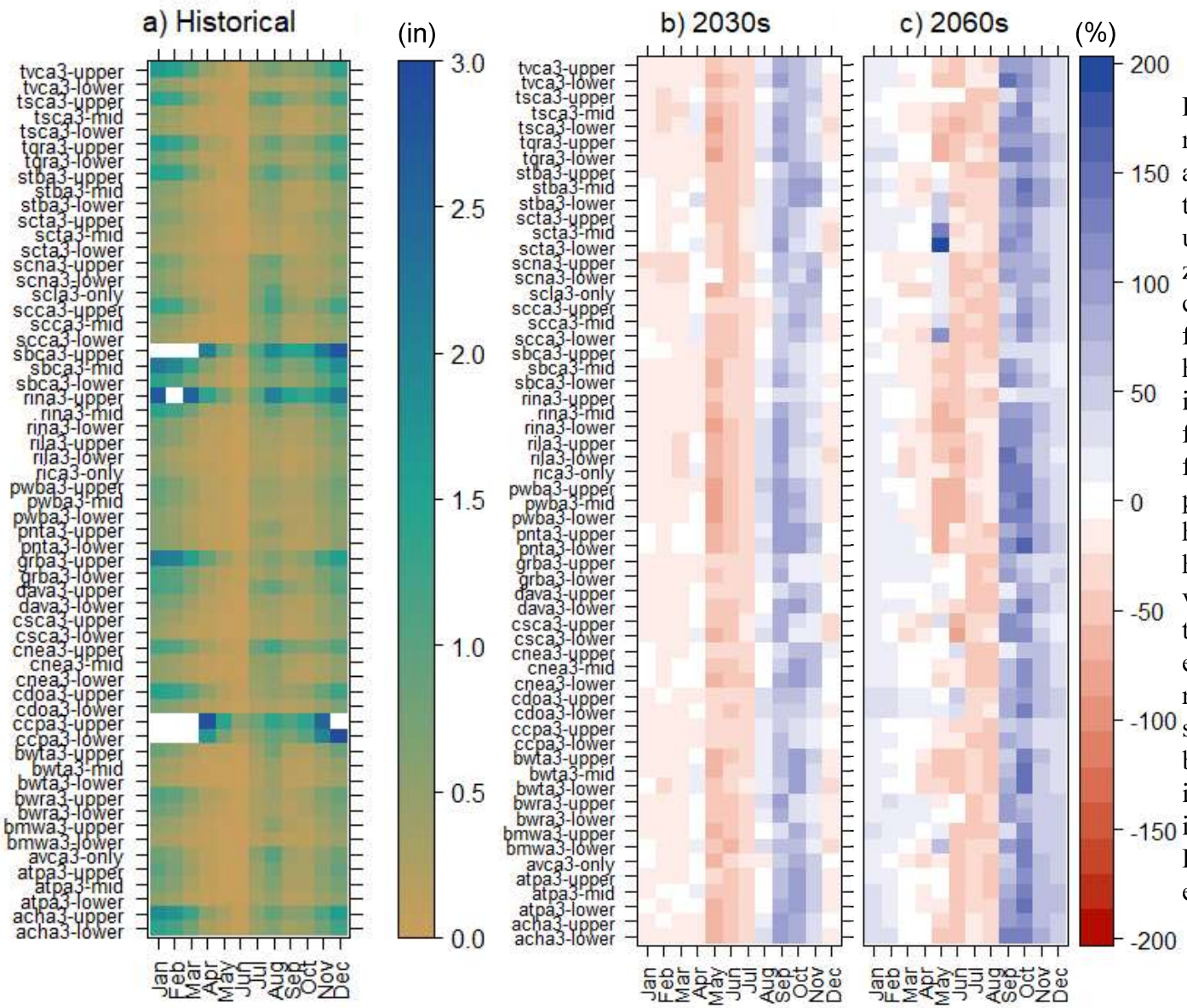

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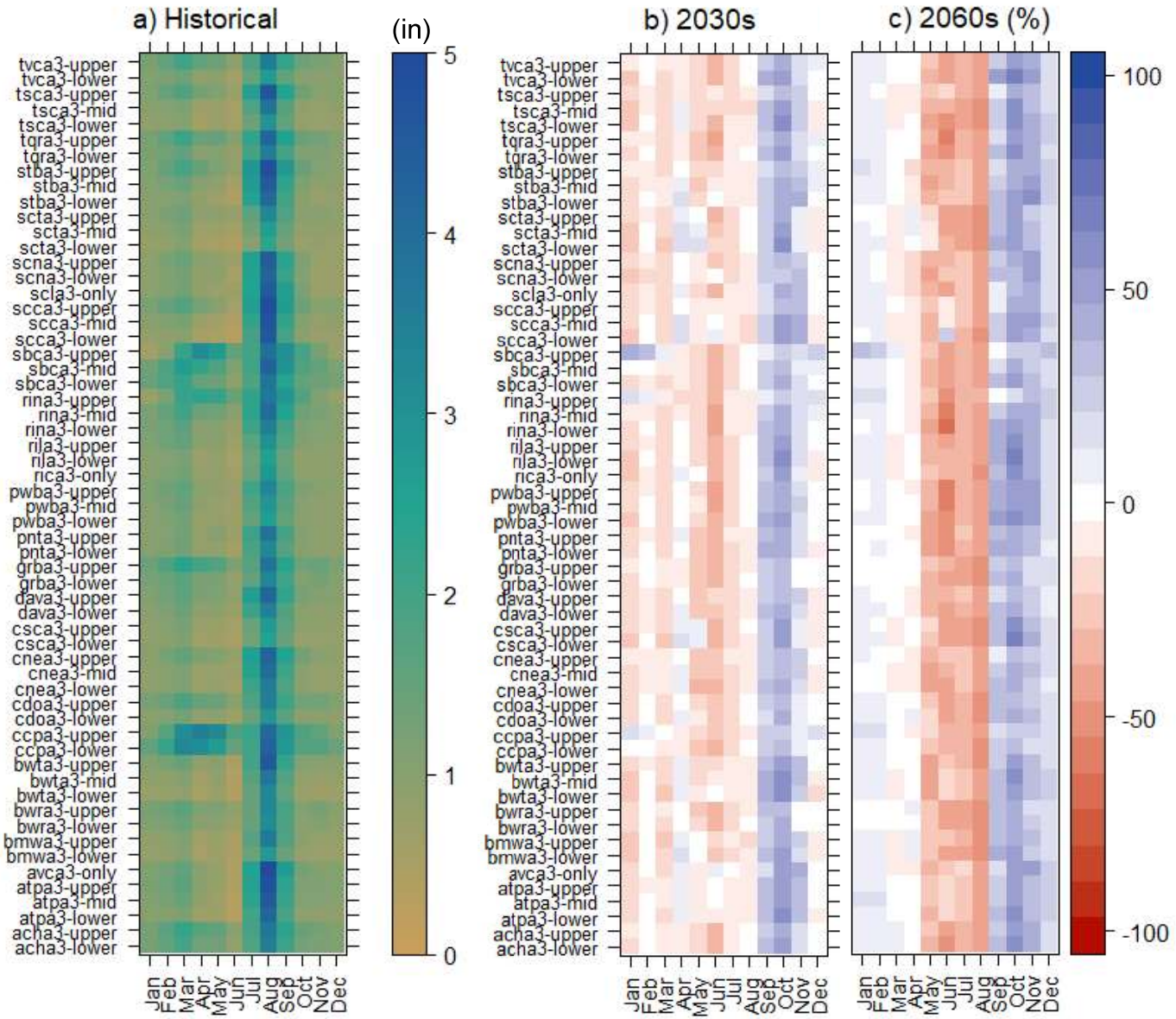

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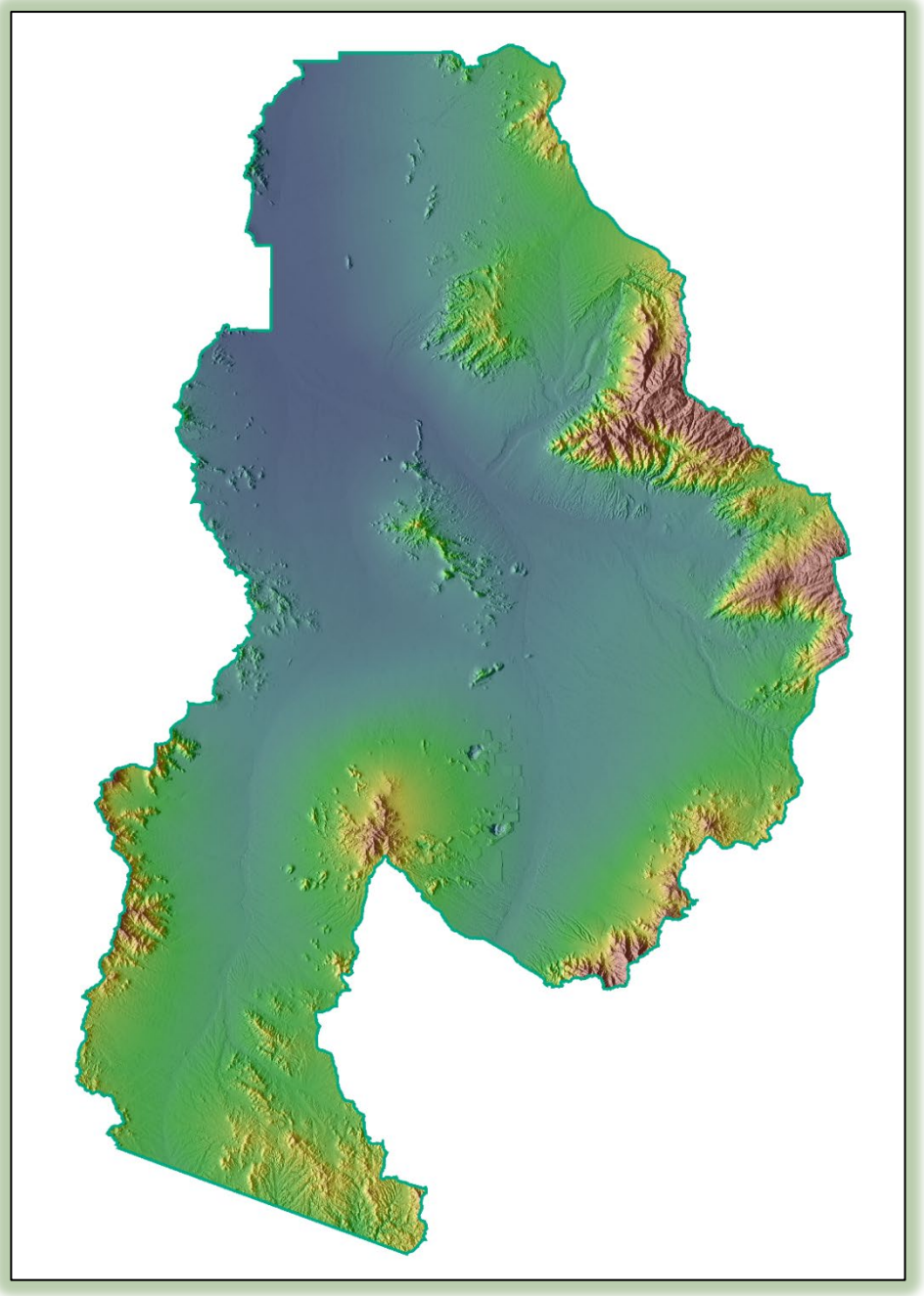
Appendix C

Supply and Demand Assessment

Lower Santa Cruz River Basin Study

Supply and Demand Assessment



June, 2021

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Acronyms and Abbreviations

Abbreviation	Description
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
AOEO	Arizona Office of Economic Opportunity
ASR	Annual Storage and Recovery
AWBA	Arizona Water Banking Authority
AWS	Assured Water Supply
CAGRD	Central Arizona Groundwater Replenishment District
CAP	Central Arizona Project
CAP:SAM	Central Arizona Project: Service Area Model
CAWCD	Central Arizona Water Conservation District
GIS	Geographic Information System
CRSS	Colorado River Simulation System
GMA	Groundwater Management Act
GPHUD	Gallons Per Housing Unit Per Day
GSF	Groundwater Savings Facility
LBDCP	Lower Basin Drought Contingency Plan
LSCRB	Lower Santa Cruz River Basin
LTSA	Long-Term Storage Account
LTSC	Long-Term Storage Credit
M&I	Municipal and Industrial
MAG	Maricopa Association of Governments
ML	Member Lands (CAGRD)
MSA	Member Service Areas (CAGRD)
NASS	National Agricultural Statistical Service
NIA	Non-Indian Agriculture
PAG	Pima Association of Governments
RCP	Representative Concentration Pathways
Reclamation	U.S. Bureau of Reclamation
SAWUA	Southern Arizona Water Users Association
Study	Lower Santa Cruz River Basin Study
TAMA	Tucson Active Management Area
TAZ	Traffic Analysis Zone
USF	Underground Storage Facility

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Executive Summary

The Lower Santa Cruz River Basin Study (Study) is a collaborative regional planning effort that began in February of 2016 as part of the Bureau of Reclamation's (Reclamation) WaterSMART program. The Study area is the Tucson Active Management Area (TAMA), defined by the Arizona Department of Water Resources (ADWR) as part of the 1980 Groundwater Management Act. The Study's overarching goal is to identify where physical water resources are needed to mitigate supply and demand imbalances due to climate change and other factors and to develop strategies to improve water reliability for municipalities, industry, agriculture and the environment.

The Study process involves assessing current and projected supply and demand imbalances under an array of future scenarios and evaluating the risks that these imbalances pose on water management, infrastructure and environmental systems. While the use of renewable Colorado River water supplies in the region has grown significantly over the past few decades, infrastructure constraints and limitations on recharge and recovery capacity have resulted in localized supply and demand imbalances. These imbalances have the potential to intensify in the future.

The Central Arizona Water Conservation District (CAWCD) operates the Central Arizona Project (CAP), a 336-mile canal system that conveys Colorado River water to Maricopa, Pinal and Pima counties. CAWCD is a non-federal cost-share partner of the Study and conducted the Supply and Demand Assessment in conjunction with Study participants. Six scenarios were developed as part of the Assessment, each representing a plausible future supply and demand condition for the region. These scenarios varied in their assumptions regarding climatic, socio-economic and behavioral factors. Using CAWCD's Central Arizona Project Service Area Model (CAP:SAM), a computer model designed to simulate the behavior of water users, projections of future supply and demand were developed for each scenario using a planning horizon of 2020 to 2060. The purpose of this report is to document the assumptions embedded in the model scenarios and to summarize the results of the Assessment.

Total demand for the study area is projected to increase across all scenarios with the exception of Scenario B, ranging from a 0.5% to a 37% increase compared to historic levels. The bulk of the increase is associated with the municipal sector and is influenced to a large degree by the projected magnitude and location of population growth. It is anticipated that CAP supply utilization will increase to meet these growing demands. For those providers that do not have access to renewable supplies, or whose demand exceeds the CAP supply available in a given year, groundwater pumping will increase to fill the

gap. While some volume of groundwater pumping is allowable under the Assured Water Supply Rules, anywhere from 8,800 to 38,100 AF may be subject to subsequent replenishment using renewable supplies.

At present, many Tucson area water providers store a portion of their CAP entitlements for the purpose of accruing long-term storage credits. In conjunction with increased CAP utilization to meet demand, the use of CAP supplies for long-term storage is projected to decline. This decline may be exacerbated by shortages to the CAP system. In particular, scenarios that contemplate deep and frequent reductions to the CAP supply under a hotter and drier future, result in severe reductions to the volume available for storage.

Effluent production is projected to grow in all model scenarios. This volume represents a supply that can be used to offset some of the stress placed on the aquifer due to reduced storage of CAP supplies and increased groundwater pumping. In addition, targeted recharge of CAP supplies that are available in a given year may also serve to alleviate the imbalances and help support sensitive environmental systems.

This Assessment serves as a basis for evaluating a range of future supply and demand conditions and the ways in which water users might respond under these conditions. The information presented in this report was compiled and restructured to develop input files for the groundwater modeling portion of this Study. Reclamation subsequently ran ADWR's TAMA Regional Groundwater Flow Model using the input files and evaluated the impact of these scenarios on the regional aquifer system.

1.0 Background and Scope

1.1 WaterSMART Program

Water resource managers in the Western U.S. face increasing uncertainty surrounding future water availability due to climate change, population growth, aging infrastructure and increasing environmental demands. In response to the 2009 SECURE Water Act, the Bureau of Reclamation (Reclamation) established the WaterSMART[1] (Sustain and Manage America's Resources for Tomorrow) program as a framework for wisely managing the nation's water supplies and evaluating future scarcity. The program provides an opportunity for state agencies, Tribes and local entities to work collaboratively with the federal government on long-range regional scale planning studies. The principal goal of these studies is to generate a range of projections of future water supply and demand and to identify where adaptation strategies may be needed to address potential imbalances.

1.2 Lower Santa Cruz River Basin Study

The grant application for the Lower Santa Cruz River Basin (LSCRB) Study was submitted in 2015 on behalf of the Southern Arizona Water Users Association (SAWUA), in conjunction with the Central Arizona Water Conservation District (CAWCD), the Arizona Department of Water Resources (ADWR), the Pima Association of Governments (PAG), the Cortaro-Marana Irrigation District and the University of Arizona. The proposal was for a $785,750 Study, with $392,750 provided by Reclamation and $393,000 in cost-share from the non-Federal partners. The Study proposal was awarded for the Federal Fiscal Year of 2016, and the Study officially began in February 2016 upon the signing of the Memorandum of Agreement by all parties. As the Study progressed and partners requested a more sophisticated climate analysis, two time extensions and a total budget increase of $640,000 were approved, with commensurate increases in the 50/50 cost-share commitment by the partners. The final budget of the Study is $2,065,750, and it is scheduled to conclude in September, 2021.

The extent of the Study area is the Tucson Active Management Area (TAMA), as defined by ADWR as part of the 1980 Groundwater Management Act. This allowed the Study to utilize information collected by ADWR, as well as ADWR's groundwater flow model. The terms "TAMA" and "LSCRB" are used interchangeably in this document.

[1] https://www.usbr.gov/watersmart/

The Basin is approximately 3,870 mi^2 in size and contributes flow to the Santa Cruz River, a tributary of the Gila River. It encompasses the Tucson metropolitan area and spans the counties of Pima, Pinal and Santa Cruz. The Basin is discretized hydrologically into two parallel groundwater sub-basins: Upper Santa Cruz and Avra Valley (Figure 1), with a general surface flow direction of southeast to northwest.

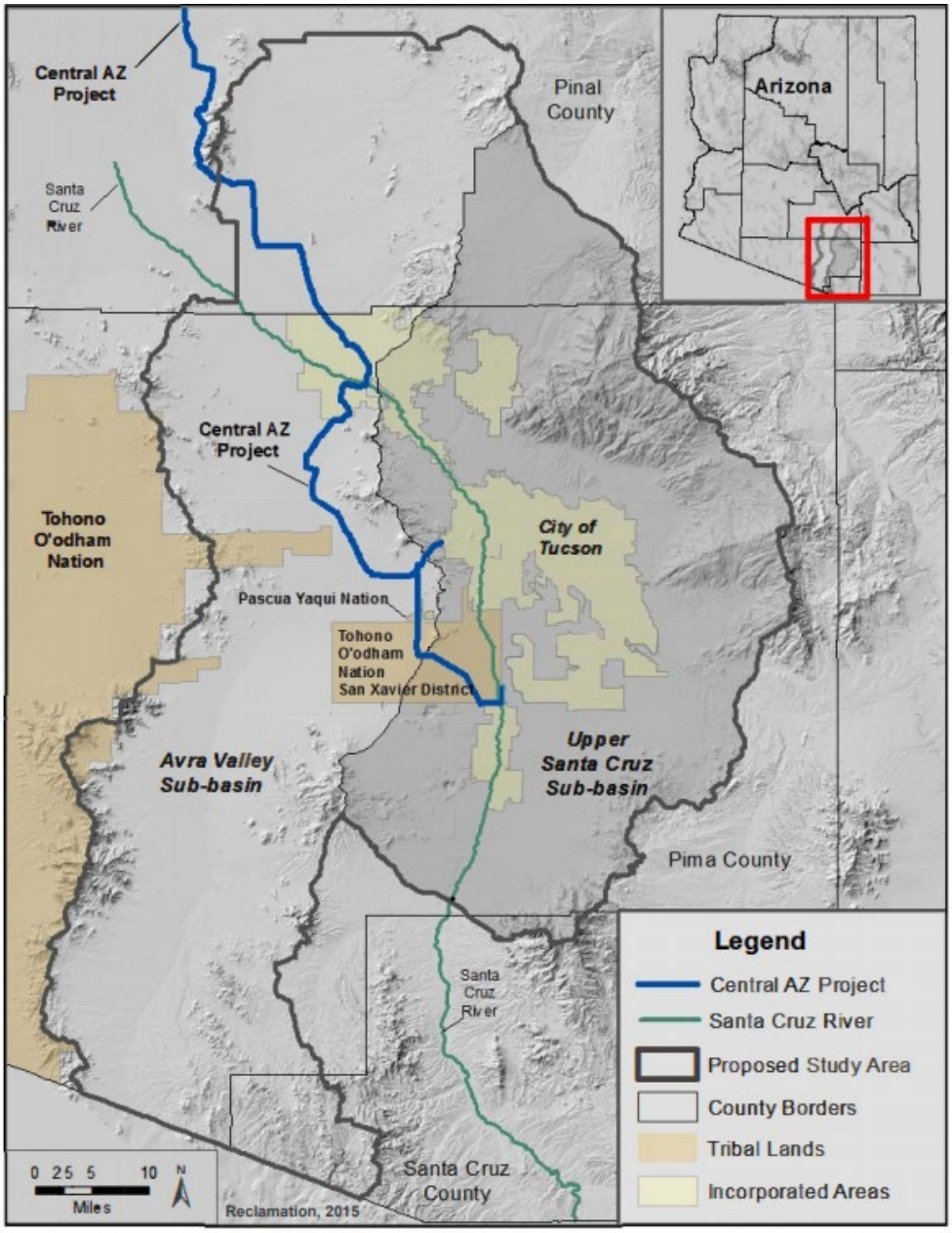


Figure 1 - Lower Santa Cruz River Basin Study Area

Historically, the LSCRB has relied heavily on groundwater pumping to meet demands. It is estimated that during the late 1980s and early 1990s as much as 97% of the total water demand was met by pumping groundwater. As it became clear that this approach was un-sustainable and fraught with negative consequences, water resource managers began to shift their focus to the use of renewable supplies. In 1993 the final phase of construction of the Central Arizona Project (CAP) was completed and for the first time, deliveries of Colorado River water to the region were possible. During this time, the Basin also saw an increase in the utilization of recycled water (i.e. treated effluent) to meet demands. Since that time, the use of these renewable supplies has substantially reduced the reliance on groundwater pumping (Figure 2), which today accounts for roughly 47% of the total Basin-wide demand.

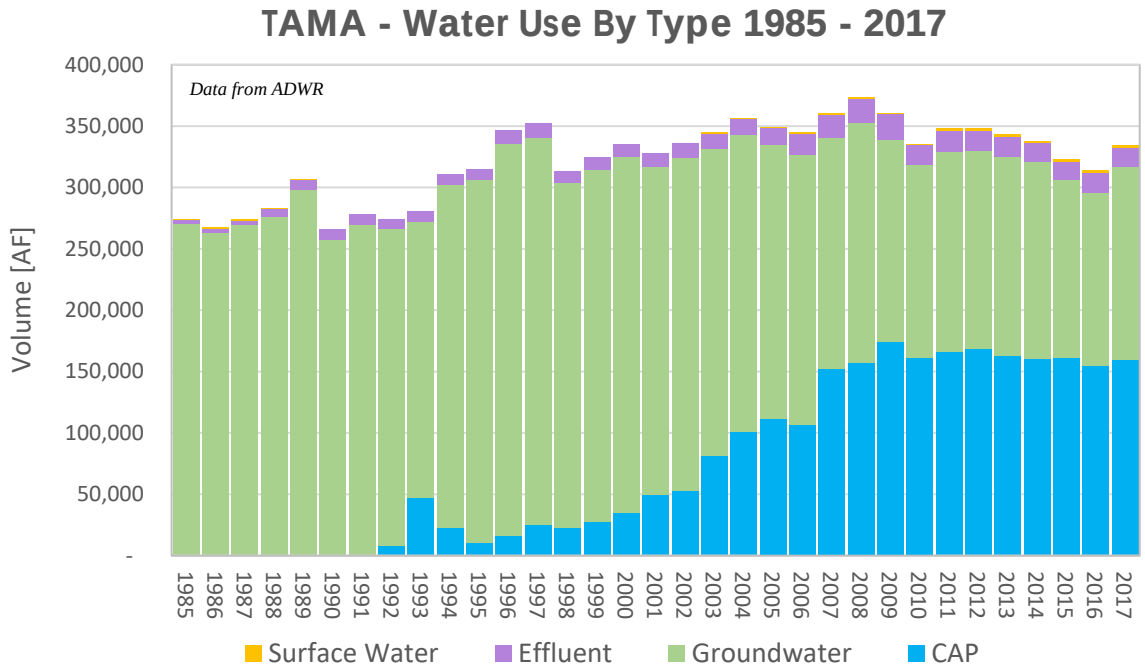


Figure 2 - Water use in the Tucson Active Management Area (TAMA) by type from 1985 – 2017

While the trend in supply utilization is viewed as a success story and has led to groundwater levels rebounding in many parts of the Basin, key regions within the Study area still exhibit supply and demand imbalances, as evidenced by declining groundwater levels. This poses a risk to local supply availability as well as the environment (e.g. land subsidence and loss of riparian vegetation). This situation is likely to worsen due to the impacts of climate change and population growth. This Study used the best available tools to identify the severity and locations of supply and demand imbalances under a range of future climate and growth conditions.

1.3 Basin Study Process

All Reclamation Basin Studies must include four elements: (1) projections of future water supply and demand, considering specific impacts resulting from climate change; (2) an analysis of how existing water and power infrastructure and operations will perform in the face of changing water realities; (3) development of appropriate adaptation strategies to meet current and future water demands and (4) a quantitative or qualitative trade-off analysis of the adaptation strategies identified. For the LSCRB Study this translated into seven key tasks (Figure 3).

Projecting water supply and demand imbalances required two separate analyses. One was to develop basin-scale climate change projections and investigate their impacts on the Basin's surface water hydrology. This Hydroclimate Analysis [2] was tailored to stakeholder needs for information regarding changes in seasonality and extremes. The results of the Hydroclimate Analysis were used to project changes in aquifer recharge from stream infiltration. The second analysis consisted of developing population and economic growth projections as drivers of future water demand, as well as estimating the location of these demands. Both analyses provided input to a groundwater flow model to estimate changes in groundwater levels.

As part of the second Basin Study element, the impacts of these projected imbalances on water supply infrastructure and environmental systems will be evaluated. In steps three and four, adaptation and mitigation strategies to address the imbalances are proposed and evaluated through a trade-off analysis.

For the LSCRB Study, sub-teams comprised of Study participants and subject matter experts were formed to address the tasks within each element and a Project Team was established to guide the overall efforts of the Study.

[2] https://www.usbr.gov/lc/phoenix/programs/lscrbasin/LSCRBS_Hydroclimate_2021.pdf

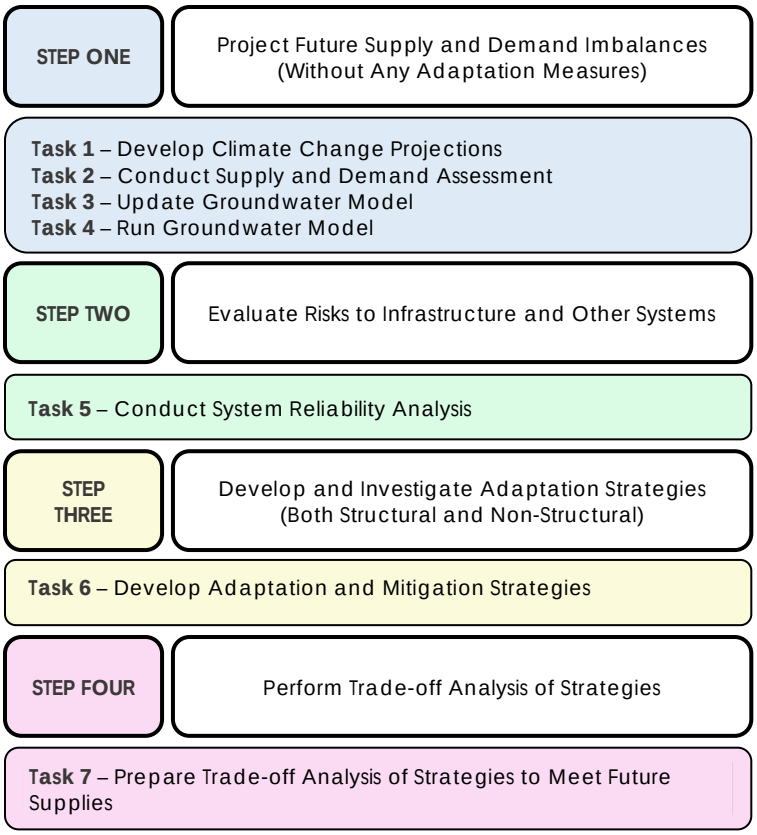


Figure 3 - General Framework for the Lower Santa Cruz River Basin Study

2.0 Supply and Demand Assessment

As outlined in Figure 3, one of the first tasks in any Reclamation Basin Study is to conduct an assessment of water resource supply and demand. This is a multi-part process that begins with evaluating current conditions, followed by the development of supply and demand projections. For this Study existing data from ADWR, as well as data provided by Study participants, were compiled to determine the availability of water supplies within the region. Demand for these supplies were subsequently quantified by sector (i.e. municipal, industrial, tribal, agricultural, etc.). This provided a snapshot of current conditions in the LSCRB and served as a starting point for generating the supply and demand projections.

Changes in supply and demand through time are influenced by a large number of climatic, socio-economic and behavioral factors. Often the magnitude and trend of these factors is either unknown or highly variable. To address this uncertainty, projections should evaluate a large range for each of these factors. A common best practice is to employ a scenario planning approach. Scenarios are comprised of assumptions about the factors that influence supply and

demand through time. Scenarios group together internally consistent combinations of factors that are associated with a plausible narrative for how the future may unfold. Utilizing a scenario planning process allows for the generation of a range of plausible future conditions that can then be evaluated.

In coordination with Study participants, projections of future water supply and demand for the LSCRB were developed by CAWCD, a non-federal cost-share partner of the Study. CAWCD operates and manages the CAP, a 336-mile long aqueduct system designed to supply approximately 1.5 million AF of Colorado River Water annually to central and southern Arizona. Nearly 70 miles of CAP canal, 9 pumping plants and 23 turnouts are located within the Study area (Figure 4). CAWCD has a broad range of roles and responsibilities within the region that include:

- Delivering over 230,000 AF of Colorado River water annually to municipal, industrial, tribal and agricultural customers
- Levying two ad valorem taxes for the purposes of repayment, operations and maintenance (O&M) and enhancing the reliability of Municipal and Industrial (M&I) supplies during shortage through firming performed by the Arizona Water Banking Authority (AWBA)
- Serving as the recovery agent of over 835,000 AF of water stored by the AWBA for the purposes of enhancing supply reliability
- Replenishing groundwater on behalf of members of the Central Arizona Groundwater Replenishment District (CAGRD). The CAGRD serves to provide a mechanism for landowners and water providers to demonstrate an assured water supply per the 1995 Assured Water Supply (AWS) Rules.

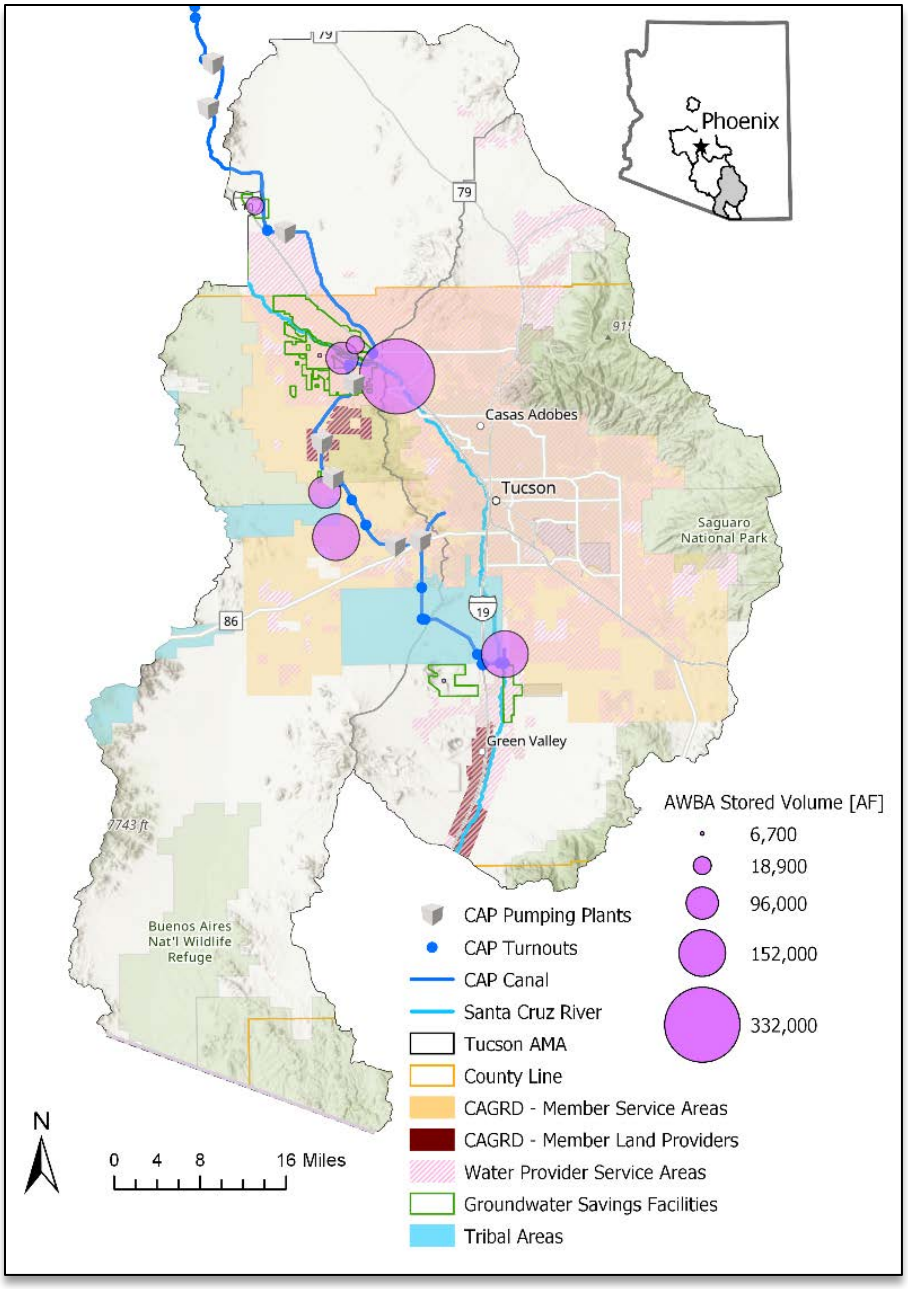


Figure 4 - CAP infrastructure, CAGRD membership and AWBA storage volumes in the Study area. Detailed maps of Underground Storage Facilities and Groundwater Savings Facilities in the TAMA can be found on ADWR's website[3]

CAWCD's Resource Planning and Analysis department has developed unique modeling and technical capabilities that are well suited to evaluate future supply and demand conditions for the region. In particular, CAWCD has

[3] https://new.azwater.gov/recharge/permitted-facilities

developed the CAP Service Area Model (CAP:SAM), a complex computer model built using GoldSim[4] software and designed to simulate over 135 water users (tribes, municipal providers, irrigation districts, institutional users) and 16 supply types within CAWCD's three-county service area (Maricopa, Pinal and Pima; Figure 5). CAP:SAM was specifically designed to generate "what-if" scenarios and includes the ability to evaluate a wide range of future conditions, including the rate and pattern of population growth, shortage impacts, effluent reuse, supply portfolio management decisions, trends in agricultural use, etc. CAP:SAM has significant capabilities to assist in planning and analysis for sub-regions like the LSCRB and has been used in the same capacity (i.e. to generate future supply and demand projections at the sub-basin scale) for two other Reclamation sponsored Basin Studies in the state of Arizona: the West Salt River Valley Basin Study[5] and the Eloy and Maricopa-Stanfield Basin Study[6].

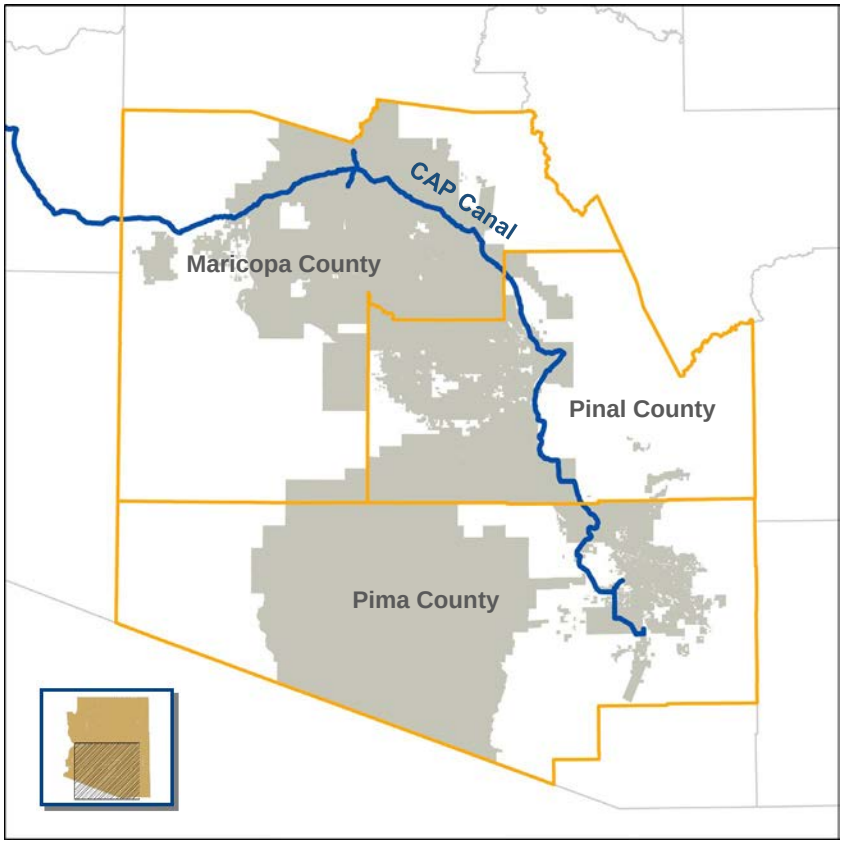


Figure 5 – CAWCD's three county service area. Shaded region represents Indian contracts, Municipal and Industrial subcontracts, Irrigation Districts and non-subcontractors with relationship to the CAGRD.

[4] https://www.goldsim.com/web/home/
[5] http://westcaps.org/basin-study/
[6] http://pinalpartnership.com/ems-basin-study/

For this Study, supply and demand projections were developed for CAWCD's entire three-county service area under six modeling scenarios, using a planning period of 2020 – 2060. While the model domain of CAP:SAM is greater than the Study area, there is regional interdependency of both supply and demand that has sub-regional effects. This report describes the development of these projections and the results of the Supply and Demand Assessment as they pertain to the LSCRB. Results from this effort were provided as inputs for the groundwater flow modeling (Figure 3; Tasks 3 and 4) conducted by Reclamation to evaluate the impacts to the aquifer system and groundwater levels.

3.0 Water Management Framework

Arizona's water management framework is an elaborate and substantial combination of laws, rules and authorities. While a full review of this framework is beyond the scope of this document, an understanding of some of the major components is necessary to effectively interpret model results and place this Assessment in the broader state-wide water management context. The following sections provide a brief summary of some of the key water management concepts and describes the different water use requirements by sector. Of particular importance for the municipal sector are the AWS rules and the role of the CAGRD in helping satisfy these rules. The modeling performed in this Study assumes that the existing legal and regulatory framework stays in place through 2060, the end of this Study's planning period.

3.1 Active Management Areas

In response to extensive groundwater depletion, Arizona's 1980 Groundwater Management Act (GMA) was passed and the principal components were codified into the Arizona Groundwater Code, Title 45, Chapter 2 of the Arizona Revised Statutes. In addition to creating the ADWR to administer the code's provisions, the GMA established Active Management Areas (AMAs), geographic regions containing the majority of the State's population, in which groundwater overdraft historically was most severe. As a result, groundwater withdrawal, use and transportation are intensively regulated within these areas.

The Act established management goals for each AMA related to the overall reduction in mined groundwater and mandated that all new development within an AMA secure access to a reliable, physically available water supply that is of sufficient quality for 100 years. The LSCRB Study area fully encompasses the Tucson AMA. This AMA has a management goal of safe-yield, or the long-term balance between groundwater that is withdrawn and water that is naturally and artificially recharged back into the aquifer on an annual basis.

3.2 Assured Water Supply and the CAGRD

In 1995 ADWR adopted AWS rules that limited the volume of mined groundwater that new subdivisions can use to be consistent with the management goal of the AMAs, which for the Tucson AMA is Safe Yield. Groundwater can still be used to satisfy the requirement for a 100-year physically available water supply, but groundwater withdrawals that are made in excess of the AWS limits must be offset through the recharge of an equal volume of renewable supplies within the same AMA.

A developer can demonstrate an AWS in two ways. First, a municipal water provider can obtain a Designation of Assured Water Supply (DAWS) for its entire service area. The development that occurs within the provider's service area is automatically deemed to have an AWS because the provider has been designated as having sufficient physical and legal supplies to serve current, committed and future demand. Second, a developer can apply for a Certificate of Assured Water Supply (CAWS) in order to prove an AWS for a single subdivision.

Voluntary membership in the CAGRD, either on an individual subdivision basis (Member Land; ML) or for an entire water provider (Member Service Area; MSA), is one of the primary ways in which an applicant can satisfy the renewable supply requirement of the AWS rules. Excess groundwater withdrawals made by a member are offset by recharge of renewable supplies performed by the CAGRD. This ensures that the proposed water use is consistent with the management goal of the AMA.

In CAP:SAM, each water provider is characterized as having one of the following options for their AWS status: (1) MSA, (2) ML, (3) DAWS on Own (i.e. not a member of the CAGRD), (4) Undesignated and (5) Other. The status of a provider can change through time. For example, an undesignated provider can become designated, or an undesignated provider can become a ML provider if it starts serving new subdivisions. The category of "Other" is applied to certain institutional providers (e.g., prisons, universities, etc.).

For the "without-adaptation" scenarios of this Study, CAP:SAM modeling assumed that the AWS Rules remain in place through the Study period, and that water providers maintain their current strategy for complying with the AWS rules. For water providers with a DAWS, which have both time and volume limits, this further assumes that those providers modify/renew their Designation as necessary throughout the study period. For those providers that satisfy the provisions of the AWS rules through membership in the CAGRD, they are similarly assumed to maintain that status through the end of the simulation.

All but one of the Study area's 26 water providers modeled in CAP:SAM are either CAGRD ML water providers or MSAs, though their reliance on CAGRD replenishment varies considerably. Many of the smaller water providers in the Study area have small portfolios of renewable supplies or in some cases no renewable supplies at all. Provided that groundwater for these areas is physically available and access is not financially restricted, future growth in these areas will rely heavily on the CAGRD to stay in compliance with the AWS rules. By extension, the CAGRD itself is presumed to continue to exist and stay in compliance with the applicable statutory requirements. This includes submission of successive 10-year Plans of Operation, approved by ADWR, which require demonstration of sufficient renewable supplies to support current and projected membership, and annual requirements to stay current with replenishment obligations.

Lastly, it is important to note the differences between the modeling performed for this Study and the modeling conducted by ADWR for AWS purposes, and by the CAGRD for its 2015 Plan of Operation. Though there are shared tools (the groundwater flow model and CAP:SAM respectively), the modeling assumptions made in these regulatory processes are unique and in some cases specific to certain legal requirements. These analyses serve critical roles, but their purposes are sufficiently different such that they cannot be used for direct comparison to this Study.

3.3 Agricultural Rights

Agricultural demand has historically accounted for approximately 30% of the total water demand in the Study area. Per the GMA, only land that has been issued a Certificate of Irrigation Grandfathered Right (IGFR) can legally be irrigated using groundwater within an AMA. Irrigation in this context is defined as the growing of crops for sale, human consumption or livestock/poultry feed on two or more acres[7]. These IGFRs were issued by ADWR based on crop type and acres that were irrigated entirely or partially with groundwater in any year from 1975 to 1980. The GMA further prohibits the issuance of new IGFRs, effectively capping the irrigated acres within the AMAs. IGFRs are subject to conservation goals as outlined in ADWR's AMA management plans[8].

Most irrigation districts that provide water supplies to IGFRs have also been permitted by ADWR as Groundwater Savings Facilities (GSFs). A GSF is an arrangement in which a partner, i.e. a tribe, water provider, institution, etc., provides a renewable water supply like CAP water to the district, reducing the amount of groundwater pumped by the district. The partner earns a long-term

[7] A.R.S. § 45-402.18
[8] https://new.azwater.gov/ama/management-plan/fourth-management-plan

storage credit (LTSC) that is equivalent to the volume that would have been pumped, less a 5% cut to the aquifer. This water supply used by the irrigation district is termed "in-lieu" groundwater due to the fact that the renewable supply is being used in-lieu of mined groundwater. CAP:SAM accounts for both parts of this transaction. ADWR typically issues the GSF permit volume based on the sum of the groundwater rights within an irrigation district, so as agricultural demand is adjusted in CAP:SAM due to efficiency changes, crop mix, or urbanization, the irrigation district's GSF capacity is adjusted accordingly.

4.0 Pre-Adaptation Scenario Development

After receiving consensus from Study participants that CAP:SAM was a suitable tool for evaluating supply and demand in the Study area, a series of plausible pre-adaptation (i.e. without measures to reduce imbalances) modeling scenarios were developed. This was an iterative and collaborative process between CAWCD and study participants that began in the spring of 2017 with a Project Team meeting.

Early on in the scenario development process, Study participants expressed an interest in characterizing scenarios based on "risk" to water supply reliability and the environment. The relative risk associated with each scenario was ranked based on two key drivers: 1) population growth, which consists of both the rate and spatial pattern of growth and 2) climate change severity. For example, a scenario with rapid population growth in suburban and ex-urban areas under an increasingly warmer and drier climate, would pose a large risk to water resources in the Study area.

Conversely, a scenario with slow population growth concentrated in existing urban areas and a climate warming that is less severe, would pose a comparatively smaller risk to water reliability and the environment. Scenarios were developed by combining different levels of population growth, growth pattern and severity of climate change. While there are many additional factors that are used to characterize a model scenario, these three factors are by far the most influential.

4.1 Growth

Growth Rate

The Arizona Office of Economic Opportunity (AOEO) is the agency tasked with producing official county and statewide population projections. Much like the decennial census, these projections are developed using the cohort-component method, in which future population estimates are modeled based on demographic changes (i.e. births, deaths, migration, etc.). The AOEO

projections consist of three series: low, medium and high (Figure 6) and are typically updated every three years.

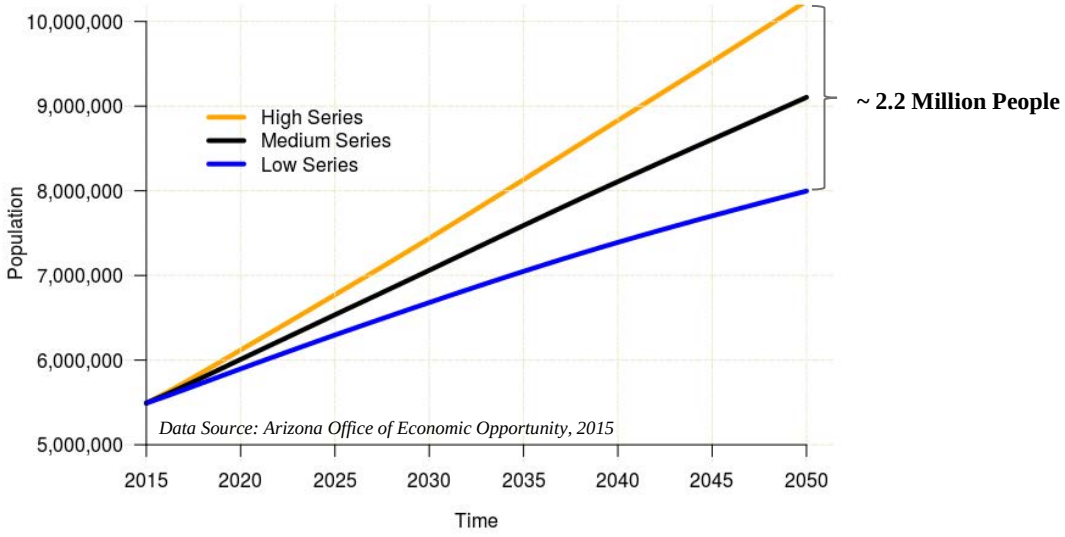


Figure 6 - Arizona Office of Economic Opportunity's low, medium and high series population projections for the three-county CAP service area (Maricopa, Pinal and Pima counties)

In CAP:SAM the fundamental unit for modeling population growth, and consequently growth in municipal demand, is the housing unit. Annual projections of new housing units are generated using a growth curve. To account for the lingering effects of the Great Recession (e.g. faster than normal housing growth rate post-crash) as well as to test a wide range of potential growth scenarios, CAP:SAM allows the user to define a number of parameters related to this curve:

- The initial rate of housing units
- The duration of the housing recovery (if applicable)
- The shape of the recovery curve
- The post-recovery "ordinary" rate of housing units (if applicable)
- The percentage growth rate following the housing recovery
- The percentage growth rate at the end of 50 years

A graphical example of how these parameters define the shape of this growth curve is shown below (Figure 7).

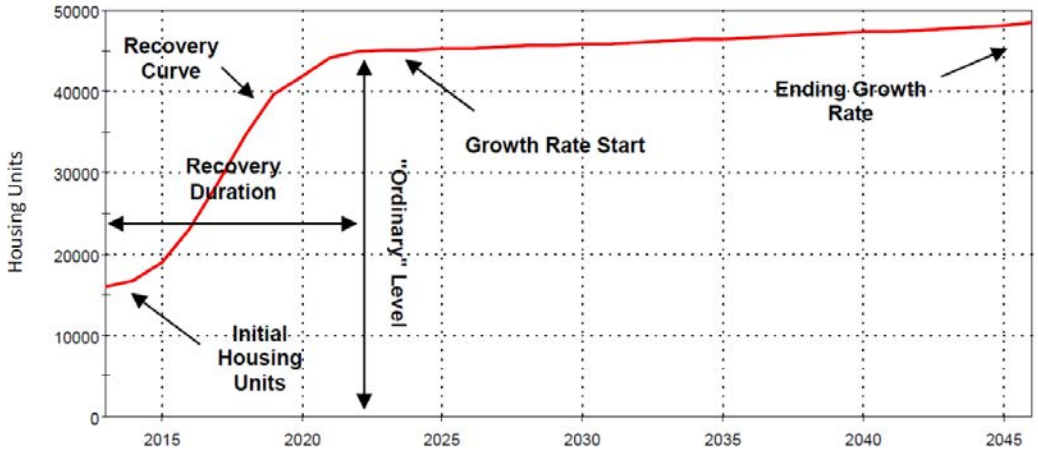


Figure 7 – Parameters of CAP:SAM's annual housing unit growth curve

For this Study, rate of population growth was divided into three categories: slow, medium and rapid, which correspond to AOEO's low, medium and high population series, respectively. In each case a unique housing unit growth curve was developed by optimizing the aforementioned parameters to match AOEO's control totals. In general, housing unit growth rate in CAP's service area has largely rebounded from the effects of the Great Recession (Figure 8). Therefore, each growth curve assumes a relatively short recovery duration prior to reaching post-recovery "ordinary" growth levels.

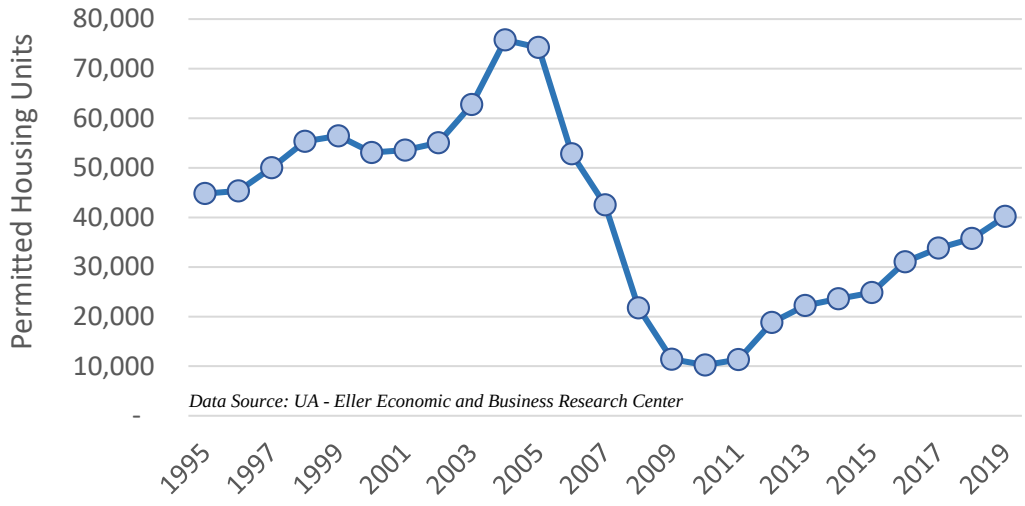


Figure 8 – Annual housing permits in CAP's three-county service area

Spatial Pattern

Once the magnitude of housing unit growth is determined, CAP:SAM distributes this growth based on geographic reference projections of housing units by water provider through time. CAP:SAM is capable of utilizing any reference projection, including the official forecasts developed by the Maricopa, Pima and Central Arizona Associations of Governments (MAG, PAG and CAG). The official forecast estimates housing unit counts at the decadal time-step for Traffic Analysis Zones (TAZ; Figure 9). These projections are based on growth modeling that incorporates a large number of factors, including demographic data, construction data, planned developments, land uses, employment patterns and transportation infrastructure. Additional work using a Geographic Information System (GIS) was performed by CAWCD to characterize the projections by current and anticipated water provider service area.

To accommodate a variety of growth rates while maintaining the integrity of the spatial growth pattern, CAP:SAM matches the total projected housing units generated in the model with the corresponding point in the reference projection at each time-step. For example, a particular model run might project 2.8 million housing units for the three-county area in 2030, but the reference projection might have projected 2.9 million for 2030. CAP:SAM accounts for this by estimating the point within the reference projection at which 2.8 million units were distributed, and then applies that estimate to each water provider.

In addition to dynamically adjusting the rate at which growth occurs, CAP:SAM can incorporate alternative growth patterns. To implement this capability, CAP contracted with a consulting firm—Applied Economics—that had developed a socioeconomic model for Maricopa, Pinal and Pima counties. As part of the contract work, Applied Economics developed eight different growth scenarios by varying key assumptions that affect the relative distribution of housing units. Some of the key factors included relative proximity to transportation infrastructure and existing development, how quickly planned but unbuilt development takes place, relative willingness to commute to employment centers, and land use capacity factors.

Three of the alternate growth patterns developed by Applied Economics were used in this Study: “Official”, “Outward Growth” and “Compact” (Figure 9). The Official projection mirrors the officially adopted growth pattern generated by the Associations of Governments. The Outward Growth places a greater portion of the housing units in the suburban and exurban areas. For the Study area, this translates to fewer housing units projected in the centrally located Tucson Water service area and more housing units projected for water providers that serve the periphery of the TAMA. The Compact projection places more housing units in the existing urban areas, focusing growth in Tucson Water’s service area.

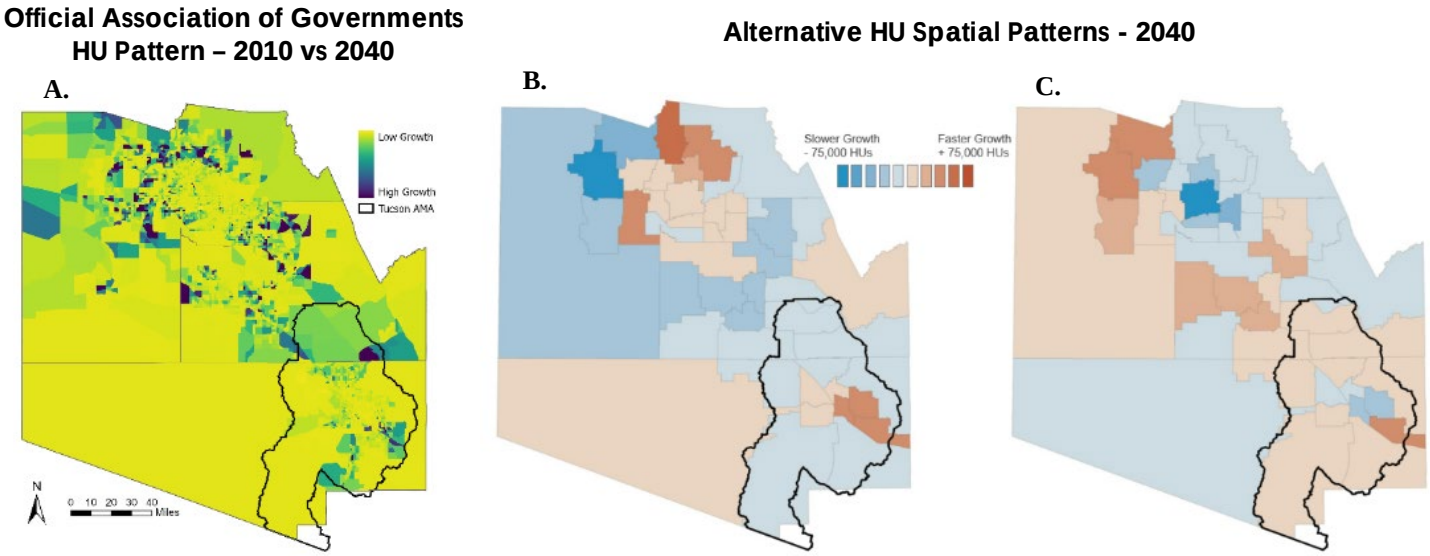


Figure 9 - (A) Official HU spatial pattern developed by the Associations of Governments. (B) Compact and (C) Outward Growth alternative spatial patterns developed by Applied Economics. Study area is outlined in black. Patterns are shown for an example year (2040).

4.2 Climate

Climate scenarios are assumptions about how the key drivers that impact the Earth's climate will vary in the future. The Intergovernmental Panel on Climate Change's Fifth Assessment Report developed standardized scenarios known as Representative Concentration Pathways (RCPs)[9]. Each RCP represents a set of greenhouse gas concentration projections through the year 2100. RCPs vary in the degree of radiative forcing they project, based on a number of climate change factors. These scenarios are widely used by the scientific community to characterize potential future climate conditions.

The Study uses the terms "best-case" and "worse-case" to indicate climate projections corresponding to RCP 4.5 and 8.5, respectively (Figure 10). The use of the phrase, "worst case" is avoided because it is possible that greenhouse gas emissions may exceed the levels projected in RCP 8.5. It is important to note that although it is referred to as "best" case in this Study, RCP 4.5 projects a future climate that is still warmer than current conditions. The "worse-case" climate is characteristic of a very hot, very dry future condition.

[9] https://www.ipcc.ch/report/ar5/syr/

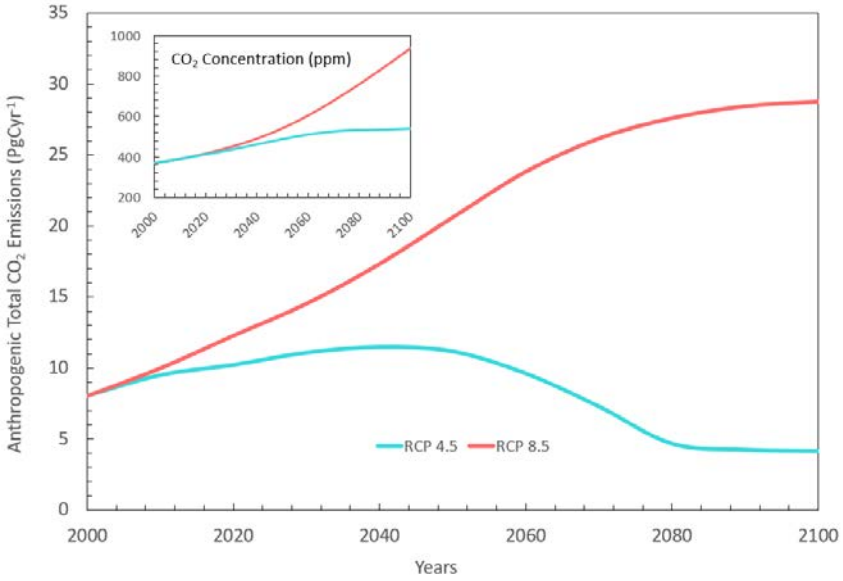


Figure 10 - CO2 emissions and concentration projections through 2100 for RCP 4.5 and 8.5, as provided in the Intergovernmental Panel on Climate Change's Fifth Assessment Report

An additional climate category was included to represent current climate conditions (i.e. no climate change). This category does not represent a plausible future condition but was evaluated to maintain consistency with projections developed by ADWR, which does not account for the effects of climate change.

A warming climate in CAP:SAM is broadly modeled as having the following impact:

- A slower rate of decline in per capita water use, i.e. under hotter climates, external water use increases and slows the historically observed decrease in per capita use
- A gradual increase in crop consumptive use
- More frequent, severe and long-lasting reductions to the CAP supply and other surface water supplies

Of the above modeled impacts, the one that most significant influences the CAP:SAM projections is the reduced availability of Colorado River water conveyed via the CAP and other renewable supplies. In CAP:SAM these reductions are modeled using representative traces that describe the magnitude, duration and frequency of shortages throughout the simulation

period. Three shortage traces were developed[10] and evaluated as part of this Study (Figure 11). The magnitude of the reductions defined by the traces are analogous to the shortage tiers outlined in the 2019 Lower Basin Drought Contingency Plan[11] (LBDCP; Figure 12).

CAP:SAM ultimately has the ability to evaluate a suite of hydrological inputs, including those from the Colorado River Simulation System (CRSS)[12], to develop hundreds of realizations for a given model scenario. For this Study however, single shortage traces were chosen due to the cost of running projections through the groundwater flow model. Moreover, using individual shortage traces retains supply variability information, which allows for a more direct comparison across the different "what-if" scenarios.

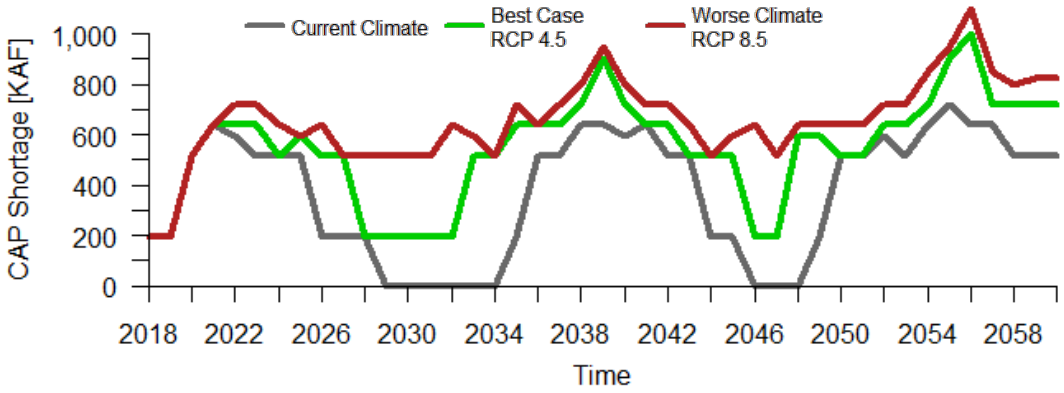


Figure 11 - CAP shortage sequences for the three climate categories

[10] These traces represent speculative stress to the CAP system. They should not be used to infer future reservoir operations, or construed as any indication of the magnitude and timing of supply reductions attributable to Arizona or the Central Arizona Project.
[11] The Lower Basin Drought Contingency Plan, signed on January 31, 2019 by Governor Ducey, established earlier and deeper reductions to Arizona's CAP supplies. These contributions to Lake Mead are in addition to the shortage reductions set forth by the 2007 Interim Guidelines.
[12] https://www.usbr.gov/lc/region/g4000/riverops/model-info-APR2018.html

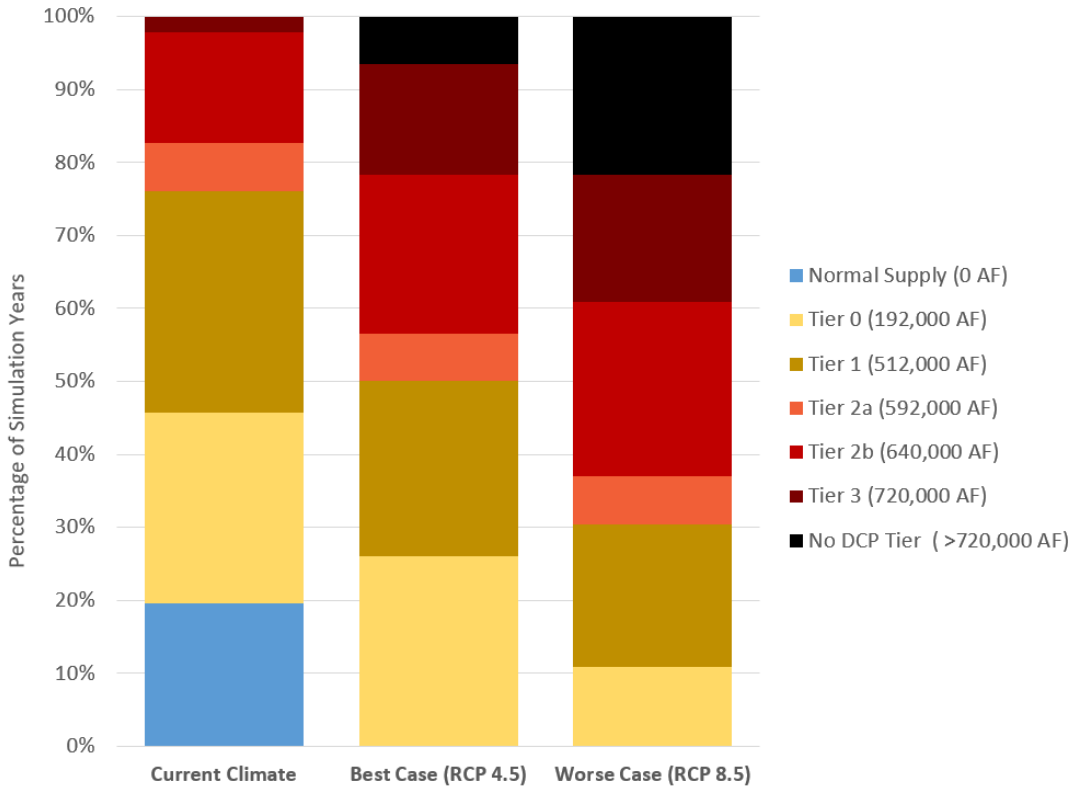


Figure 12 - Frequency and magnitude of reductions to the CAP supply aggregated by climate scenario. Reductions ≤ 720,000 AF are associated with Lower Basin Drought Contingency Plan tiers

Current Climate

The current climate trace depicts a pattern of CAP shortage volumes that are similar to the supply traces from the CRSS model, in which observed hydrology is used. A handful of normal supply years (i.e. no CAP shortage) are intermixed between decadal long periods of shortages that increase in duration and severity as projected uses in the Colorado River Basin increase. The maximum shortage projected in this trace is 720,000 AF, a Tier 3 LBDCP reduction.

Best-Case Climate

As previously mentioned, the best-case climate scenario refers to a future climate condition that is warmer than the current climate scenario. As such, this trace projects overall more reductions to the CAP supply with a clear trend towards deeper, longer and more frequent shortages. Under this shortage trace, there are no normal supply years projected. This trace was created to test reductions to the CAP supply that were severe enough to affect some of the highest priority water users, and includes a reduction as large as 1,000,000 AF or approximately two-thirds of the normal CAP supply. This magnitude of shortage

is greater than any reduction agreed to by CAWCD, but is consistent with results from regionally downscaled global circulation models.

Worse-Case Climate

The worse-case climate trace follows the same general pattern as the best-case climate but is overall more severe. Shortages to the CAP supply never drop below 512,000 AF, a Tier 1 reduction under the LBDCP. The maximum reduction projected in this trace is 1,100,000 AF.

4.3 Modeling Scenarios

Six "without-adaptation" supply and demand scenarios were developed by choosing unique combinations of the growth rate, growth pattern and future climate (Table 1). These scenarios were selected to capture, to the greatest extent possible, the range of potential supply and demand futures in the LSCRB.

Table 1 - Pre-adaptation LSCRBS Modeling Scenarios
(*This table is a modified version of the LSCRB Study supply and demand matrix*)

Scenario ID	Climate Emissions	Growth		Relative Risk
		Rate	Spatial Pattern	
A	Current	Medium	Official	Base
B	Best-Case	Slow	Compact	Low
C	Best-Case	Rapid	Outward	High
D	Worse-Case	Slow	Compact	Low
E	Worse-Case	Medium	Official	Moderate
F	Worse-Case	Rapid	Outward	High

A number of subsequent Project Team meetings were used to flesh out the details of these scenarios and achieve group consensus. A larger Stakeholder Advisory meeting and a public meeting were convened on February 26, 2018 and March 12, 2018 respectively, to solicit additional input on the proposed scenarios. After incorporating the feedback that was received, approval of the scenarios was made on May 8, 2018 by the Project Team.

While climate and growth are the principal drivers of supply and demand, embedded in each of these scenarios are over 25 different parameter settings that affect factors like the relative rate of municipal conservation, agricultural irrigation efficiency, development of agricultural land, etc. For a full list of the modeling assumptions see Appendix B.

5.0 CAP Service Area Model (CAP:SAM)

5.1 Overview

CAP:SAM is best thought of as a systems model and while it uses hydrological data as an input to determine supply availability, it does not explicitly model physical hydrological processes (e.g. precipitation, runoff, etc). The principal utility of CAP:SAM rests in its ability to generate a large array of future supply and demand conditions by manually or probabilistically varying key model parameters that characterize the response of water users to different situations. The response of water users is also highly influenced by sets of laws, rules, rights and practices that define the water management framework applicable to CAWCD's service area. Substantial effort has gone into representing this framework within the model.

5.2 Model Steps

CAP:SAM performs hundreds of complex, interrelated calculations at each model time step. However, the overall structure can be simplified into four basic steps: 1) project demands, 2) determine supplies, 3) request supplies and 4) fulfill demands (Figure 13).

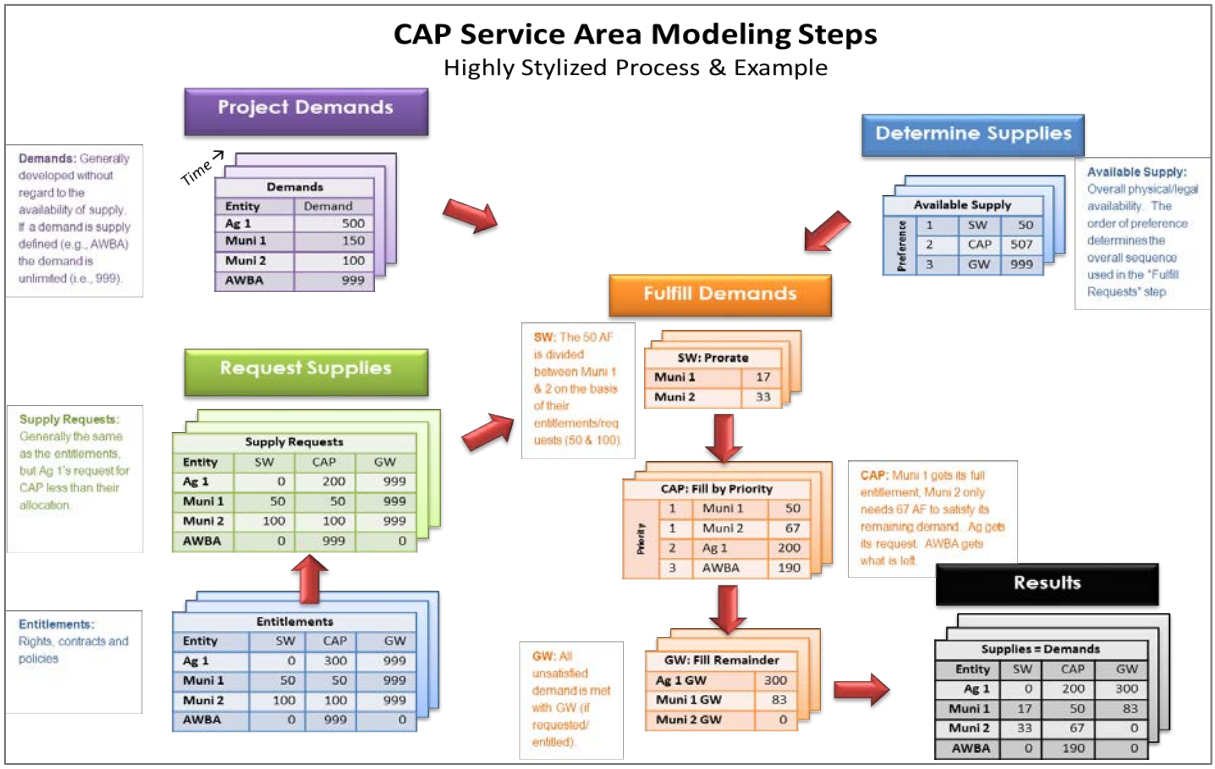


Figure 13 - Simplified version of CAP:SAM's modeling steps

Project Demands

Projecting demand is the first major calculation performed in the model. CAP:SAM generates projections of demand for over 80 public and private water utilities, 23 Agricultural Irrigation Districts and Grandfathered Irrigation Rights, 12 Tribes and Tribal Districts and over 20 other user categories, including the CAGRD, AWBA and industrial users such as mines and power plants. Together, these users account for the majority of the water demand within the three-county model domain. Projections of demand are generally developed without consideration of the available supply. The basis of these projections is discussed further in section 4.2.

Determine Supplies

The second step performed in the model is to determine the supplies available to a specific user. CAP:SAM tracks the total legal and physical supply availability for 16 supply types in each projection year. Supply categories include Effluent, Surface Water, including the Salt River Project, and CAP water. Long-term storage accounts (LTSAs) and Groundwater Allowances (i.e. volume of allowable groundwater pumping not subject to replenishment granted upon issuance of a CAWS or DAWS) are tracked and debits and credits to these accounts occur through time. To model the CAP supply from the Colorado River, CAP:SAM allows the user to input an annual diversion supply for Arizona, demands from on-River users, total system losses, and the net storage to CAP's storage reservoir, Lake Pleasant. CAP:SAM can also utilize externally generated Colorado River supply scenarios from CRSS. For supplies that have multiple users, like CAP water, this model step calculates the aggregate supply available, prior to allocation by priority and individual user.

Request Supplies

CAP:SAM contains extensive water supply data for each of the water-using entities that are simulated by the model. For municipal water providers, this includes legal entitlements to surface water and CAP water, initial balances of both LTSCs and groundwater allowances, remediated groundwater volumes, and for providers that do not have a DAWS, attributes related to any subdivisions that are currently enrolled as MLs of the CAGRD. Similarly, CAP:SAM contains supply portfolios for irrigation districts, Tribes, and others. Most of the supply data for the Study originated from publicly available sources, but Study participants also reviewed and provided revisions to the data.

The "request" step of the model determines how much of each supply in an entity's portfolio will be available to satisfy demand, if necessary. In many cases, the "request" is set at the full volume of the supply that is legally available to

that entity, but there are individual circumstances in which entitlement volumes are individually adjusted either by percentage, or by setting a limit to represent specific preferences or operational limitations. For instance, there are a few water providers that have entitlements to CAP water that they are not putting it to use for legal or operational reasons. In those specific cases, the "request" for that supply is reduced.

For CAP supplies, requests are further differentiated between water destined for a water treatment plant versus annual storage and recovery (ASR). ASR involves storing water underground and subsequently pumping it out for delivery in the same year. CAP:SAM also contains individualized preferences for earning underground LTSCs with any CAP entitlement that is available to a provider after their annual demand has been satisfied. The request portion of the model also includes distribution to CAP water storage facilities, including deliveries to irrigation districts as in-lieu GSFs, or to direct recharge projects (Underground Storage Facilities; USFs). Finally, the request step simulates transfers, leases, exchanges, reallocations, and priority conversions. For this Study, only existing or currently proposed transactions were included.

Fulfill Demands

In the final and most computationally complex model step, information from each of the other three steps (project demand, determine supplies and request supplies) is brought together and reconciled. For each projection year, CAP:SAM takes the demands for each entity and steps through each supply type in a defined sequence, incrementally satisfying the demand of each entity based on their request and their volume of unsatisfied demand. That sequence is a reflection of observed historic behavior, which is largely based on utilizing lower cost supplies first. The allocation method varies among the supplies (see Section 7 below), but the primary sequence for fulfilling demand is as follows:[13]

1. Effluent
2. Exempt groundwater (DAWS)
3. Surface water
4. CAP water (by internal priority system)
5. Recovered CAP long-term storage credits
6. Groundwater allowance
7. Replenished groundwater
8. Exempt groundwater (CAWS)
9. Unknown

[13] Note that in order to account for GSF arrangements, there is some iterative looping within CAP:SAM, so the fulfillment sequence is not as linear as described here.

As the model cycles through each of those supplies, credits and debits to CAP LTSAs and groundwater allowances are calculated. Accruals to LTSAs are based on the storage preference parameters set in the "request" step, and accruals to the groundwater allowance are based on the incidental recharge factor specified in the Designation of Assured Water Supply for each water provider with a DAWS. The incidental recharge factor is calculated by ADWR and represents the ratio of water that recharges the aquifer after delivery and use.

5.3 Demand

Municipal Demand

Water providers modeled in CAP:SAM are determined based on size and relationship to the CAGRD. For this Assessment, 26 water providers in the TAMA were modeled (Appendix A). These providers vary considerably in population served and availability of renewable supplies. The majority of these providers (17 of 26) serve a population less than 16,000 and do not have entitlements to CAP supplies. These smaller providers therefore rely on groundwater pumping to meet current and projected demands. Three providers in the Study are serve populations greater than 40,000, with Tucson Water serving the largest population of approximately 735,000. These larger providers, along with a number of other mid-sized providers, have CAP entitlements that range from a few thousand AF to over 144,000 AF (in the case of Tucson Water), and total approximately 183,000 AF for the AMA.

Municipal water demand is a complex, multifactor phenomenon that is the result of literally millions of individual daily decisions. While this is a topic of extensive research, CAP:SAM takes a fairly simplistic yet effective aggregate approach to projecting this demand. The approach involves multiplying annual projected housing units for each water provider by the bulk water use rate for that provider. In CAP:SAM the bulk water use rate is expressed as gallons per housing unit per day (GPHUD) and is initially determined using the existing demand volume for the most recent year reported to ADWR by each provider. Historically, municipal water demand has declined steadily in the CAP service area since the mid 1980's (Figure 14). This trend in water use is modeled through a series of user defined parameters. To differentiate between the effects of observed long-term declines in water use and future growth related trends, the model separately considers new and existing municipal demand.

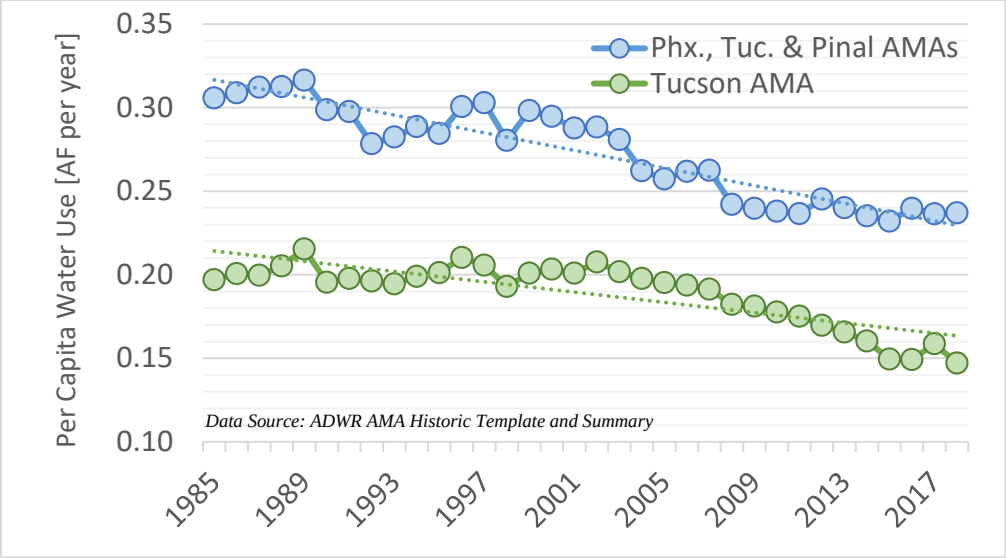


Figure 14 – Total per capita water use across the Phoenix, Tucson and Pinal AMAs from 1985 – 2018 with linear trend line (dotted line). The Study area (Tucson AMA) is isolated for comparison.

Existing Demand

Existing demand represents baseline water use, as reported to ADWR in the most recent annual report, prior to the consideration of future growth. The demand and the count of housing units for that year are used to generate the initial GPHUD value. It is important to note that while the majority of a water provider's demand is associated with residential deliveries, the total demand used to compute the initial GPHUD includes non-residential deliveries (i.e. Industrial, Commercial, Turf, Government and Construction as characterized by ADWR).

The model allows a water provider's GPHUD to vary based on a set of parameters. These parameters include an annual rate of change (+ or -, in %), along with both a cumulative maximum change (in %), and a minimum "floor" (in GPHUD). The floor prevents the modified GPHUD value from dropping to unrealistically low values (if for example a negative rate of change has been specified). If an initial GPHUD is below the floor, its value is held constant at the initial value. CAP:SAM then generates a projection of existing demand by multiplying the modified GPHUD values, which vary through time, by the number of existing housing units at the start of the simulation period, which remains fixed.

New Demand

New demand is simulated in CAP:SAM on the basis of housing units that are projected to be built in each water provider's planned service area. The projected housing units for each provider is determined largely on the basis of

the rate and spatial pattern of growth as discussed in Section 4.1. Similarly to existing demand, CAP:SAM multiplies the projected housing units by a provider specific GPHUD. The GPHUD value used to compute new demand is different than that used to calculate existing demand. CAP:SAM uses as a default a new GPHUD that is 80% of the provider's existing GPHUD, although this can be modified based on preferences. Embedded in this assumption is that newly built housing units will be more water efficient than older, existing units. The same parameters that can be adjusted for existing GPHUD can also be modified for new GPHUD (i.e. annual rate of change, maximum change and minimum floor).

Agricultural Demand

The general CAP:SAM formula for calculating annual demand for an IGFR is as follows:

$$Irrigation\ Demand = \frac{(Total\ Acres\ Irrigated)\ x\ (Crop\ Mix)\ x\ (Consumptive\ Use)}{Irrigation\ Efficiency}$$

Each of the factors listed in the above equation are allowed to vary throughout the simulation.

The footprint of irrigated agriculture cannot expand (other than on tribal lands) but urbanization due to population growth can reduce total agricultural acres and result in a commensurate reduction in irrigation demand. To model this effect, a GIS analysis was performed using ADWR's GIS layer for irrigation districts and individual rights, crop type imagery from the National Agricultural Statistics Service (NASS)[14] and TAZs from the county Association of Governments. The analysis identified and quantified the acreage for each TAZ that wholly or partially intersected active agricultural land. As new housing units are projected for one of these TAZs, reduction in agriculture acreage is calculated based on the average density of surrounding urban uses. For TAZs that straddle active agricultural land and undeveloped desert land, CAP:SAM allows the user to set a preference so that more or less of the agricultural land is developed. The default is that the housing units are split proportionally.

Initial crop mix for a district or right is determined by the NASS crop type imagery. CAP:SAM has the functionality to modify the composition of this crop mix through time to simulate a switch from higher water use crops (e.g. alfalfa and cotton) to lower water use ones. This functionality has not yet been utilized in this study.

[14] https://nassgeodata.gmu.edu/CropScape/

Crop consumptive use and irrigation efficiency are key factors that affect total irrigation demand. Initial crop consumptive use is based on published crop specific values provided in ADWR's Third Management Plans[15]. The initial Irrigation efficiency for each IGFR is computed as the ratio of the total water required to irrigate existing crops and the total agricultural demand reported by ADWR. Each of these parameters can vary through time based on user defined annual percentage rates. The annual rate of change for both parameters is typically set to non-zero, positive values to represent an increase in crop consumptive use due to climate change and an increase in the efficiency of irrigation through time. For this study irrigation efficiency was set to a constant 85% across the simulations.

Tribal Demand

CAP:SAM runs include projections of tribal water use. The majority of tribal water use is modeled as irrigation demand using the same methodology outlined above. CAP:SAM also makes assumptions regarding off-reservation storage at USFs and GSFs, as well as off-reservation leasing. Tribal supplies that are leased to other water providers are included in the individual water provider portfolios. There are three tribal reservations within the Study area (Figure 4) for which individual projections are generated.

5.4 Supplies

Effluent

In the process of fulfilling annual demands, CAP:SAM makes projections of effluent use. This effluent use includes non-potable reclaimed water distribution (i.e., "purple pipe") and any recovered effluent that is indirectly satisfying potable demand (i.e., water that has been stored and is physically groundwater, but is legally accounted for as effluent). CAP:SAM relies on ADWR reported data for a base year, and then allows the use of the effluent supply to increase in proportion to the overall demand.

Importantly, CAP:SAM's effluent accounting does not reflect the total volume of effluent produced or potentially available to a water provider. This capability is currently under development, but for this Study, separate calculations of effluent production were made. In some cases, those calculations resulted in effluent volumes that were greater than what providers have identified plans for putting to use, and were thus characterized as "unused." That term simply denotes that based on current utilization rates and plans, there is likely a volume of effluent that is available for new uses. Appropriately, effluent factors significantly in this

[15] https://new.azwater.gov/ama/management-plan/3

Study as a resource that can be more fully utilized to address groundwater level declines, and could have a large role in reducing reliance on CAGRD replenishment.

Exempt Groundwater (Designated Providers)

For a water provider with a DAWS, certain types and volumes of groundwater are exempt from the requirement for offsetting pumping with recharge of a renewable supply (i.e. satisfying the AWS rules). The most notable is pumping that is required as part of a remediation project for contaminated groundwater. CAP:SAM allows these volumes to be specified and used to satisfy annual demand early in the sequence of supply utilization, even if the provider has renewable supplies that exceed annual demand.

Surface Water

Direct use of surface water supplies other than CAP is limited in the Study area. Most streams are ephemeral or intermittent, flowing only in response to high intensity, short duration precipitation events. While surface water resources are not a significant component of the supplies used in the TAMA, CAP:SAM does consider surface water for other entities in CAP's three-county service area. For example, a primary source of surface water within CAP:SAM's modeling domain is the Salt River Project (SRP). It is important to note that CAP:SAM does not attempt to fully simulate the SRP system. Notably, the SRP supply available to cities is not differentiated between water originating from reservoirs, versus water pumped from wells that is legally accounted for as surface water for AWS purposes. As an approximation of the volumes of SRP water available to each water provider in the "request" step of CAP:SAM, values from SRP's 2008 AWS study were used. Data from each water provider's ADWR Annual Report is then used as the base year for the CAP:SAM projection. That usage rate then varies based on the on-Project demand for the SRP system. To the extent that that demand is increasing, it can grow until it reaches the "request" volume.

CAP:SAM accounts for other surface water in a manner similar to SRP supplies, using ADWR annual reporting data, along with specific data provided by individual users.

CAP Water

CAP supplies are classified into six categories: Third Priority (P3), Indian, M&I, Non-Indian Agriculture (NIA), the Agricultural Pool and Other Excess[16]. These supplies are allocated among tribal entities, municipal and industrial users, as well as

[16] https://knowyourwaternews.com/a-matter-of-priorities/

institutions like the CAGRD and AWBA. Entitlements are based on contract volumes and all existing and pending leases and exchanges are modeled in CAP:SAM. The volumes of NIA-priority supply that have been recommended for reallocation by the Director of ADWR have also been included. In years when Other Excess supplies are available, they are utilized for banking and replenishment by the AWBA and CAGRD, respectively.

Long-Term Storage Credits

CAP:SAM contains the initial balance of LTSCs for each water provider, as tracked by ADWR. The storage preference settings (referenced in section 5.2) allow the supply of CAP LTSCs to increase, and the model makes a cut-to-the-aquifer calculation. Credits can also be recovered (pumped) and used to meet annual demands. For AWS purposes, that recovered water is legally identical to the supply used to create the credit (e.g., CAP water). The use of CAP LTSCs as a supply in CAP:SAM is affected by two primary factors: a preference factor set for each water provider during normal water supply conditions, and a calculation of reduction to a provider's supply based on shortage conditions. The preference factor for most water providers is 1% (i.e., treating the LTSC balance like a 100-year supply), though in cases where providers have indicated a specific management strategy for their credits, the factor has been adjusted. The shortage provisions are tied to reductions to a providers' CAP water supply that are not otherwise firmed by the AWBA (e.g., NIA-priority supplies). When their CAP supplies are reduced, the reduction is made up with recovery of the providers' credits, if available.

Groundwater Allowance (Designated Providers)

Water providers that have a DAWS have a groundwater allowance which represents a volume of groundwater that is permitted to be withdrawn without an obligation to replenish under the AWS rules. This allowance was initially established to help municipal providers transition from groundwater resources to renewable supplies. The manner in which a groundwater allowance is calculated is unique to the AMA. For designated providers in the Study Area that provided water to customers prior to 1995, the initial volume was based on 15x the provider's 1994 demand. This allowance is gradually reduced over time until it goes away in 2025. In addition, designated providers in the Tucson AMA are allowed additional groundwater equivalent to 4% of the previous year's total demand. This is based on the assumption that this volume of water is being returned incidentally recharged to the aquifer. Finally, providers can acquire extinguishment credits that are granted by ADWR when grandfathered

groundwater rights are permanently retired.[17] The management of a groundwater allowance varies by water provider: some have opted to use the balance as it is accrued, some never use it and some treat it like a long-term supply. CAP:SAM allows each of those approaches to be simulated by setting a usage preference percentage (i.e., 100%, 0%, 1% respectively).

Replenished Groundwater

For water providers that have a relationship with the CAGRD, this supply is the volume of groundwater that is reported to ADWR and the CAGRD as "excess groundwater." The physical supply is no different from any other groundwater pumped by the provider, but it generates an obligation on the part of the CAGRD to replenish the aquifer with an equal volume of renewable supply (through recharge or use of previously stored water).[18]

Because CAP:SAM was initially developed to support the CAGRD's 2015 Plan of Operation, the model has some particularly elaborate capabilities to estimate the volume of replenished groundwater, including tracking data on the 1,160 currently enrolled CAGRD ML subdivisions, along with Category 2 MLs (golf courses that do not participate in CAGRD's replenishment reserve program, and MSAs.[19]

Exempt Groundwater (Undesignated Providers)

For water providers that do not have a DAWS, there are several categories of groundwater use that do not require replenishment. These include the groundwater allowances granted to each CAWS issued to subdivisions served by the provider, any non-subdivision demand, pre-1995 subdivision demand, and lost and unaccounted for water. Because the volume of replenished groundwater is calculated in a previous model step, the primary calculation of this supply is based on the amount of demand that hasn't yet been satisfied.

Unknown

Within CAP:SAM, the "unknown" supply is calculated primarily as a zero checksum to verify that a providers' entire demand has been satisfied with supplies that are consistent with the AWS Rules. For purposes of this Study, any volumes of "unknown" were assumed to be satisfied with groundwater.

[17] A more complex set of calculations are made for the Pinal AMA where groundwater allowances are affected by unique provisions related to pre-2007 extinguishment credits

[18] In keeping with CAGRD operations, a three-year lag in demand is introduced to simulate the time difference between when Excess Groundwater is reported and when the replenishment takes place.

[19] See http://www.cagrd.com/operations/plan-of-operation/current-plan and https://www.cagrd.com/news/1389-cagrd-mid-plan-review for or additional detail.

6.0 Modeling Results

6.1 Demand

Projected housing units in the Study area grow year-over-year under all six modeling scenarios (Table 2). The magnitude of this growth is determined by the combined impact of the rate as well as the spatial pattern (Section 4.1) defined for each scenario. For Scenarios C and F, which assume a rapid growth rate coupled with an outward spatial pattern, over 912,000 housing units are projected by the year 2060. This represents a roughly 54% increase from current levels. In contrast, Scenarios B and D, which contemplate a more conservative future growth condition (i.e. slow rate coupled with a compact spatial pattern), result in a projection of approximately 526,000 housing units at the end of simulation, a 21% increase from current levels. Combined, the modeled scenarios represent a range of roughly 387,000 housing units by 2060.

Table 2 - Total projected housing units in 2060 by water provider. Scenarios that are grouped together utilize the same spatial pattern and growth rate

	Total Housing Units (2060)			Housing Unit Growth 2020 vs 2060 [%]		
Water Provider	A &E	B & D	C &F	A &E	B & D	C &F
Avra Water Co-op	2,098	1,885	3,769	+10%	+0%	+50%
Arizona Water Company, Oracle	3,831	2,064	7,747	+58%	+30%	+80%
Comm. Water Co. of Green Valley	14,427	13,014	27,268	+16%	+9%	+56%
Farmers Water Company	10,293	8,902	17,007	+46%	+43%	+67%
Flowing Wells Irrigation District	7,581	7,569	8,743	+0%	+1%	+14%
Green Valley DWID	6,109	5,520	12,761	+23%	+16%	+63%
Lago Del Oro	7,586	4,751	14,107	+53%	+28%	+75%
Las Quintas Serenas	1,571	1,413	2,962	+27%	+22%	+62%
Los Cerros	1,048	726	2,549	+43%	+20%	+77%
Marana	34,798	24,971	58,412	+58%	+49%	+77%
Marana Domestic	418	349	1,383	+17%	+0%	+75%
Metro Diablo	5,394	2,524	8,959	+75%	+56%	+87%
Metro Hub	1,533	1,639	1,998	+5%	+12%	+28%
Metro Main	24,518	22,618	34,480	+9%	+5%	+37%
Metro West	301	144	1,597	+65%	+27%	+93%
Oro Valley	29,812	23,817	54,646	+33%	+19%	+64%
Quail Creek	2,545	2,235	4,225	+24%	+15%	+54%
Ray Water	2,793	2,425	4,994	+18%	+8%	+55%
Ridgeview	570	316	1,133	+55%	+26%	+78%
Saguaro	1,083	747	1,225	+51%	+31%	+57%
Sahuarita	7,110	5,942	13,930	+35%	+26%	+67%
Spanish Trail	4,157	2,650	4,382	+75%	+63%	+76%
Tucson	445,766	381,775	611,536	+28%	+20%	+50%
University of Arizona	75	75	76	+3%	+5%	+7%
Vail	7,834	6,036	10,565	+58%	+48%	+68%
Voyager	1,670	1,612	2,012	+6%	+4%	+22%
Total	**624,921**	**525,720**	**912,467**	**+31%**	**+21%**	**+54%**

As described in Section 5.3 of this report, annual municipal demand for each water provider is modeled in CAP:SAM as the product of housing units and GPHUD. Both housing units and the GPHUD values are differentiated on the basis of new vs. existing. Variations in housing unit projections in conjunction with different usage rates, have a marked impact on demand projections for the Study area (Table 3). This is particularly relevant for providers located north, south and east of the Tucson city limits. A large range in projected demand for these areas is due to variations in the number of housing units under the different spatial growth patterns. These providers include Marana, Oro Valley, Sahuarita, Green Valley DWID, Community Water Company of Green Valley and Spanish Trail.

Not surprisingly, the impact of differing growth assumptions is most evident when comparing slow and compact growth (Scenarios B and D) to rapid outward growth (Scenarios F and C). Based on additional assumptions regarding future trends in GPHUD (Appendix B), Scenarios B and F are the endmembers for the municipal demand projections. Demand in 2060 ranges from a maximum of about 271,500 AF in Scenario F to a minimum of about 158,300 AF in Scenario B.

Table 3 - Total projected water demand in 2060 by scenario by water provider

	Total Municipal Demand - 2060 [AF]					
Water Provider	A	B	C	D	E	**F**
Avra Water Co-op	755	709	1,099	751	797	1,140
Arizona Water Company, Oracle	900	582	1,598	609	927	1,625
Comm. Water Co. of Green Valley	2,444	2,564	4,638	2,595	2,803	4,664
Farmers Water Company	1,993	1,857	3,530	1,906	2,143	3,552
Flowing Wells Irrigation District	1,875	1,876	2,120	1,986	1,985	2,239
Green Valley DWID	2,308	2,110	4,384	2,232	2,441	4,626
Lago Del Oro	4,017	3,013	6,240	3,187	4,244	6,584
Las Quintas Serenas	547	491	1,000	519	578	1,055
Los Cerros	337	265	673	280	356	710
Marana	7,451	5,397	12,860	5,823	8,132	13,682
Marana Domestic	240	223	470	236	254	496
Metro Diablo	841	474	1,296	491	858	1,313
Metro Hub	759	802	934	848	804	988
Metro Main	7,189	6,779	9,750	7,176	7,607	10,304
Metro West	64	47	201	49	67	204
Oro Valley	12,477	10,142	22,178	10,727	13,185	23,397
Quail Creek	710	641	1,095	679	750	1,156
Ray Water	655	579	1,145	611	687	1,181
Ridgeview	643	516	921	546	680	973
Saguaro	503	414	540	438	531	570
Sahuarita	2,010	1,771	3,521	1,866	2,113	3,675
Spanish Trail	1,099	682	1,185	708	1,176	1,238
Tucson	127,782	112,775	171,693	119,283	135,080	181,302
University of Arizona	1,307	1,308	1,309	1,385	1,384	1,386
Vail	2,205	1,805	2,805	1,894	2,307	2,928
Voyager	498	489	557	517	526	586
Total	**181,609**	**158,309**	**257,744**	**167,342**	**192,416**	**271,574**

Detailed descriptions for projections of housing units, GPHUD values and total municipal demand are provided in Appendix C of this report.

Agricultural Demand

Despite persistent urbanization, recent agricultural demands have remained relatively constant in the Study area, exhibiting modest year to year fluctuations. This is due in part to increases in crop and commodity prices and to a lesser degree Federal subsidy programs. From 2000 to 2018, agricultural demand averaged just over 100,600 AF with a maximum and minimum of approximately 113,500 AF and 86,300 AF, respectively.

The full range of agricultural demand projections for the Study area developed by CAP:SAM fall within this historical variability (Figure 15). In general, all projections decrease slightly from current demand due to an assumed continuation of agricultural land urbanization. Demand decreases more rapidly for scenarios that assume a larger increase in irrigation efficiency through the projection period (Appendix B). Increases in crop consumptive use as a result of a hotter and drier future climate counterbalance this decline. The percent decrease in projected demand by the year 2060 ranges from a maximum of 13% to a minimum of 4%.

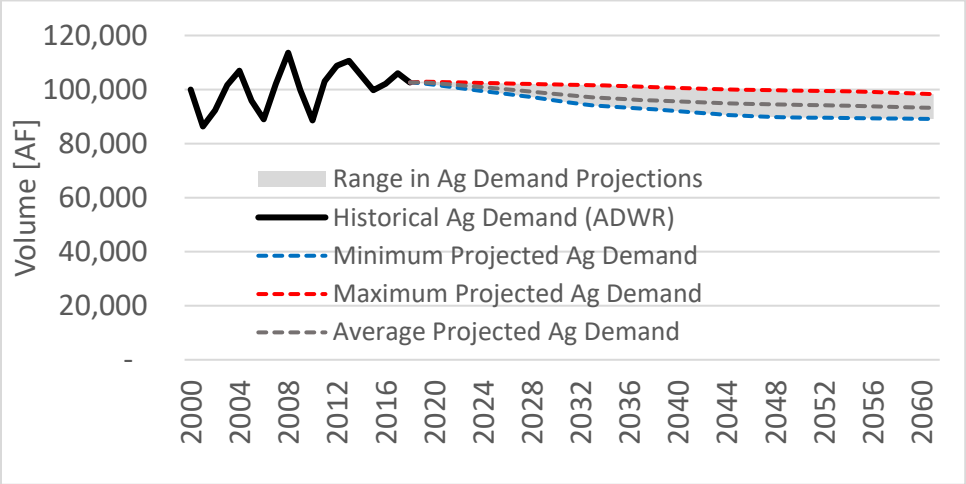


Figure 15 - Range in projected agricultural demand

Tribal Demand

Tribal demand in the TAMA is predominately agricultural demand with a small portion of municipal and industrial demand. In total this demand represents a small component of the projected demand for the Study area. Projected tribal demand across all sectors ranged from 17,600 AF to 19,200 AF in 2060, representing roughly a 4% decrease and increase from current levels, respectively.

Industrial Demand

CAP:SAM has the capability to model industrial demands that can be either tied to, or independent of, municipal demand. For this Study, projections of Industrial demand were generated outside of CAP:SAM as part of the groundwater modeling tasks (Tasks 3 and 4; Figure 3). These projections assumed a constant demand of ~45,000 AF per year, of which over 70% is associated with mining activity. Industrial demand projections for Scenarios C and F also assume an increase in mining activity beyond current levels. Industrial demand is anticipated to be fully satisfied through groundwater pumping. Detailed descriptions of these projections can be found in the groundwater modeling Technical Memorandum and are excluded from further discussion in this report.

Other Demand

Some historic municipal and agricultural demand not modeled in CAP:SAM was included and held constant in the groundwater model runs. This includes approximately 12,000 AF per year associated with agricultural activity that occurs in the Pinal and Santa Cruz AMAs but falls within the groundwater model domain. In addition, approximately 6,000 AF per year of municipal demand associated with small water providers not modeled in CAP:SAM was included in the groundwater model. Similarly to the industrial demand, these projections are covered in the groundwater model Technical Memorandum and therefore not discussed in this report.

Total Demand

Total projected demand in 2060 ranges from a 5% decrease (Scenario B) to a 37% increase (Scenario F), compared to current levels (Figure 16). Scenarios C and F resulted in the greatest increase in demand, primarily as a result of rapid, outward population growth. Scenarios B and D, which assume slow and compact growth, resulted in the smallest increase in demand. In addition to slower, more urban-centric growth, Scenario B includes additional assumptions regarding agricultural efficiency and municipal conservation (Appendix B) that result in the projected demand for 2060 being lower than historic demands. Scenarios A and E both result in moderate increases in demand of 2% and 8%, respectively.

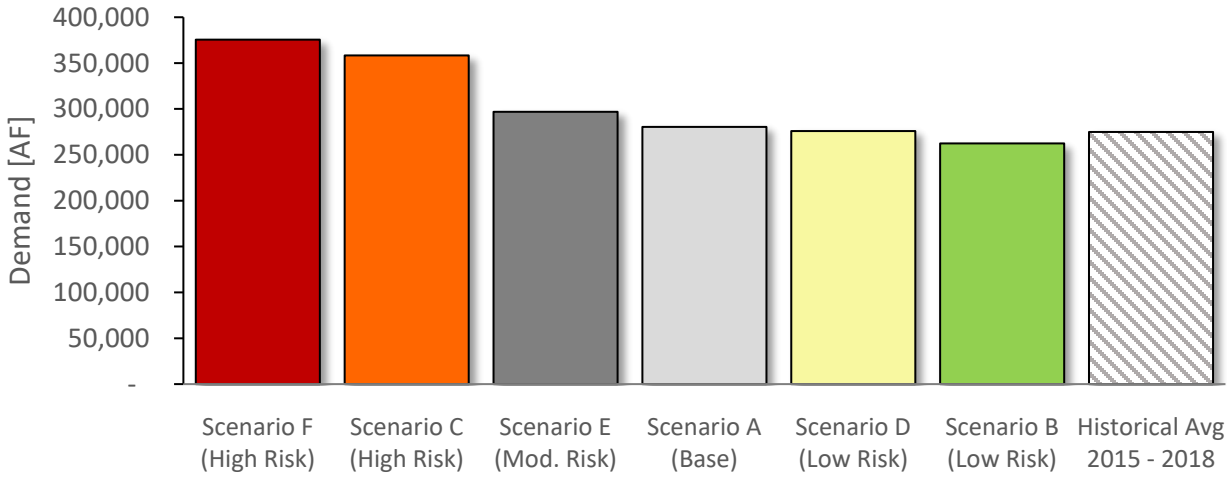


Figure 16 – Total projected demand in 2060 by Scenario. Historical average determined using ADWR's AMA Historic Template and Summary. "Risk" refers to the relative impact to water supply reliability and the environment due to the degree of climate change and projected population growth.

6.2 Supply

Supplies that are projected to meet demands at the end of the simulation period are shown in Figure 17. The availability of these supplies is driven in large part by two factors: climate and the location in which growth is projected to occur. As previously discussed (Section 4.2), the effect of modeling a warmer and drier climate in CAP:SAM is a reduction in the annual availability of CAP supplies. These reductions have a ripple effect and impact the utilization of subsequent supplies. For example, if in a typical year a water provider's portfolio is made up of half renewable CAP supplies and half groundwater supplies, a 50% reduction to their CAP supplies would result in the provider increasing their groundwater usage by 50% to meet their total demand. Water providers in the Study area differ substantially in their access to renewable CAP supplies and their relationship with the CAGRD. Many of the larger, designated providers serving the central portions of the TAMA have comparatively large CAP entitlements, while the smaller providers serving the peripheral areas of the AMA have either small entitlements or no CAP supplies at all. These smaller providers relying heavily on groundwater to meet demands. Much of the projected groundwater use for these smaller providers incurs a replenishment obligation on the part of the CAGRD. Due to this spatial distinction, the location of anticipated growth heavily impacts what supply types are used to meet projected demand.

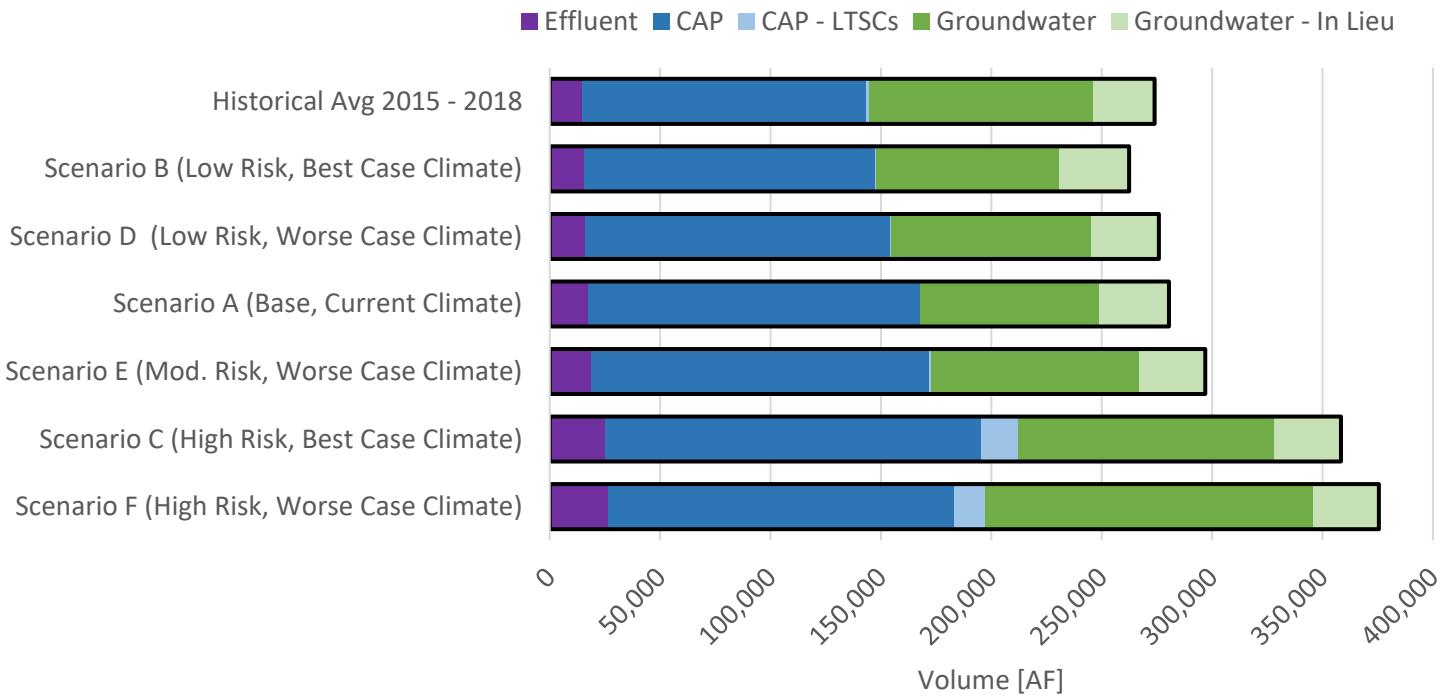


Figure 17 - Projected supply utilization to meet municipal, agricultural and tribal demand in 2060. Historical average determined using ADWR's AMA Historic Template and Summary. "Risk" refers to the relative impact to water supply reliability and the environment due to the degree of climate change and projected population growth.

For each model scenario, effluent use is projected to increase in proportion with increases in municipal demand. Effluent represents on average approximately 6% of the total supply across scenarios in 2060. CAP supply utilization is also projected to increase across all scenarios, as use of the supply shifts from earning LTSCs to meeting growing annual demands. In the rapid growth scenarios (C and F), as municipal sector demand grows, recovery of stored CAP LTSCs increases substantially from historic levels. There is also a higher reliance on groundwater in Scenarios C and F to meet this demand. The outward growth projection for these scenarios results in more growth occurring in communities with smaller and less diverse renewable supply portfolios. As noted earlier, much of this groundwater reliance would generate a requirement for replenishment under the AWS rules, either by the CAGRD or the water provider themselves. In-lieu supplies vary slightly amongst scenarios as a function of CAP availability, but in general remain fairly constant.

6.3 Effluent

Effluent in excess of what is used to meet municipal demand is modeled anually for the TAMA. This volume is characterized as being stored, either at constructed or managed USFs. The proportion of excess effluent allocated among these different uses was informed by stakeholder input as well as the annual Effluent Generation and Use Reports prepared by the Pima County Regional Wastewater Reclamation Department[20]. Current effluent supplies, as well as those projected (Figure 18), represent a valuable resource that can be utilized to alleviate the supply and demand imbalances identified in this Study.

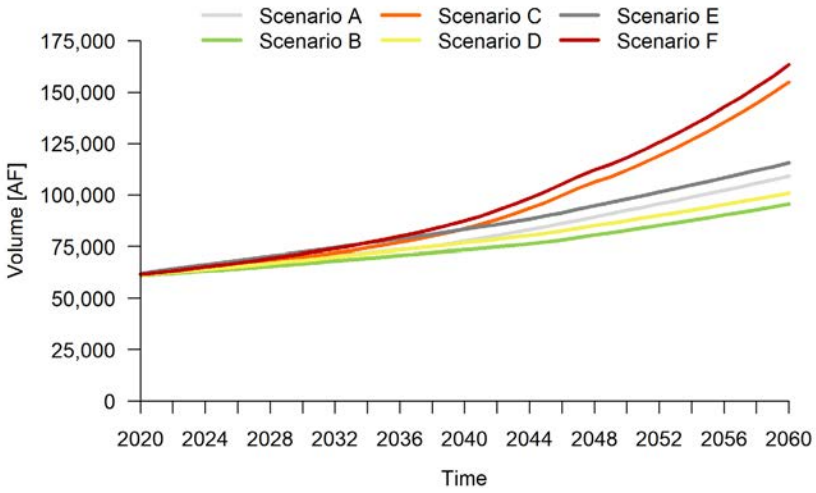


Figure 18 - Total projected effluent production.

Currently about 63% of the effluent generated in the TAMA is being discharged to the Santa Cruz River through the Tres Rios and Agua Nueva Water Reclamation Facilities. Much of this discharge is associated with the Lower Santa Cruz Managed Recharge Project which generates LTSCs for the participants. Effluent discharged into the Santa Cruz River is considered "managed" recharge (i.e. discharge to a naturally water-transmissive are such as a streambed) until it reaches Trico Road, near the county line. Under each modeling scenario, the percentage of effluent discharged to the Santa Cruz River is projected to increase, ranging from approximately 71% to 80% in 2060 (Figure 19).

Effluent supplies that are projected to be discharged into the Santa Cruz River, beyond what is necessary to maintain wildlife habitat, are a crucial resource to consider for adaptation strategies. While discharging effluent results in a net

[20] https://webcms.pima.gov/government/wastewaterreclamation/

benefit to the aquifer, this water could be distributed elsewhere within the region to address localized problem areas.

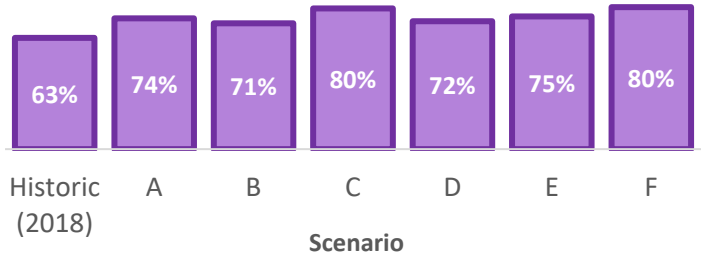


Figure 19 - Percent of produced effluent that is projected to be discharged to the Santa Cruz River in 2060

6.3 Pumping

Pumping generates a net stress on the aquifer that must be offset by recharging an equal volume of water in order to achieve regional safe-yield. While much of the pumping in the Tucson AMA is stored water which is then recovered in the same year (ASR), the spatial disconnect between the locations where pumping and recharge occur can result in local aquifer impacts, even while satisfying the AMA's safe-yield goal. Total pumping projected across all scenarios is shown in Figure 20. As a reminder, these pumping volumes exclude approximately 64,000 AF annual pumping associated with historic demands not modeled in CAP:SAM, as well as industrial demand projections.

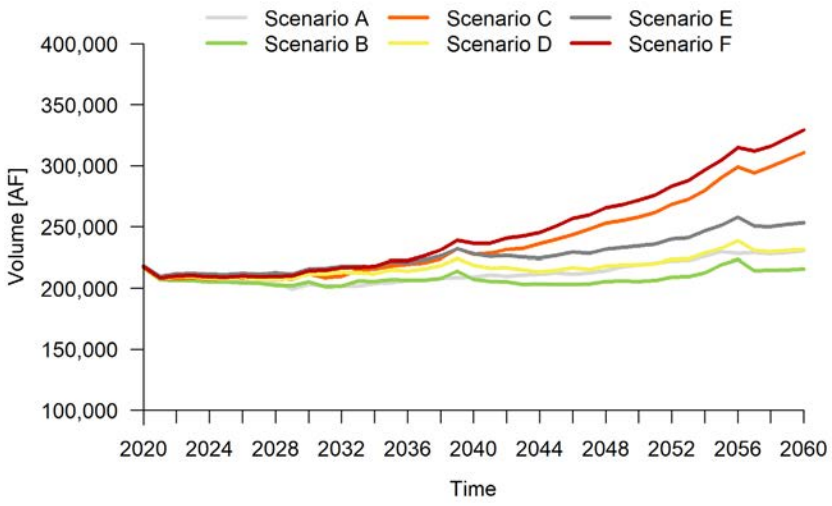


Figure 20 – Total pumping by scenario. Projections include agricultural pumping, municipal pumping (groundwater, ASR, CAP LTSC recovery), tribal recovery and AWBA recovery

With the exception of Scenario B, pumping is projected to steadily increase for all scenarios during the projection period. Pumping volumes in 2060 represent a net increase from historical levels that ranges from 6% (Scenario A) to over 50% (Scenario F). While annual variations in pumping occur in Scenario B, there is effectively no net increase in pumping from historical levels. Reduced availability of renewable supplies, an increased recovery burden placed on the AWBA during times of shortage and growth in groundwater dependent areas, all result in an increase in projected groundwater pumping. Abrupt spikes in pumping that occur in 2039 and 2056 are associated with the simulation of extreme reductions to the CAP supply (Figure 11).

AWBA Recovery

Since its inception in 1996, the AWBA has stored over 4 million AF of CAP water underground. During times of declared shortage on the Colorado River, these credits will be recovered (pumped) for the purpose of increasing the reliability of supplies for CAP M&I subcontractors and Fourth Priority (P-4) On-River M&I users (known as firming). Credits will also be used to meet the State's Indian firming obligations, as well as to meet interstate water banking obligations with Nevada. A comprehensive analysis of the magnitude, timing and frequency of credit recovery for the purpose of firming is beyond the scope of this report but is discussed in great detail in the 2021 Joint Recovery Update authored by the Recovery Planning Advisory Group[21].

To date, approximately 830,000 AF of AWBA credits have been accrued in the Tucson AMA. Recovery of these credits is projected to occur across all scenarios (Figure 21). In general, AWBA recovery represents a small component of the total projected pumping and ranges from a total of approximately 87,000 AF to 110,000 AF over the projection period. During years of severe impact to the CAP system, recovery peaks as a result of increased firming for M&I and tribal users. This phenomenon is most prevalent in Scenarios D, E and F, in which the worse-case climate is assumed. For each scenario, an interstate recovery volume of about 3,300 AF is projected to begin in 2030 and remains constant through the simulation.

[21] https://new.azwater.gov/rpag

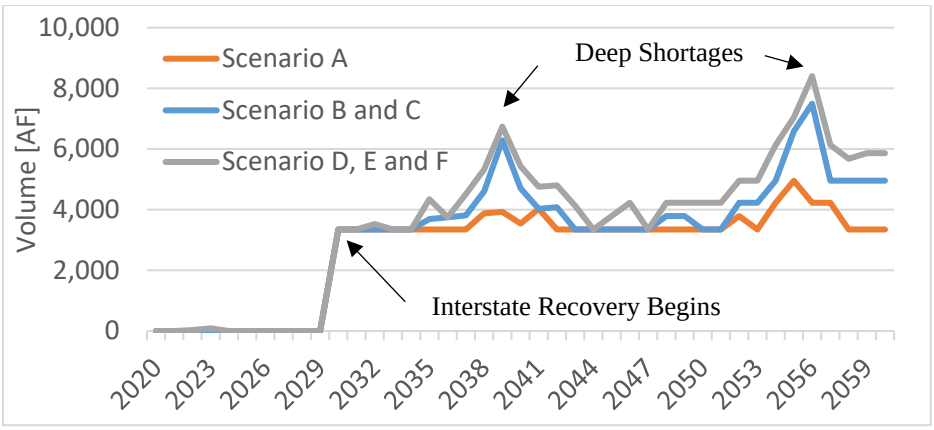


Figure 21 – Projected AWBA recovery volumes

Annual Storage and Recovery

Annual storage and recovery is a strategy used by many of the water providers in the Study area to utilize their CAP water. In each scenario there is a general upward trend in annual storage and recovery as existing CAP supplies are fully utilized (Figure 22), with the rate of increase varying across scenarios. During the initial half of the simulation period, there is a modest difference among the scenarios in projected ASR.

By the latter half of the simulation period, the effect of the growth assumptions are evident. Due to the rapid growth assumption, ASR under Scenarios C and F ramps up quickly. As previously mentioned, large reductions to the CAP supply are projected to occur during the latter part of the simulation period. These reductions, particularly those projected to occur in 2056, result in fairly drastic reductions to ASR volumes. ASR then rebounds as reductions to the supply are less severe. Scenarios with less aggressive growth assumptions result in a more gradual increase in ASR over time and do not exhibit the same reductions associated with severely reduced CAP availability.

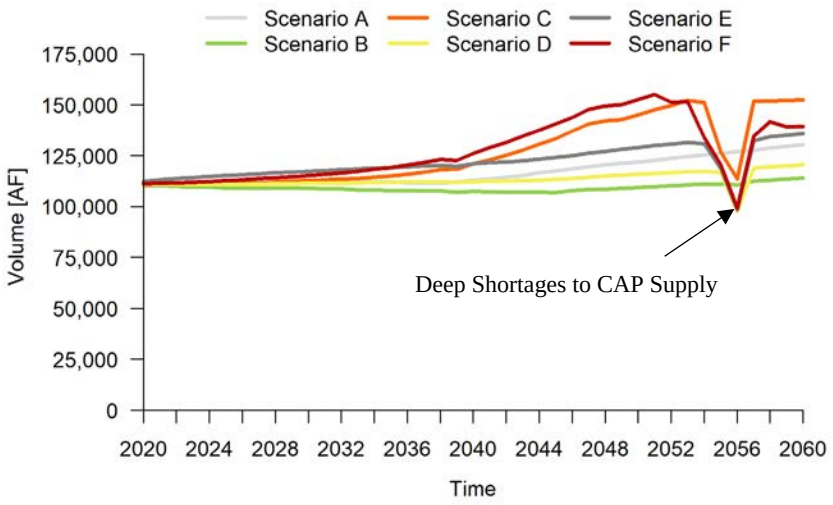


Figure 22 – Annual storage and recovery projections

Groundwater Subject to AWS

CAP:SAM makes projections of groundwater demand for several legal categories, but it does not simulate the physical properties of the regional groundwater aquifer. As such, it does not have the ability to constrain the supply of groundwater on the basis of physical availability or pumping extraction costs. The ability to continue to satisfy the physical availability provisions of the AWS rules is beyond the scope of CAP:SAM's capabilities, but is a central benefit of connecting CAP:SAM results to the groundwater flow model.

While total groundwater pumping is not constrained in CAP:SAM, if the projected demand for a provider exceeds the availability of renewable supplies, exempt groundwater and LTSCs, the corresponding volume incurs a replenishment obligation under the AWS rules. This volume requires offsetting replenishment by either the CAGRD or the provider themselves, and depends on the acquisition or development of renewable supplies within the AMA. The rate of groundwater use that is subject to replenishment varies substantially across scenarios (Figure 23). Total volume for the simulation period ranges from a maximum of 570,000 AF in Scenario F to a minimum of 231,000 F in Scenario B (Table 4).

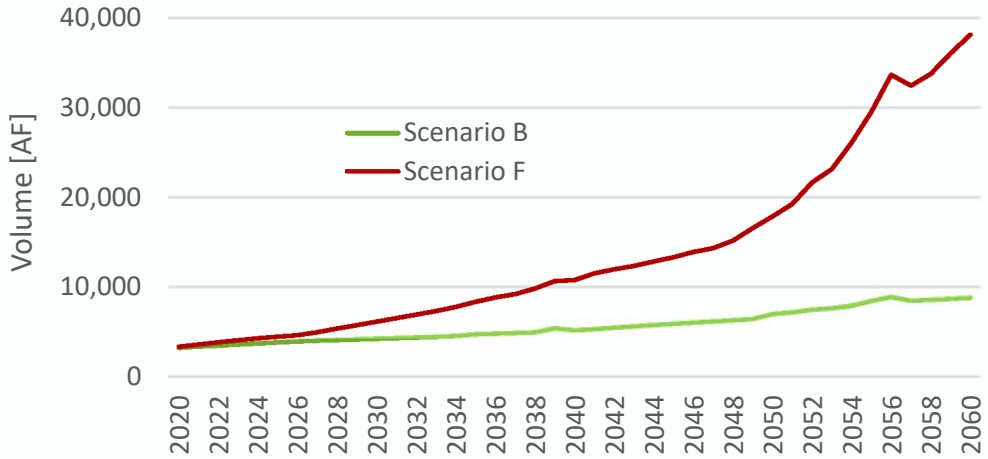


Figure 23 – High end (Scenario F) and low end (Scenario B) projections for groundwater pumping subject to replenishment under the Assured Water Supply rules.

Table 4 – Projected annual volume of groundwater subject to replenishment under the AWS rules in 2060

Modeling Scenario	Groundwater Subject to AWS Rules	
	Annual Volume (2060)	Total Volume (2020 – 2060)
Scenario A	12,700 AF	330,100 AF
Scenario B	8,800 AF	231,000 AF
Scenario C	34,400 AF	517,400 AF
Scenario D	9,500 AF	250,600 AF
Scenario E	14,300 AF	368,400 AF
Scenario F	38,100 AF	570,000 AF

6.4 Artificial Recharge

Recharge represents a net contribution to the aquifer that offsets groundwater pumping from a regional safe-yield perspective. Projections of artificial recharge (i.e. excluding natural recharge) over the study period exhibit a general downward trend (Figure 24). Variability in the utilization of recharge capacity is influenced heavily by reductions to the CAP supply. This is true for water providers storing their CAP entitlements, as well as entities like the AWBA and CAGRD storing Other Excess CAP supplies. Effluent storage at USFs is projected to modestly increase during this time period.

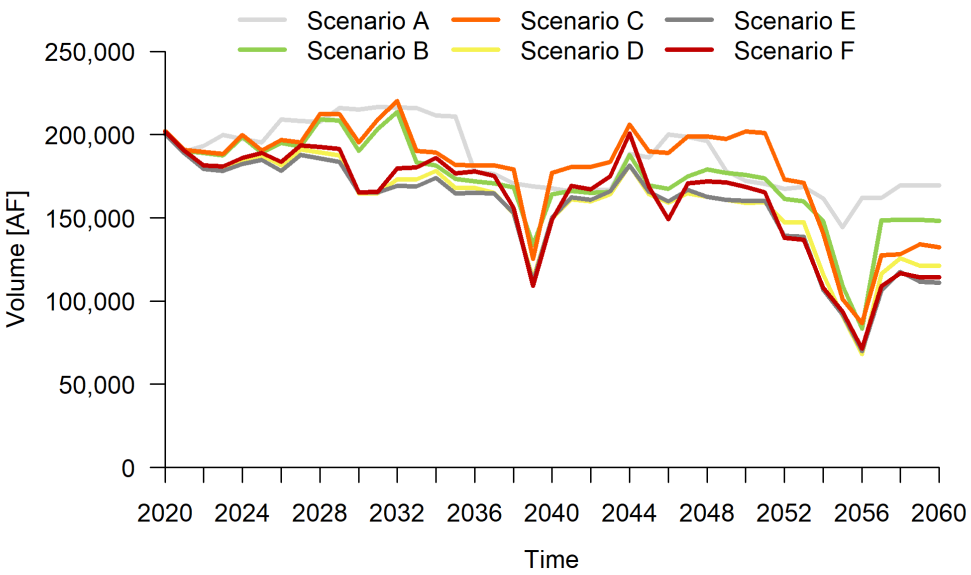


Figure 24 – Total annual recharge volume. Includes effluent and CAP supplies stored at USFS. Does not include GSF storage

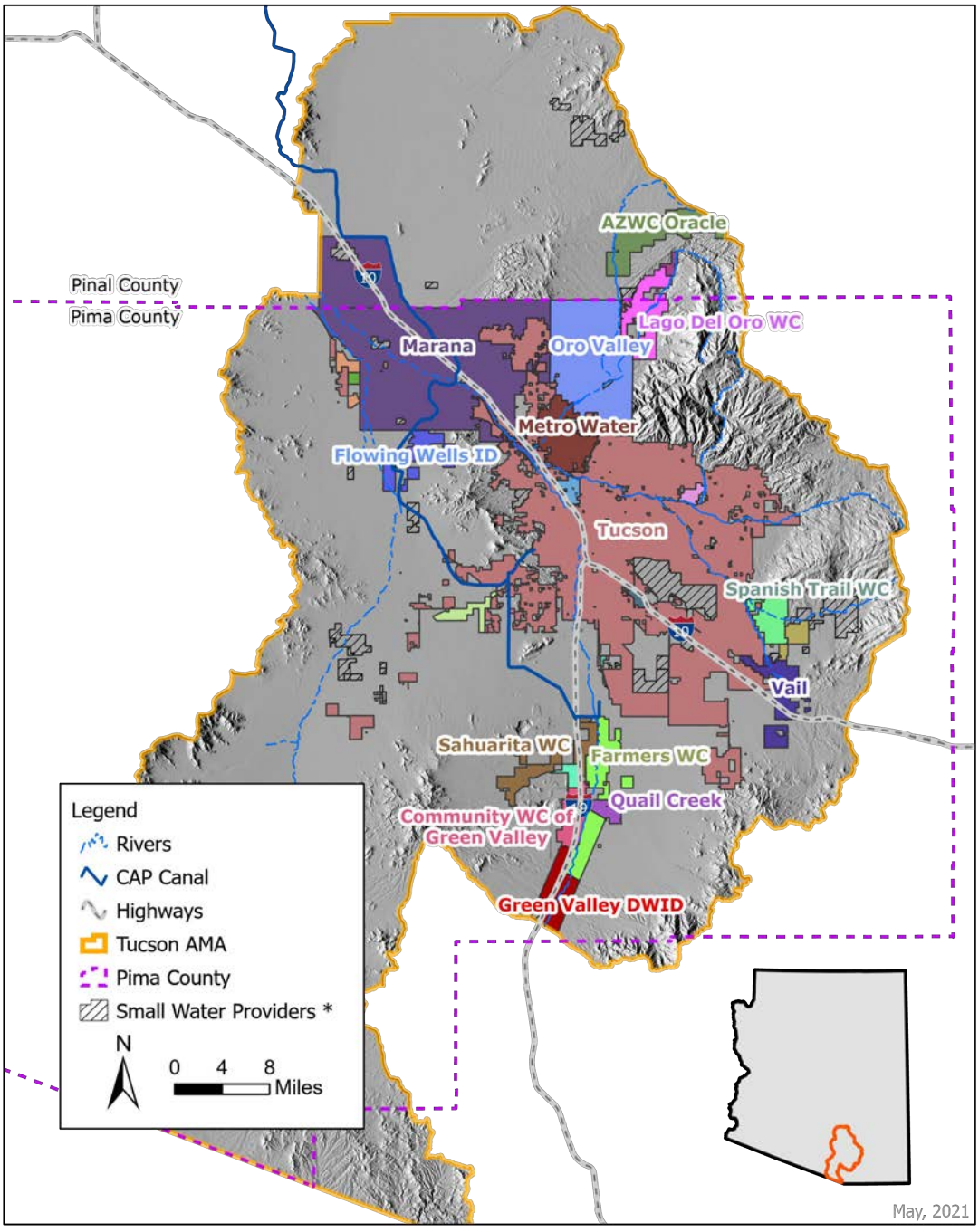
7.0 Connection to Groundwater Flow Model

Upon completion of the Supply and Demand Assessment, CAP provided CAP:SAM modeling results, including those discussed in Section 6.0, to Reclamation for use as MODFLOW input files for the groundwater modeling. A detailed description of these files can be found in a CAP memo included as Appendix D.

Appendix A – Water Provider Service Areas

Water Provider Service Areas

Lower Santa Cruz River Basin Study



Water providers highlighted but not explicitly labeled include: Avra Water Co-op, Las Quintas Serenas, Los Cerros, Marana Domestic Water Improvement District, Metro Diablo, Metro Hub, Metro West, Ray Water Company, Ridgeview, Saguaro, University of Arizona and Voyager

* Small water providers are not explicitly modeled in CAP:SAM for this Study

Appendix B – CAP:SAM Modeling Parameters

Key CAP:SAM Modeling Parameters by Scenario

Parameter	Scenario					
	A	B	C	D	E	F
CAP Shortages	Current Climate	Best-Case Climate	Best-Case Climate	Worse-Case Climate	Worse-Case Climate	Worse-Case Climate
Surface Water Reduction	Current Climate	Best-Case Climate	Best-Case Climate	Worse-Case Climate	Worse-Case Climate	Worse-Case Climate
Growth Rate (AOEO[1] Series)	Medium	Slow	Rapid	Slow	Medium	Rapid
Growth Pattern (Applied Economics)	Official	Compact	Outward	Compact	Official	Outward
Existing GPHUD[2], Rate of Change [%]	-0.8	-0.6	-0.6	-0.4	-0.4	-0.4
Existing GPHUD, Max Rate of Change [%]	-15	-15	-15	-10	-10	-10
Existing GPHUD, Min Value	150	180	180	200	200	200
New GPHUD, Rate of Change [%]	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
New GPHUD, Min Value	150	180	180	200	200	200
New GPHUD, Max Rate of Change [%]	-5	-5	-5	-5	-5	-5
Ag Efficiency , Rate of Change [%]	0.1	0.1	0.1	0.1	0.1	0.1
Ag Efficiency, Max [%]	80	90	80	80	80	80
Ag Climate Consumptive Use Rate of Change [%]	0	0.1	0.1	0.2	0.2	0.2

* Parameters that are applicable across all scenarios include:
  - Use of the 2045 CAP buildup schedule
  - Medium housing unit recovery rate
  - No crop type replacement
  - No reinvestment in underutilized agricultural lands
  - Maximum 20% AWBA firming for municipal and industrial subcontractors

[1] AOEO = Arizona Office of Economic Opportunity

[2] GPHUD = Gallons per housing unit per day

Appendix C – CAP:SAM Supply and Demand Projections

CAP:SAM Supply and Demand Projections by Water Provider

Appendix D – Groundwater Modeling Memo

CAP Memo Detailing CAP:SAM Files Provided to Reclamation for the Purpose of Groundwater Modeling

MEMO

Date: December 18, 2019

To: The Lower Santa Cruz River Basin Study Project Team

From: Central Arizona Project

Subject: Supply and Demand Files for Input into the Groundwater Flow Model

Background

Central Arizona Project (CAP) is a non-federal cost-share partner of the Lower Santa Cruz River Basin Study and has developed future water supply and demand projections for the study area using the CAP Service Area Model (CAP:SAM). Outputs from CAP:SAM serve as inputs into the groundwater flow modeling being conducted by the Bureau of Reclamation.

List and Explanation of Files

The following list of files were provided to the Bureau of Reclamation by CAP for the purpose of generating groundwater model runs. These files were provided for each of the six modeling.

Agriculture

- Total demand, by supply type, by district, by year
- Footprint of active acres, by Irrigation district, by grid cell, by year.
    - Changes due to involuntary fallowing and urbanization
    - Used, with total demand, to spatially distribute incidental recharge.
- Total on-reservation demand by water type, by tribe, by year
    - Used to compute incidental recharge.
- Groundwater pumping by irrigation district, by well, by year
- Groundwater pumping for IGFRs (not part of an irrigation district) by well by year

Municipal

- Groundwater pumping and recovery by water provider by well by year
    - Includes providers in CAP:SAM and all other small providers not modeled individually in CAP:SAM

Recharge

- USF recharge volumes by facility by year
    - Direct recharge input into the model
    - Include accrual of LTSCs (municipal) and Arizona Water Bank Authority storage
- Footprints of USFs (if needed)

Effluent

- Total effluent produced per year
    - This is effluent not used directly (i.e. purple pipe or recovery) to meet municipal demand.
    - Additional coordination with the supply and demand sub-team will be necessary to spatially distribute this volume

Recovery

- AWBA recovery by well by year

CAP:SAM Supply and Demand Projections by Water Provider

Scenario A

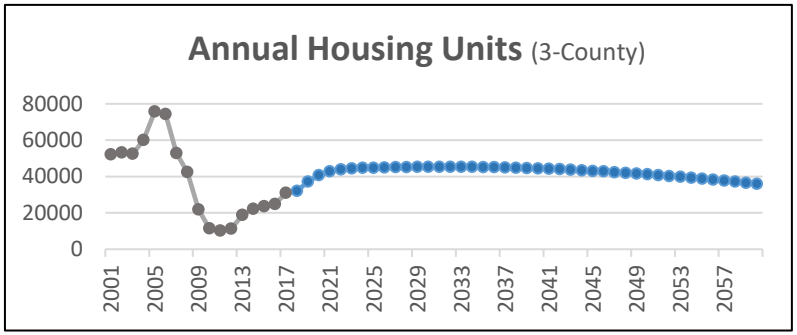
Climate: Current
Growth Rate: Medium
Growth Pattern: Official
Relative Risk: Base

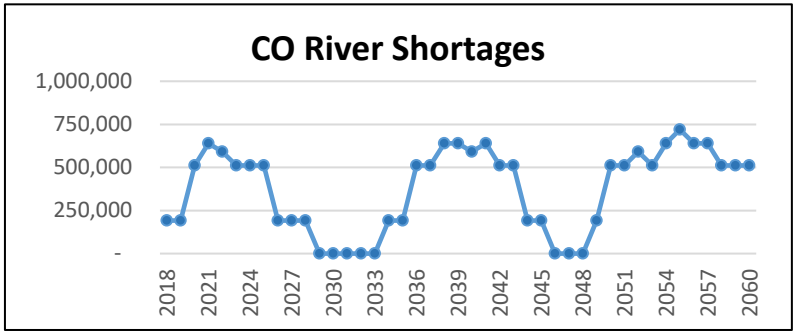
A. Official, Historic Climate [LSCRBS]

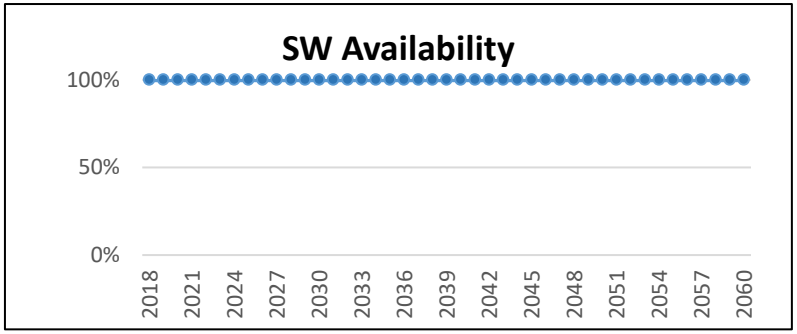
Run Date: 6/30/2020 **Filename:** CAPServiceArea_v3.50_LSCRBS_A(

Growth rate based on Medium growth series from the AZ Dept. of Administration and growth pattern from PAG, standard CAP-SAM

Allow Shortages	Yes	
Select CRSS Array	3	*3=Synthetic*
Use Specific Trace	Yes	
Selected Trace	1	*1=Moderate; 2=Deep; 3=Slight*
AWBA Max M&I	20%	
Surface Water Scenario	1	*1=No Reduction; 2=Occational; 3=Frequent*
Use CAP Buildup	Yes	
CAP Buildup Scenario	2	*1=2035; 2=2045*
HU Growth Pattern	1	*1=Baseline*
HU Forecast	2	*1=Use Curve; 2=Eller Forecast*
HU Curve	2	
HU Growth Start Rate	0%	
HU Ordinary Level	45,000	
HU Rate @ 50 yrs	-2%	
GPHUD Change Existing	-0.8%	*per year*
GPHUD Max Change Existing	-15%	
GPHUD Min Existing	150	
GPHUD Scenario New	1	
GPHUD Change New	-0.2%	*per year*
Ag Climate Adjustment	0	
Ag Efficiency Increase	0.1%	*per year*
Ag Efficiency Goal	80%	
Ag Replace Crop CU	2.66	
Ag Intensity Scenario	2	
Ag Develop on Crops	50%	*Perecent of max on active Ag*
Ag Acres Replace Percent	0%	
Ag Replace Crop Year	2025	



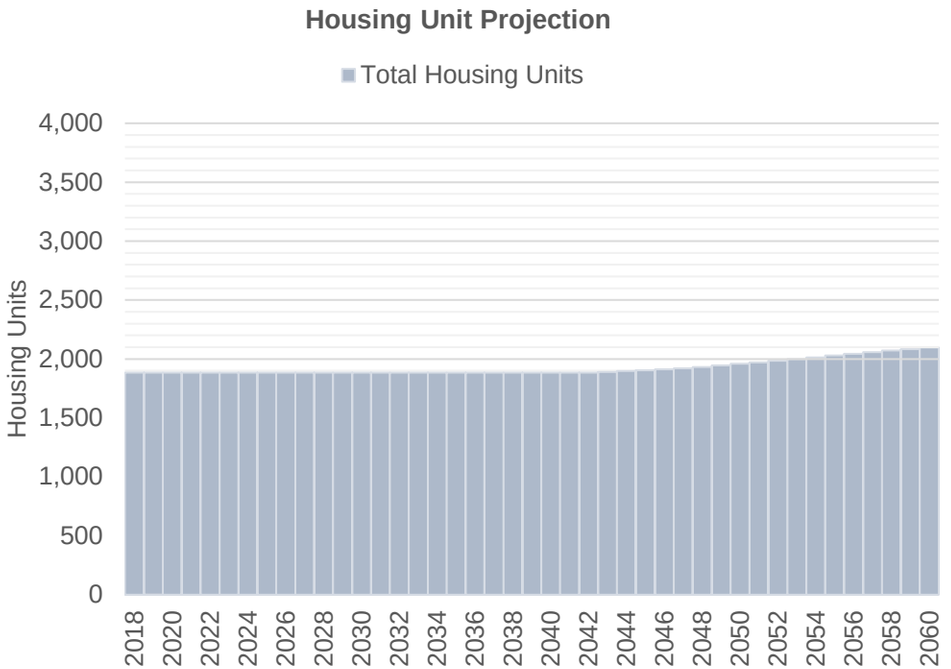


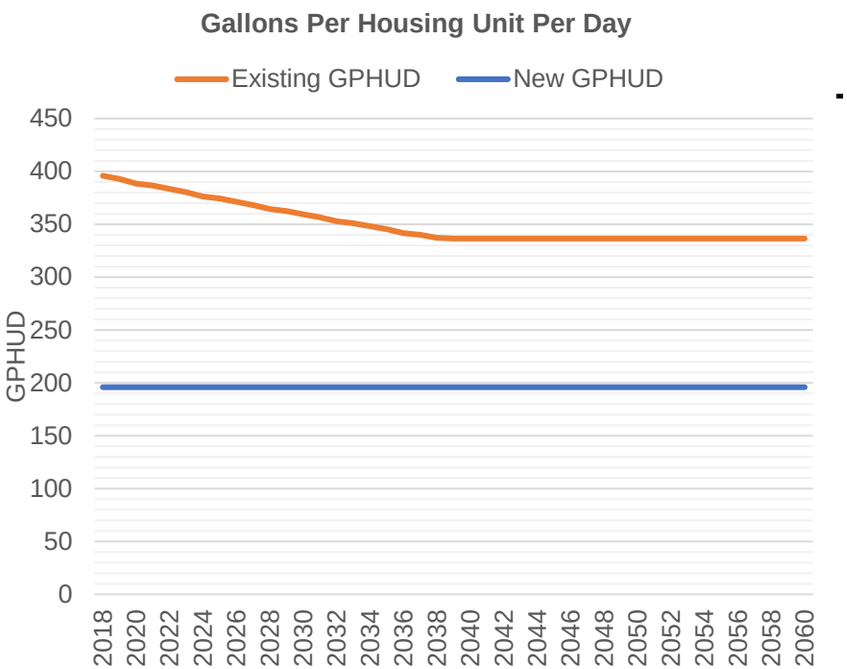


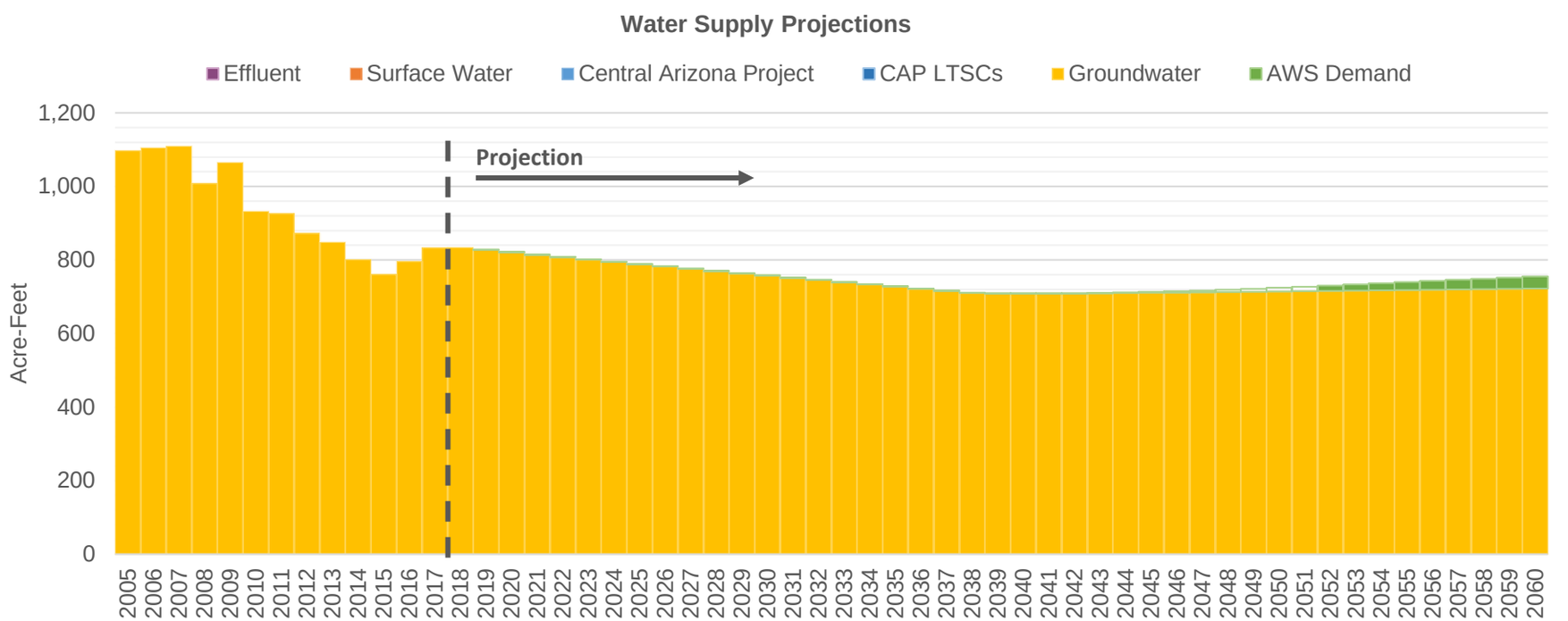
Central Arizona Project Service Area Model

AvraWaterCoop

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

AvraWaterCoop

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

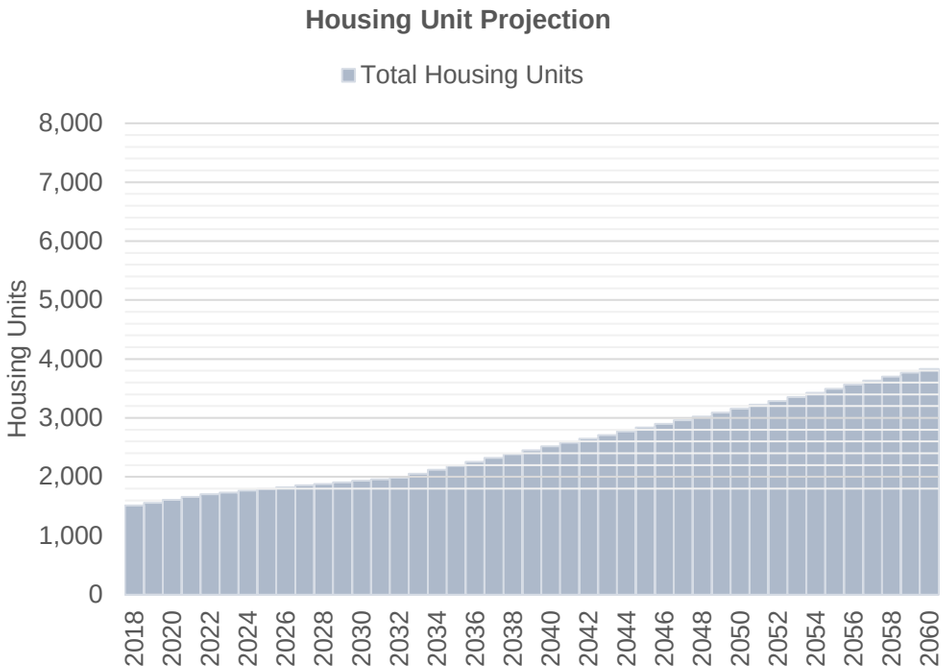
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

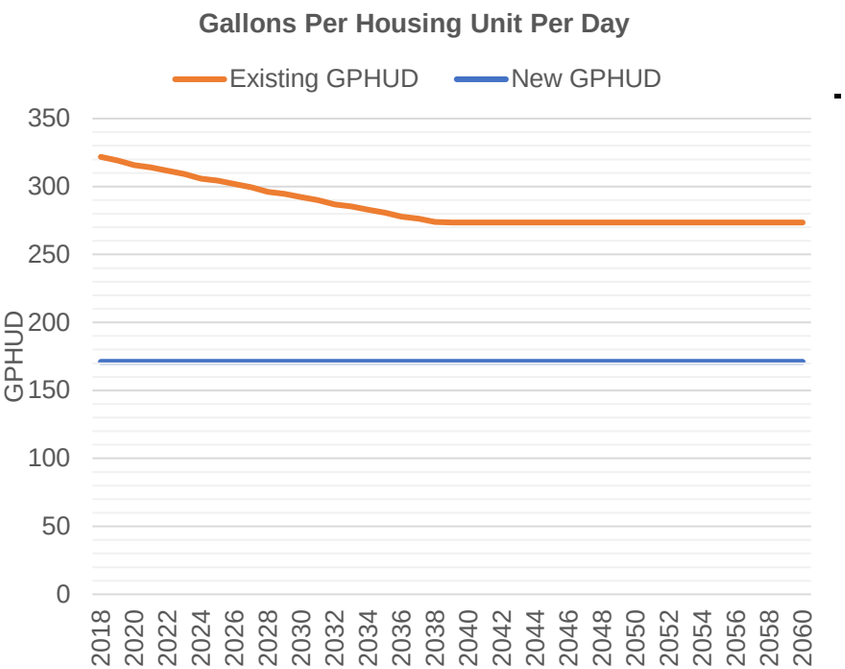
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,883	396	196	0	0	0	0	0	0	0	834	0
2019	1,883	393	196	0	0	0	0	0	0	0	827	0
2020	1,883	389	196	0	0	0	0	0	0	0	821	0
2021	1,883	386	196	0	0	0	0	0	0	0	814	0
2022	1,883	383	196	0	0	0	0	0	0	0	808	0
2023	1,883	380	196	0	0	0	0	0	0	0	801	0
2024	1,883	376	196	0	0	0	0	0	0	0	795	0
2025	1,883	374	196	0	0	0	0	0	0	0	789	0
2026	1,883	371	196	0	0	0	0	0	0	0	782	0
2027	1,883	368	196	0	0	0	0	0	0	0	776	0
2028	1,883	364	196	0	0	0	0	0	0	0	770	0
2029	1,883	362	196	0	0	0	0	0	0	0	764	0
2030	1,883	360	196	0	0	0	0	0	0	0	757	0
2031	1,883	357	196	0	0	0	0	0	0	0	751	0
2032	1,883	353	196	0	0	0	0	0	0	0	745	0
2033	1,883	351	196	0	0	0	0	0	0	0	739	0
2034	1,883	348	196	0	0	0	0	0	0	0	734	0
2035	1,883	345	196	0	0	0	0	0	0	0	728	0
2036	1,883	342	196	0	0	0	0	0	0	0	722	0
2037	1,883	340	196	0	0	0	0	0	0	0	716	0
2038	1,883	337	196	0	0	0	0	0	0	0	710	0
2039	1,883	337	196	0	0	0	0	0	0	0	709	0
2040	1,883	337	196	0	0	0	0	0	0	0	709	0
2041	1,883	337	196	0	0	0	0	0	0	0	709	0
2042	1,883	337	196	0	0	0	0	0	0	0	709	0
2043	1,889	337	196	0	0	0	0	0	0	0	710	0
2044	1,897	337	196	0	0	0	0	0	0	0	710	1
2045	1,905	337	196	0	0	0	0	0	0	0	711	3
2046	1,913	337	196	0	0	0	0	0	0	0	711	4
2047	1,921	337	196	0	0	0	0	0	0	0	712	5
2048	1,932	337	196	0	0	0	0	0	0	0	712	6
2049	1,945	337	196	0	0	0	0	0	0	0	713	8
2050	1,959	337	196	0	0	0	0	0	0	0	714	10
2051	1,972	337	196	0	0	0	0	0	0	0	715	13
2052	1,986	337	196	0	0	0	0	0	0	0	716	15
2053	2,000	337	196	0	0	0	0	0	0	0	717	17
2054	2,014	337	196	0	0	0	0	0	0	0	717	19
2055	2,029	337	196	0	0	0	0	0	0	0	718	22
2056	2,043	337	196	0	0	0	0	0	0	0	719	24
2057	2,057	337	196	0	0	0	0	0	0	0	720	26
2058	2,071	337	196	0	0	0	0	0	0	0	721	28
2059	2,084	337	196	0	0	0	0	0	0	0	721	31
2060	2,098	337	196	0	0	0	0	0	0	0	722	33

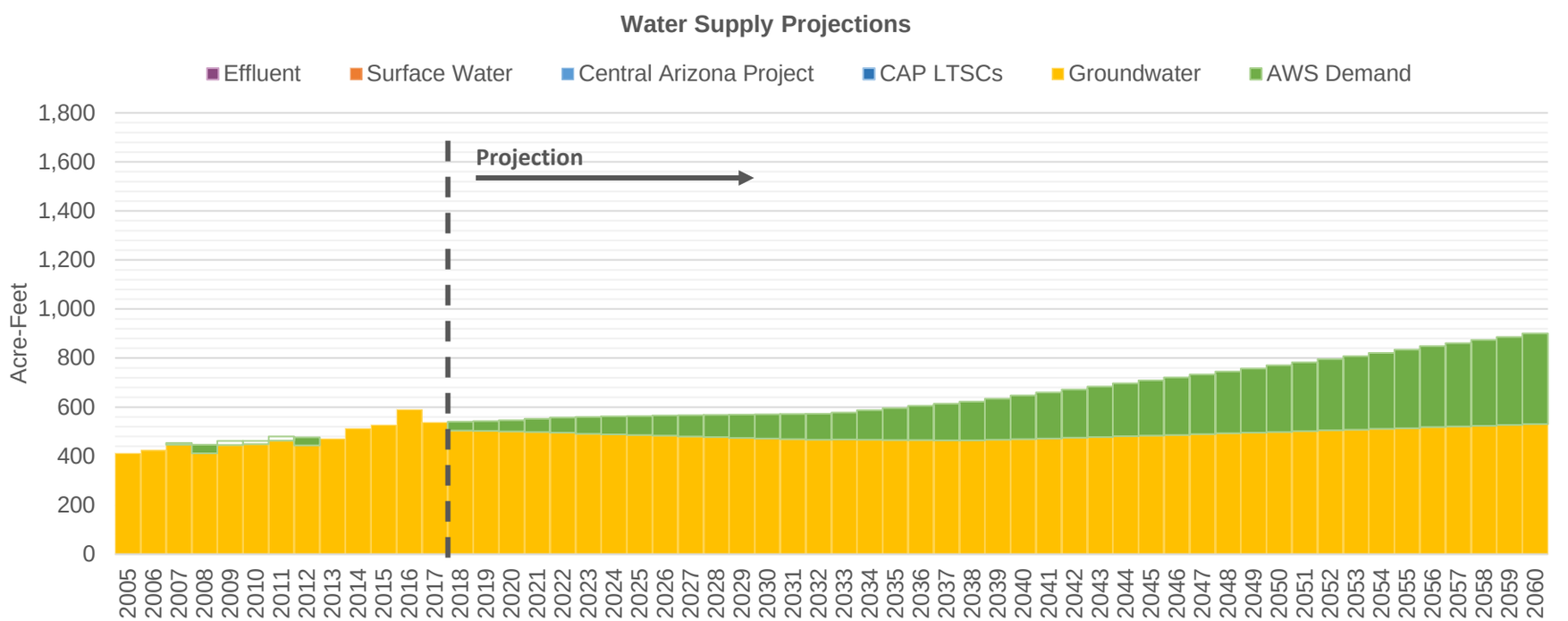
Central Arizona Project Service Area Model

AZWCOracle

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

AZWCOracle

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

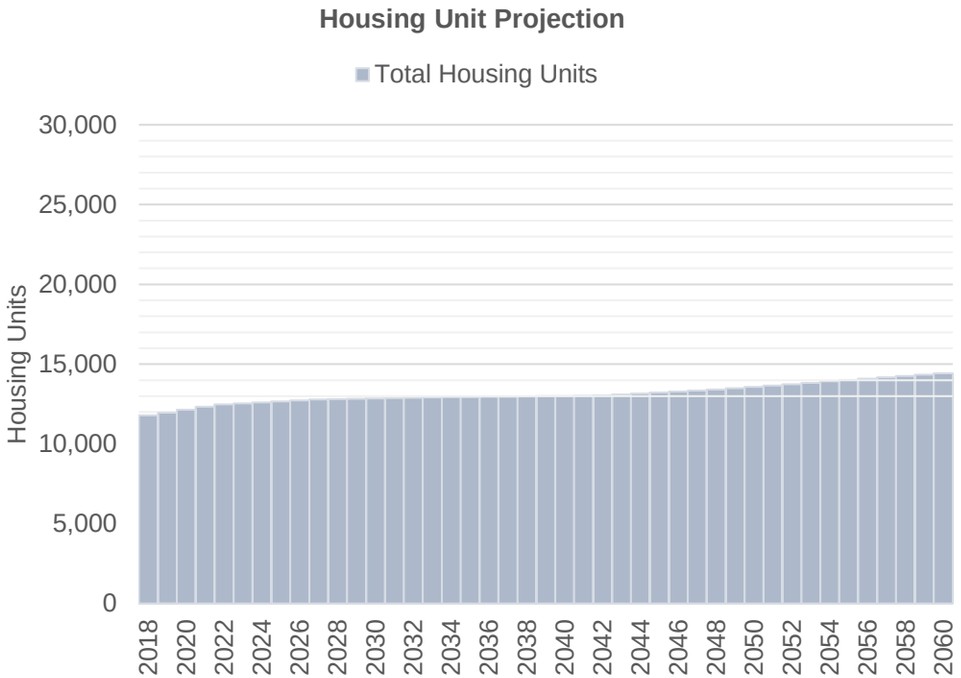
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

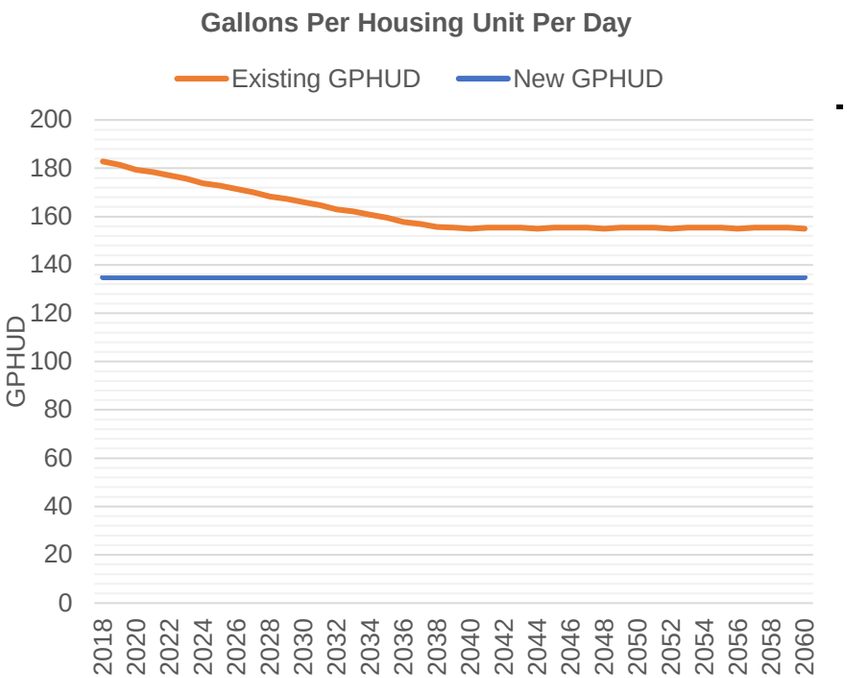
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,516	322	171	0	0	0	0	0	0	0	505	36
2019	1,560	319	171	0	0	0	0	0	0	0	503	39
2020	1,608	316	171	0	0	0	0	0	0	0	501	46
2021	1,658	314	171	0	0	0	0	0	0	0	498	54
2022	1,703	312	171	0	0	0	0	0	0	0	495	62
2023	1,733	309	171	0	0	0	0	0	0	0	491	69
2024	1,764	306	171	0	0	0	0	0	0	0	489	73
2025	1,794	304	171	0	0	0	0	0	0	0	486	78
2026	1,825	302	171	0	0	0	0	0	0	0	483	82
2027	1,855	299	171	0	0	0	0	0	0	0	480	87
2028	1,881	296	171	0	0	0	0	0	0	0	478	91
2029	1,908	295	171	0	0	0	0	0	0	0	475	95
2030	1,934	292	171	0	0	0	0	0	0	0	472	99
2031	1,960	290	171	0	0	0	0	0	0	0	469	103
2032	1.988	287	171	0	0	0	0	0	0	0	467	106
2033	2,055	285	171	0	0	0	0	0	0	0	468	110
2034	2,121	283	171	0	0	0	0	0	0	0	467	120
2035	2,187	281	171	0	0	0	0	0	0	0	466	130
2036	2,253	278	171	0	0	0	0	0	0	0	466	139
2037	2,319	276	171	0	0	0	0	0	0	0	465	149
2038	2,385	274	171	0	0	0	0	0	0	0	464	159
2039	2,451	274	171	0	0	0	0	0	0	0	466	168
2040	2,516	274	171	0	0	0	0	0	0	0	470	178
2041	2,580	274	171	0	0	0	0	0	0	0	472	187
2042	2,645	274	171	0	0	0	0	0	0	0	475	197
2043	2,709	274	171	0	0	0	0	0	0	0	478	206
2044	2,772	274	171	0	0	0	0	0	0	0	482	215
2045	2,835	274	171	0	0	0	0	0	0	0	484	225
2046	2,898	274	171	0	0	0	0	0	0	0	487	234
2047	2,960	274	171	0	0	0	0	0	0	0	489	243
2048	3,025	274	171	0	0	0	0	0	0	0	493	252
2049	3,092	274	171	0	0	0	0	0	0	0	496	262
2050	3,158	274	171	0	0	0	0	0	0	0	499	271
2051	3,223	274	171	0	0	0	0	0	0	0	502	281
2052	3,287	274	171	0	0	0	0	0	0	0	505	290
2053	3,355	274	171	0	0	0	0	0	0	0	508	300
2054	3,426	274	171	0	0	0	0	0	0	0	511	310
2055	3,496	274	171	0	0	0	0	0	0	0	514	320
2056	3,565	274	171	0	0	0	0	0	0	0	519	330
2057	3,633	274	171	0	0	0	0	0	0	0	521	340
2058	3,700	274	171	0	0	0	0	0	0	0	524	350
2059	3,766	274	171	0	0	0	0	0	0	0	527	360
2060	3,831	274	171	0	0	0	0	0	0	0	531	370

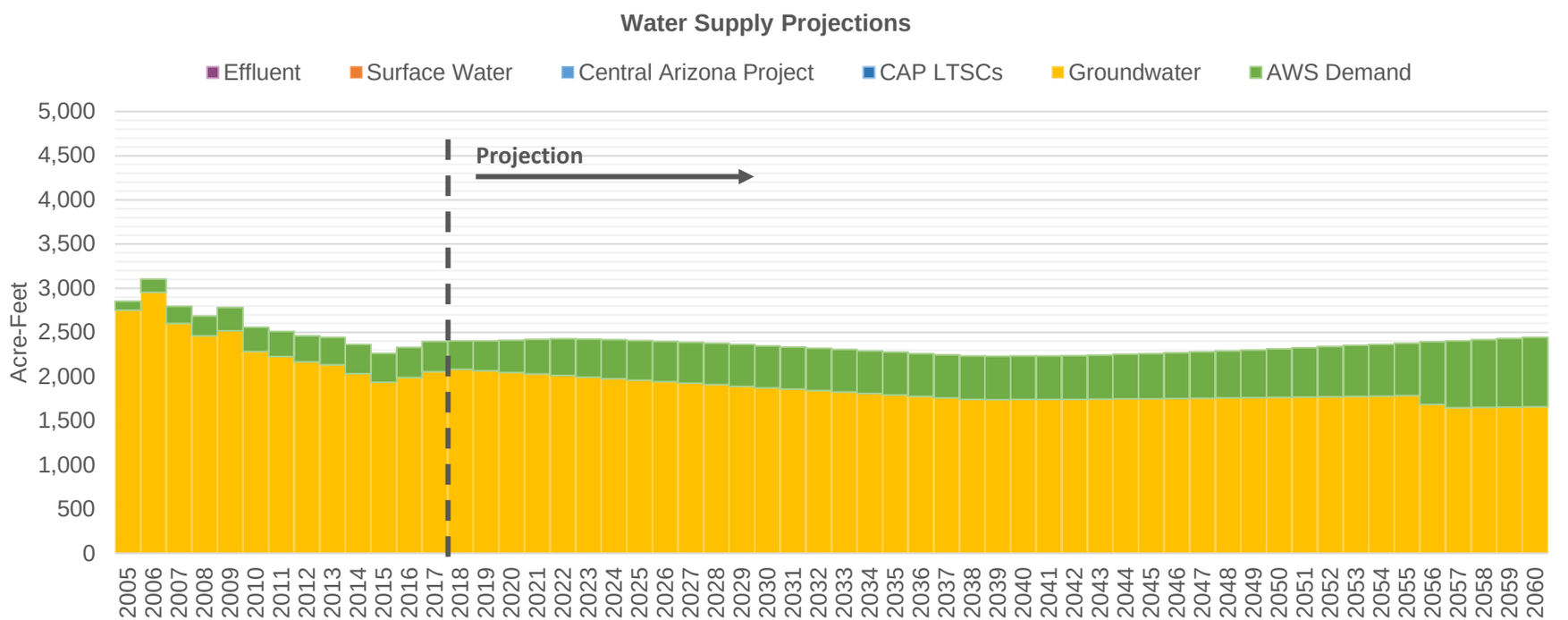
Central Arizona Project Service Area Model

CommWaterGreenVly

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

CommWaterGre

A. Official, Historic Climate [LSCRBS]

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Demand Assumptions

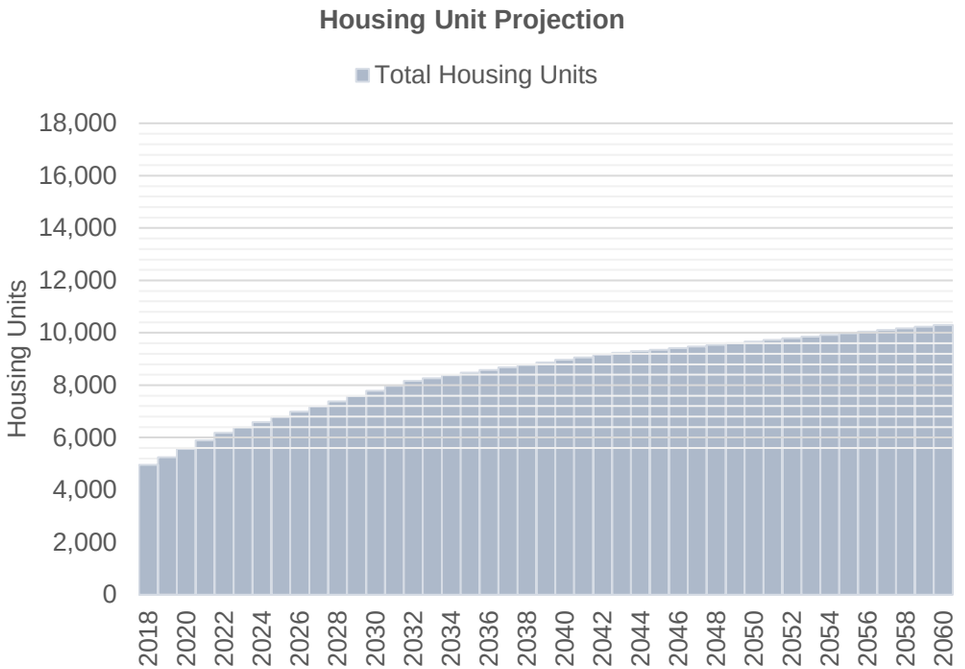
Water Supply Projections (Acre-Feet)

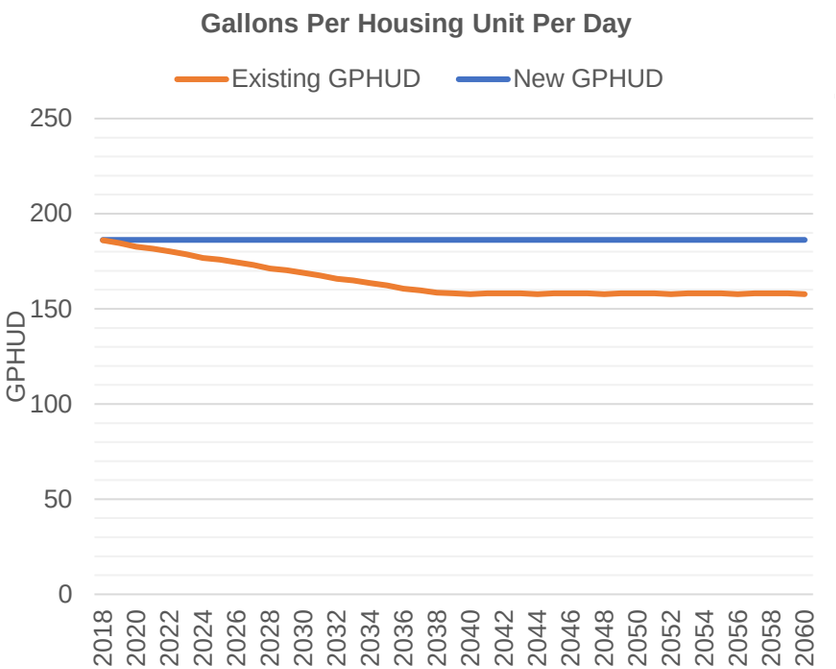
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	11,794	183	135	0	0	0	0	0	0	0	2,082	322
2019	11,963	181	135	0	0	0	0	0	0	0	2,066	338
2020	12,143	179	135	0	0	0	0	0	0	0	2,045	366
2021	12,332	178	135	0	0	0	0	0	0	0	2,029	391
2022	12,485	177	135	0	0	0	0	0	0	0	2,013	415
2023	12,546	176	135	0	0	0	0	0	0	0	1,991	434
2024	12,608	174	135	0	0	0	0	0	0	0	1,975	441
2025	12,669	173	135	0	0	0	0	0	0	0	1,958	449
2026	12,731	171	135	0	0	0	0	0	0	0	1,942	456
2027	12,787	170	135	0	0	0	0	0	0	0	1,926	463
2028	12,810	168	135	0	0	0	0	0	0	0	1,908	470
2029	12,833	167	135	0	0	0	0	0	0	0	1,891	472
2030	12,856	166	135	0	0	0	0	0	0	0	1,874	475
2031	12,879	165	135	0	0	0	0	0	0	0	1,857	478
2032	12.902	163	135	0	0	0	0	0	0	0	1.841	480
2033	12,914	162	135	0	0	0	0	0	0	0	1,824	483
2034	12,926	161	135	0	0	0	0	0	0	0	1,807	484
2035	12,937	159	135	0	0	0	0	0	0	0	1,791	485
2036	12,949	158	135	0	0	0	0	0	0	0	1,775	487
2037	12,961	157	135	0	0	0	0	0	0	0	1,759	488
2038	12,976	156	135	0	0	0	0	0	0	0	1,743	489
2039	12,990	155	135	0	0	0	0	0	0	0	1,739	491
2040	13,005	155	135	0	0	0	0	0	0	0	1,741	493
2041	13,020	155	135	0	0	0	0	0	0	0	1,741	494
2042	13,034	155	135	0	0	0	0	0	0	0	1,741	496
2043	13,094	155	135	0	0	0	0	0	0	0	1,745	498
2044	13,156	155	135	0	0	0	0	0	0	0	1,748	505
2045	13,217	155	135	0	0	0	0	0	0	0	1,750	512
2046	13,278	155	135	0	0	0	0	0	0	0	1,752	518
2047	13,338	155	135	0	0	0	0	0	0	0	1,755	525
2048	13,412	155	135	0	0	0	0	0	0	0	1,759	532
2049	13,497	155	135	0	0	0	0	0	0	0	1,762	540
2050	13,581	155	135	0	0	0	0	0	0	0	1,766	549
2051	13,665	155	135	0	0	0	0	0	0	0	1,769	558
2052	13,747	155	135	0	0	0	0	0	0	0	1,773	567
2053	13,833	155	135	0	0	0	0	0	0	0	1,776	576
2054	13,921	155	135	0	0	0	0	0	0	0	1,780	585
2055	14,009	155	135	0	0	0	0	0	0	0	1,784	595
2056	14,095	155	135	0	0	0	0	0	0	0	1,685	708
2057	14,180	155	135	0	0	0	0	0	0	0	1,648	757
2058	14,264	155	135	0	0	0	0	0	0	0	1,652	766
2059	14,346	155	135	0	0	0	0	0	0	0	1,655	775
2060	14,427	155	135	0	0	0	0	0	0	0	1,660	784

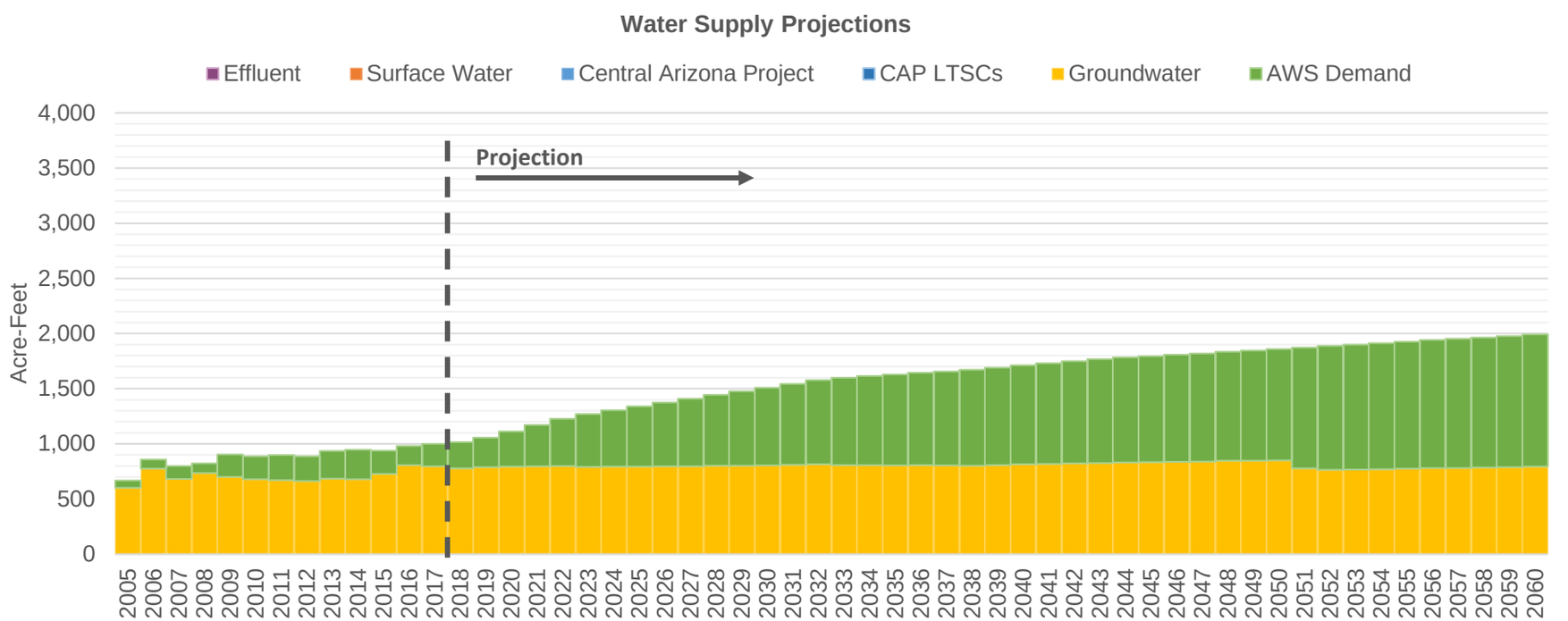
FarmersWC

Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

FarmersWC

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions

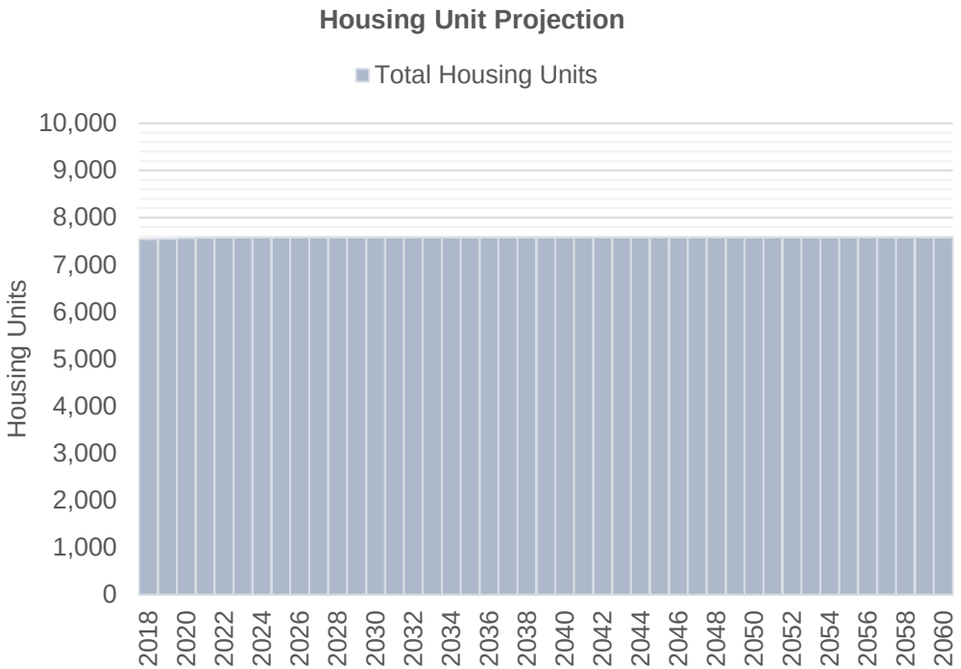
Water Supply Projections (Acre-Feet)

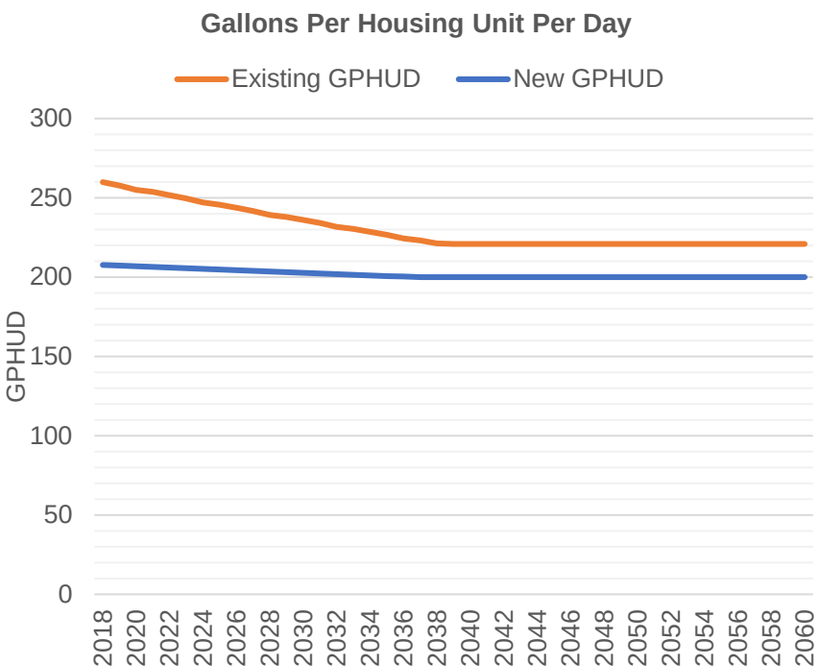
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,959	186	186	0	0	0	0	0	0	0	779	238
2019	5,250	185	186	0	0	0	0	0	0	0	790	266
2020	5,564	183	186	0	0	0	0	0	0	0	794	318
2021	5,894	182	186	0	0	0	0	0	0	0	797	373
2022	6,189	180	186	0	0	0	0	0	0	0	798	429
2023	6,388	179	186	0	0	0	0	0	0	0	792	479
2024	6,589	177	186	0	0	0	0	0	0	0	794	512
2025	6,790	176	186	0	0	0	0	0	0	0	794	546
2026	6,991	174	186	0	0	0	0	0	0	0	796	578
2027	7,192	173	186	0	0	0	0	0	0	0	798	611
2028	7,387	171	186	0	0	0	0	0	0	0	801	643
2029	7,583	170	186	0	0	0	0	0	0	0	802	673
2030	7,780	169	186	0	0	0	0	0	0	0	806	704
2031	7,976	168	186	0	0	0	0	0	0	0	810	733
2032	8.169	166	186	0	0	0	0	0	0	0	816	763
2033	8,271	165	186	0	0	0	0	0	0	0	808	792
2034	8,373	164	186	0	0	0	0	0	0	0	807	807
2035	8,474	162	186	0	0	0	0	0	0	0	806	822
2036	8,576	161	186	0	0	0	0	0	0	0	807	838
2037	8,677	160	186	0	0	0	0	0	0	0	804	853
2038	8,774	158	186	0	0	0	0	0	0	0	803	868
2039	8,872	158	186	0	0	0	0	0	0	0	807	883
2040	8,969	158	186	0	0	0	0	0	0	0	815	897
2041	9,065	158	186	0	0	0	0	0	0	0	818	912
2042	9,161	158	186	0	0	0	0	0	0	0	823	926
2043	9,232	158	186	0	0	0	0	0	0	0	826	941
2044	9,294	158	186	0	0	0	0	0	0	0	832	952
2045	9,356	158	186	0	0	0	0	0	0	0	833	961
2046	9,418	158	186	0	0	0	0	0	0	0	837	970
2047	9,479	158	186	0	0	0	0	0	0	0	840	980
2048	9,541	158	186	0	0	0	0	0	0	0	847	989
2049	9,605	158	186	0	0	0	0	0	0	0	848	998
2050	9,668	158	186	0	0	0	0	0	0	0	852	1,008
2051	9,731	158	186	0	0	0	0	0	0	0	779	1,093
2052	9,792	158	186	0	0	0	0	0	0	0	766	1,122
2053	9,856	158	186	0	0	0	0	0	0	0	767	1,132
2054	9,921	158	186	0	0	0	0	0	0	0	771	1,141
2055	9,985	158	186	0	0	0	0	0	0	0	774	1,151
2056	10,049	158	186	0	0	0	0	0	0	0	781	1,161
2057	10,111	158	186	0	0	0	0	0	0	0	781	1,170
2058	10,173	158	186	0	0	0	0	0	0	0	785	1,180
2059	10,233	158	186	0	0	0	0	0	0	0	789	1,189
2060	10,293	158	186	0	0	0	0	0	0	0	795	1,198

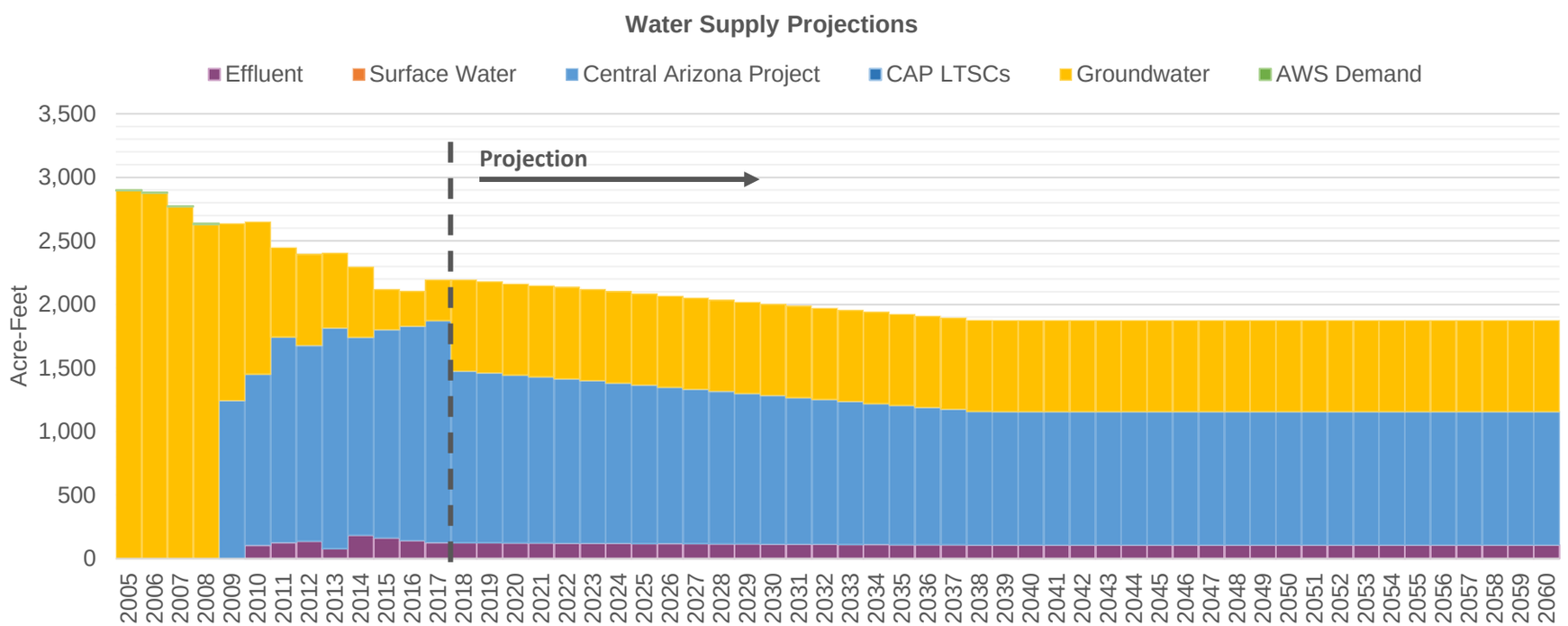
Central Arizona Project Service Area Model

FWID

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

FWID

A. Official, Historic Climate [LSCRBS]

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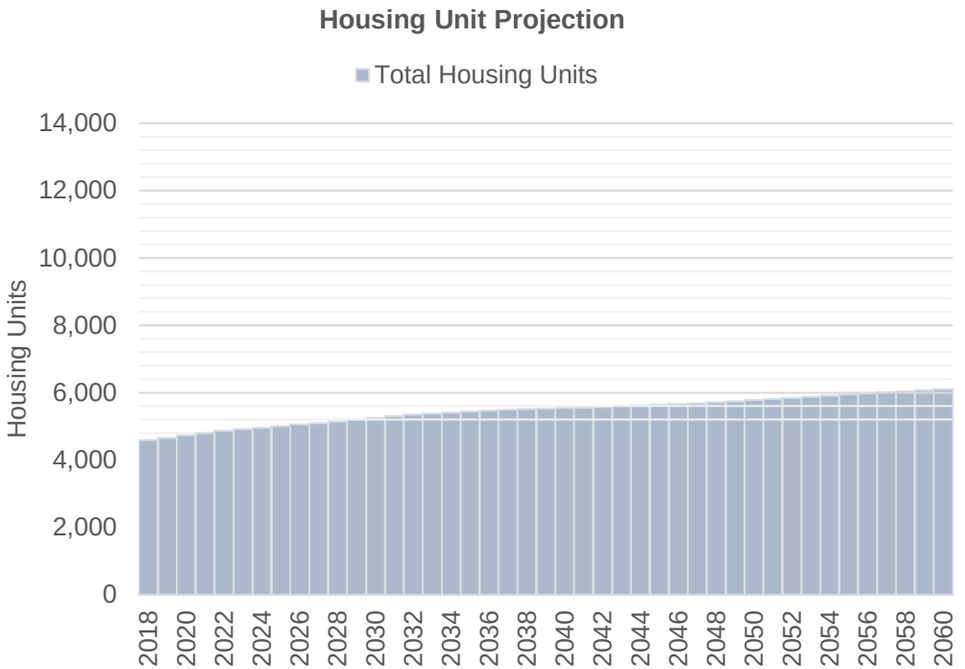
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

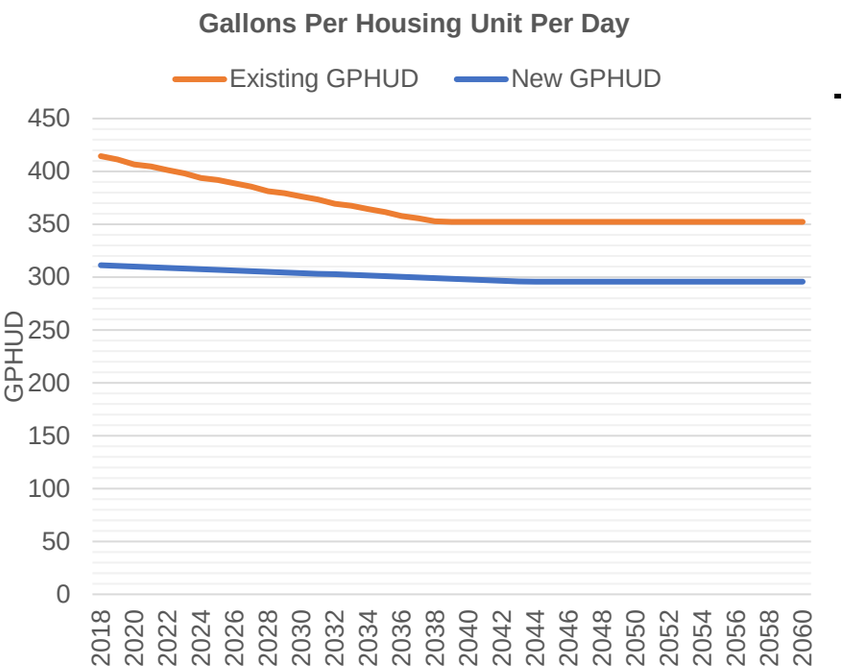
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	7,542	260	208	125	0	0	0	1,350	1,523	0	719	0
2019	7,552	258	207	125	0	0	0	1,335	1,538	0	719	0
2020	7,563	255	207	124	0	0	0	1,321	1,552	0	719	0
2021	7,574	254	206	123	0	0	0	1,307	1,566	0	719	0
2022	7,581	252	206	122	0	0	0	1,293	1,580	0	719	0
2023	7,581	250	206	122	0	0	0	1,277	1,596	0	719	0
2024	7,581	247	205	121	0	0	0	1,261	1,612	0	719	0
2025	7,581	246	205	120	0	0	0	1,245	1,628	0	719	0
2026	7,581	244	204	119	0	0	0	1,230	1,643	0	719	0
2027	7,581	242	204	118	0	0	0	1,214	1,659	0	719	0
2028	7,581	239	204	117	0	0	0	1,199	1,674	0	719	0
2029	7,581	238	203	116	0	0	0	1,183	1,690	0	719	0
2030	7,581	236	203	115	0	0	0	1,168	1,705	0	719	0
2031	7,581	234	202	114	0	0	0	1,153	1,720	0	719	0
2032	7,581	232	202	113	0	0	0	1,138	1,735	0	719	0
2033	7,581	230	202	112	0	0	0	1,124	1,749	0	719	0
2034	7,581	229	201	111	0	0	0	1,109	1,764	0	719	0
2035	7,581	227	201	110	0	0	0	1,095	1,778	0	719	0
2036	7,581	224	200	110	0	0	0	1,080	1,793	0	719	0
2037	7,581	223	200	109	0	0	0	1,065	1,808	0	719	0
2038	7,581	221	200	108	0	0	0	1,051	1,822	0	719	0
2039	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2040	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2041	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2042	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2043	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2044	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2045	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2046	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2047	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2048	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2049	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2050	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2051	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2052	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2053	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2054	7,581	221	200	107	0	0	0	1,049	1,731	0	719	0
2055	7,581	221	200	107	0	0	0	1,049	1,532	0	719	0
2056	7,581	221	200	107	0	0	0	1,049	1,731	0	719	0
2057	7,581	221	200	107	0	0	0	1,049	1,731	0	719	0
2058	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2059	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0
2060	7,581	221	200	107	0	0	0	1,049	1,824	0	719	0

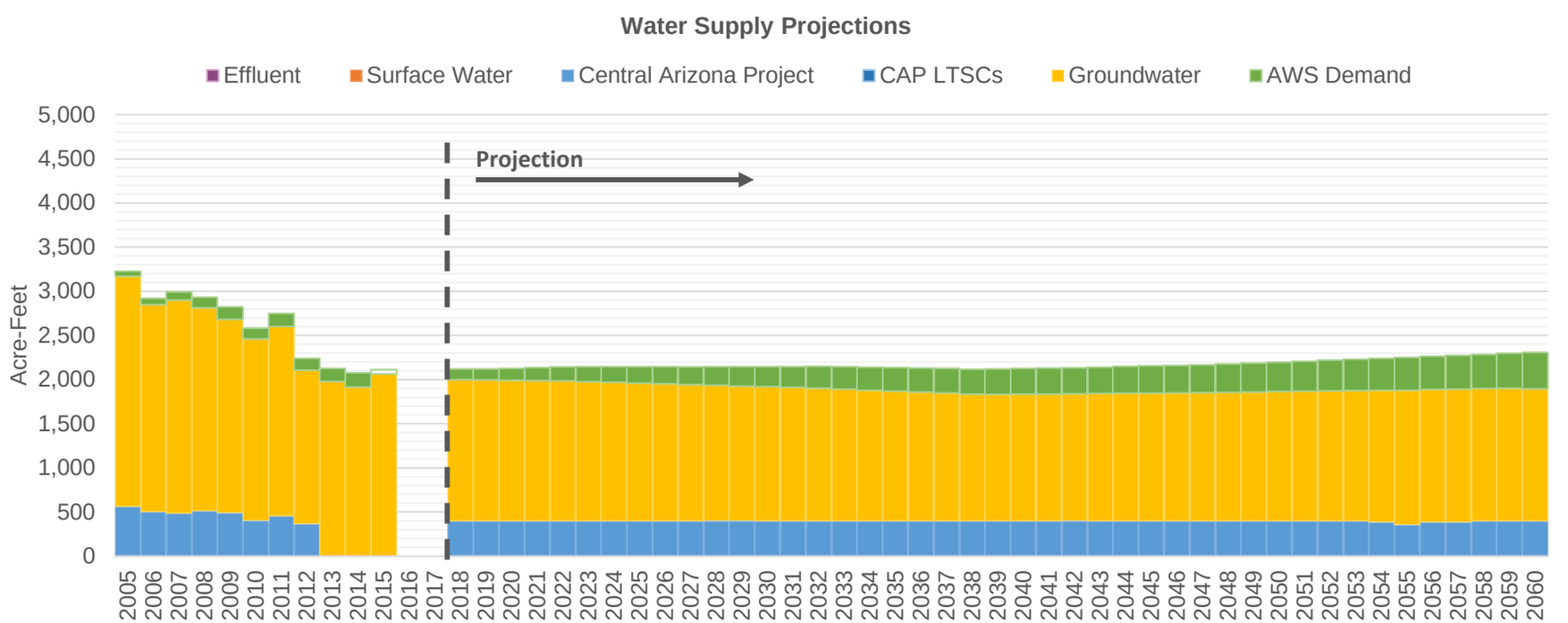
Central Arizona Project Service Area Model

GVDWID

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

GVDWID

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

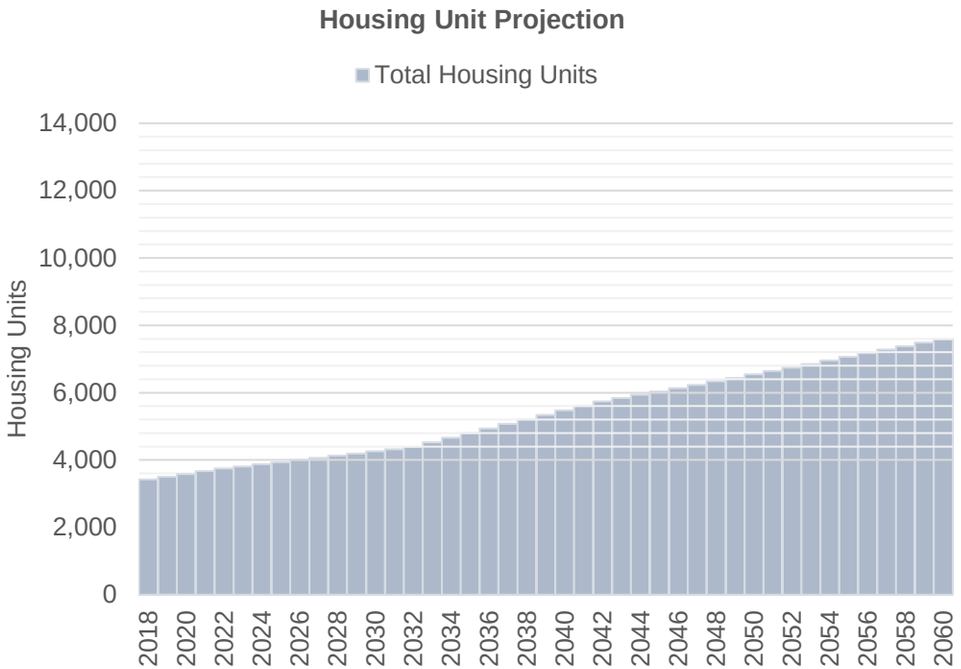
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

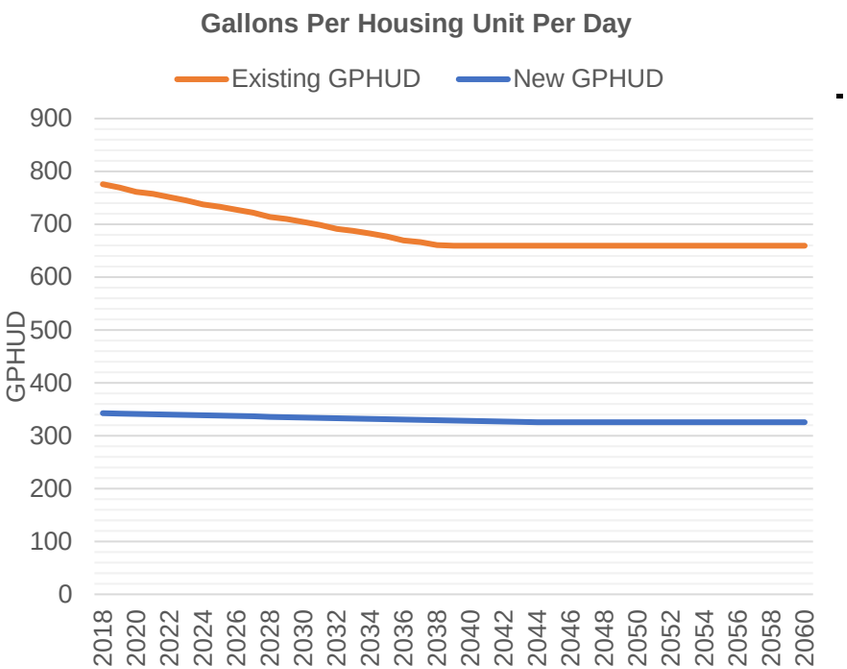
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,590	414	311	0	0	0	399	0	0	0	1,602	119
2019	4,656	411	311	0	0	0	399	0	0	0	1,597	125
2020	4,726	407	310	0	0	0	399	0	0	0	1,594	135
2021	4,800	405	309	0	0	0	399	0	0	0	1,591	146
2022	4,867	401	309	0	0	0	399	0	0	0	1,587	158
2023	4,913	398	308	0	0	0	399	0	0	0	1,579	169
2024	4,959	394	308	0	0	0	399	0	0	0	1,571	177
2025	5,005	392	307	0	0	0	399	0	0	0	1,562	185
2026	5,051	389	306	0	0	0	399	0	0	0	1,553	193
2027	5,098	386	306	0	0	0	399	0	0	0	1,545	201
2028	5,147	381	305	0	0	0	399	0	0	0	1,537	210
2029	5,197	379	304	0	0	0	399	0	0	0	1,528	219
2030	5,246	376	304	0	0	0	399	0	0	0	1,520	228
2031	5,296	373	303	0	0	0	399	0	0	0	1,512	237
2032	5.345	369	303	0	0	0	399	0	0	0	1.504	247
2033	5,375	367	302	0	0	0	399	0	0	0	1,492	256
2034	5,405	364	301	0	0	0	399	0	0	0	1,481	261
2035	5,435	362	301	0	0	0	399	0	0	0	1,470	267
2036	5,464	358	300	0	0	0	399	0	0	0	1,460	273
2037	5,494	356	300	0	0	0	399	0	0	0	1,449	278
2038	5,511	353	299	0	0	0	399	0	0	0	1,436	283
2039	5,527	352	298	0	0	0	399	0	0	0	1,434	286
2040	5,543	352	298	0	0	0	399	0	0	0	1,437	290
2041	5,559	352	297	0	0	0	399	0	0	0	1,437	293
2042	5,575	352	297	0	0	0	399	0	0	0	1,439	296
2043	5,604	352	296	0	0	0	399	0	0	0	1,442	299
2044	5,625	352	296	0	0	0	399	0	0	0	1,445	305
2045	5,645	352	296	0	0	0	399	0	0	0	1,447	309
2046	5,665	352	296	0	0	0	399	0	0	0	1,450	313
2047	5,685	352	296	0	0	0	399	0	0	0	1,453	317
2048	5,712	352	296	0	0	0	399	0	0	0	1,457	321
2049	5,745	352	296	0	0	0	399	0	0	0	1,461	326
2050	5,777	352	296	0	0	0	399	0	0	0	1,465	333
2051	5,810	352	296	0	0	0	399	0	0	0	1,470	339
2052	5,841	352	296	0	0	0	399	0	0	0	1,475	346
2053	5,875	352	296	0	0	0	399	0	0	0	1,478	352
2054	5,910	352	296	0	0	0	386	0	0	0	1,493	361
2055	5,944	352	296	0	0	0	358	0	0	0	1,520	374
2056	5,978	352	296	0	0	0	386	0	0	0	1,503	375
2057	6,012	352	296	0	0	0	386	0	0	0	1,506	382
2058	6,045	352	296	0	0	0	399	0	0	0	1,500	386
2059	6,077	352	296	0	0	0	399	0	0	0	1,504	393
2060	6,109	352	296	0	0	0	399	0	0	0	1,498	411

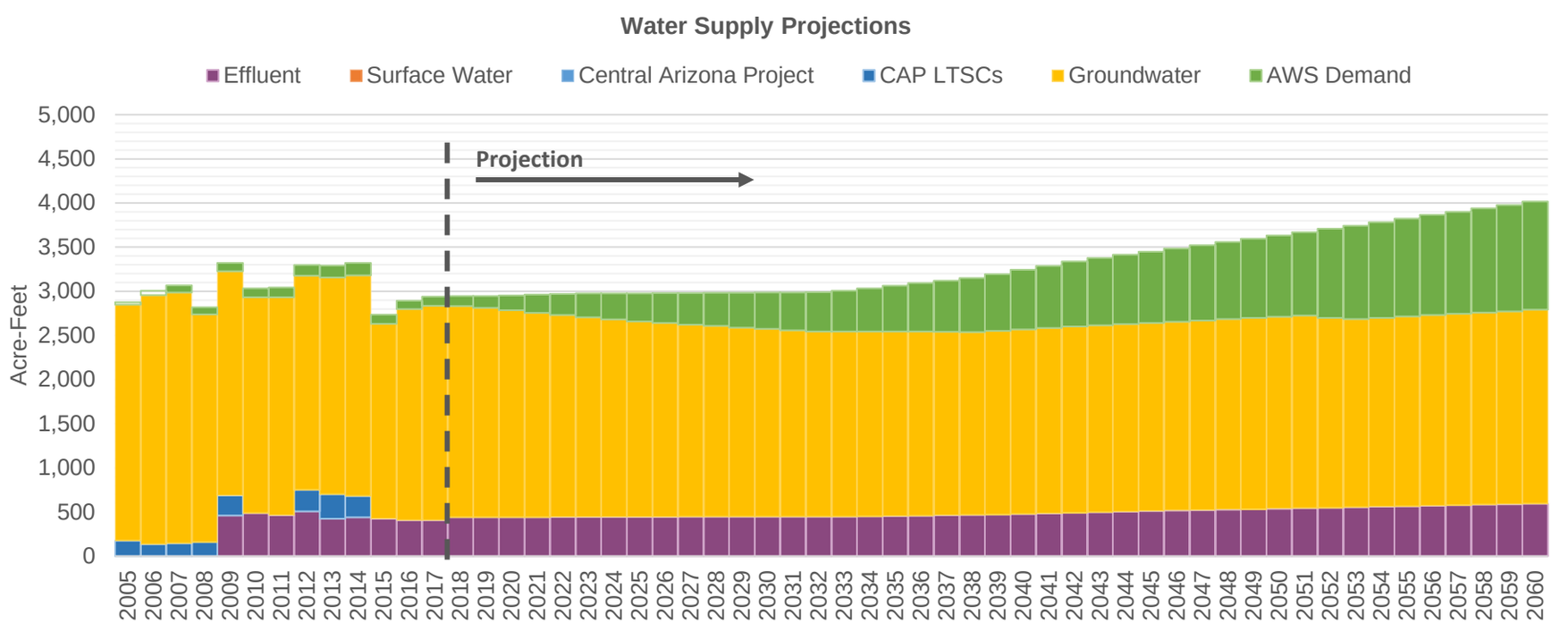
Central Arizona Project Service Area Model

LagoDelOro

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

LagoDelOro

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

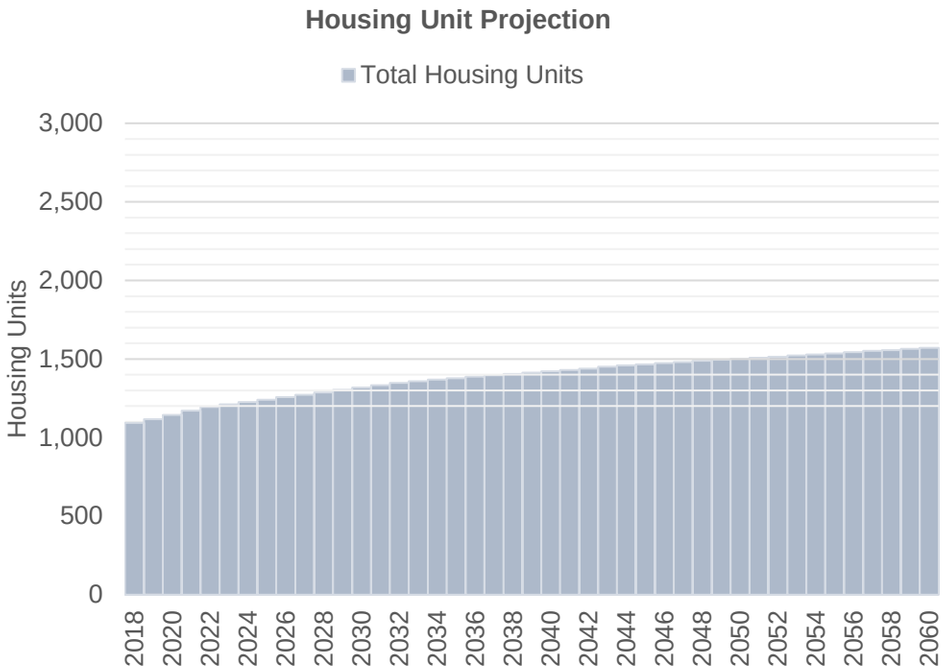
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

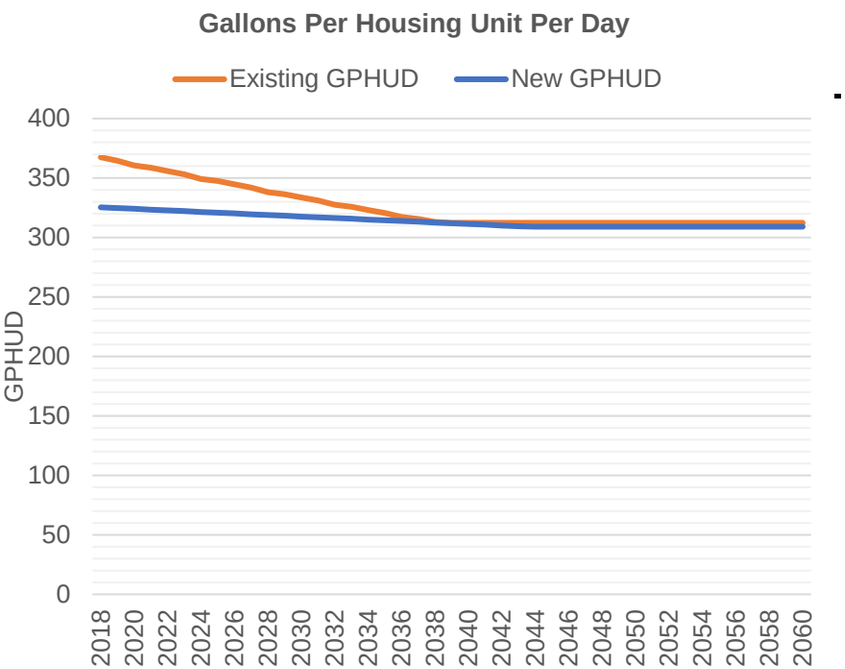
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,423	776	343	441	0	0	0	0	0	0	2,391	116
2019	3,499	770	342	441	0	0	0	0	0	0	2,371	135
2020	3,581	761	341	441	0	0	0	0	0	0	2,343	169
2021	3,668	757	341	442	0	0	0	0	0	0	2,314	206
2022	3,748	751	340	443	0	0	0	0	0	0	2,288	240
2023	3,811	745	339	444	0	0	0	0	0	0	2,260	271
2024	3,875	737	339	445	0	0	0	0	0	0	2,238	294
2025	3,939	733	338	445	0	0	0	0	0	0	2,215	318
2026	4,002	728	337	445	0	0	0	0	0	0	2,196	338
2027	4,066	722	337	446	0	0	0	0	0	0	2,177	357
2028	4,130	714	336	446	0	0	0	0	0	0	2,161	376
2029	4,193	710	335	446	0	0	0	0	0	0	2,143	394
2030	4,257	705	335	446	0	0	0	0	0	0	2,128	412
2031	4,320	699	334	447	0	0	0	0	0	0	2,111	429
2032	4.387	691	333	447	0	0	0	0	0	0	2.099	445
2033	4,524	688	333	447	0	0	0	0	0	0	2,099	460
2034	4,660	682	332	450	0	0	0	0	0	0	2,095	490
2035	4,797	677	331	454	0	0	0	0	0	0	2,090	520
2036	4,933	670	331	458	0	0	0	0	0	0	2,085	551
2037	5,069	666	330	463	0	0	0	0	0	0	2,077	582
2038	5,204	661	329	467	0	0	0	0	0	0	2,071	613
2039	5,338	659	329	471	0	0	0	0	0	0	2,079	644
2040	5,472	659	328	478	0	0	0	0	0	0	2,092	674
2041	5,605	659	327	485	0	0	0	0	0	0	2,100	704
2042	5,738	659	327	492	0	0	0	0	0	0	2,110	734
2043	5,842	659	326	499	0	0	0	0	0	0	2,115	764
2044	5,941	659	326	505	0	0	0	0	0	0	2,124	787
2045	6,040	659	326	511	0	0	0	0	0	0	2,130	809
2046	6,137	659	326	516	0	0	0	0	0	0	2,138	831
2047	6,234	659	326	521	0	0	0	0	0	0	2,147	853
2048	6,335	659	326	527	0	0	0	0	0	0	2,158	875
2049	6,439	659	326	533	0	0	0	0	0	0	2,165	897
2050	6,542	659	326	538	0	0	0	0	0	0	2,174	921
2051	6,643	659	326	543	0	0	0	0	0	0	2,183	944
2052	6,744	659	326	549	0	0	0	0	0	0	2,150	1,010
2053	6,849	659	326	555	0	0	0	0	0	0	2,129	1,060
2054	6,959	659	326	560	0	0	0	0	0	0	2,139	1,083
2055	7,067	659	326	566	0	0	0	0	0	0	2,149	1,108
2056	7,174	659	326	572	0	0	0	0	0	0	2,161	1,132
2057	7,280	659	326	578	0	0	0	0	0	0	2,167	1,156
2058	7,383	659	326	584	0	0	0	0	0	0	2,175	1,180
2059	7,486	659	326	589	0	0	0	0	0	0	2,184	1,203
2060	7,586	659	326	595	0	0	0	0	0	0	2,197	1,226

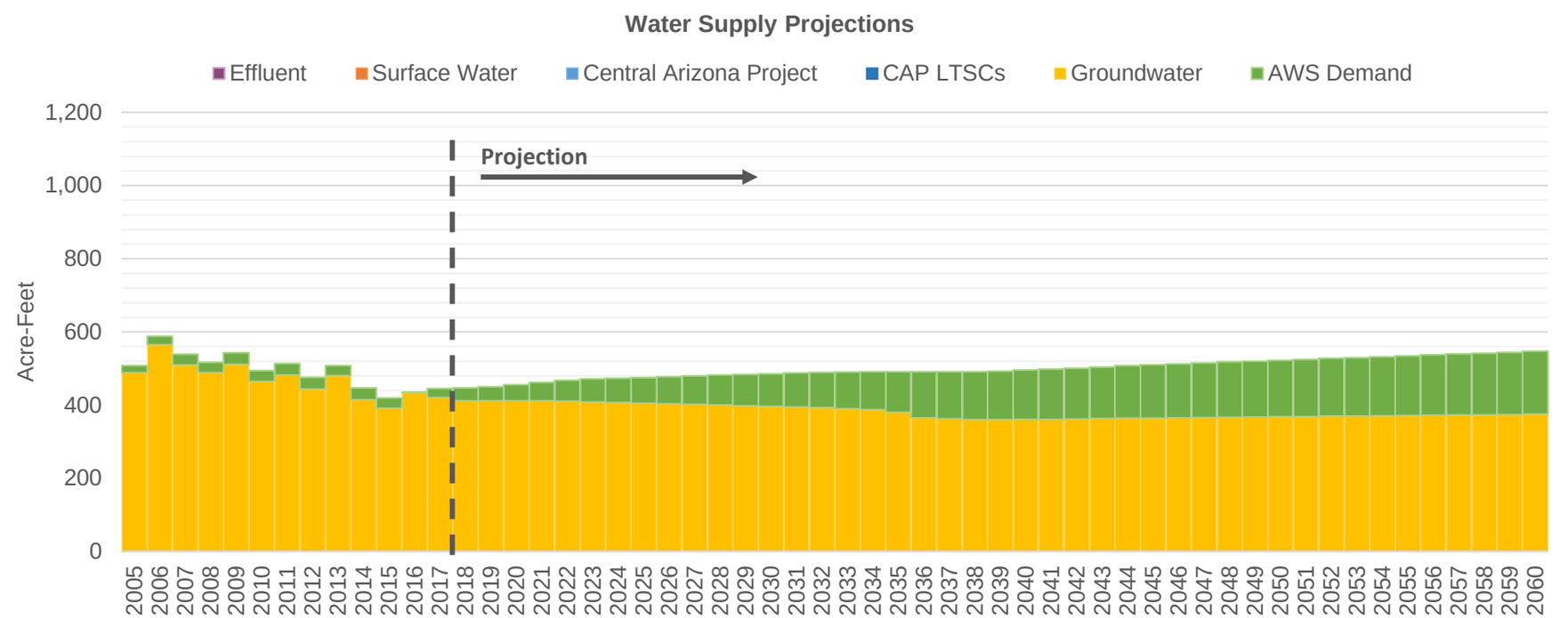
Central Arizona Project Service Area Model

LasQuintas

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

LasQuintas

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

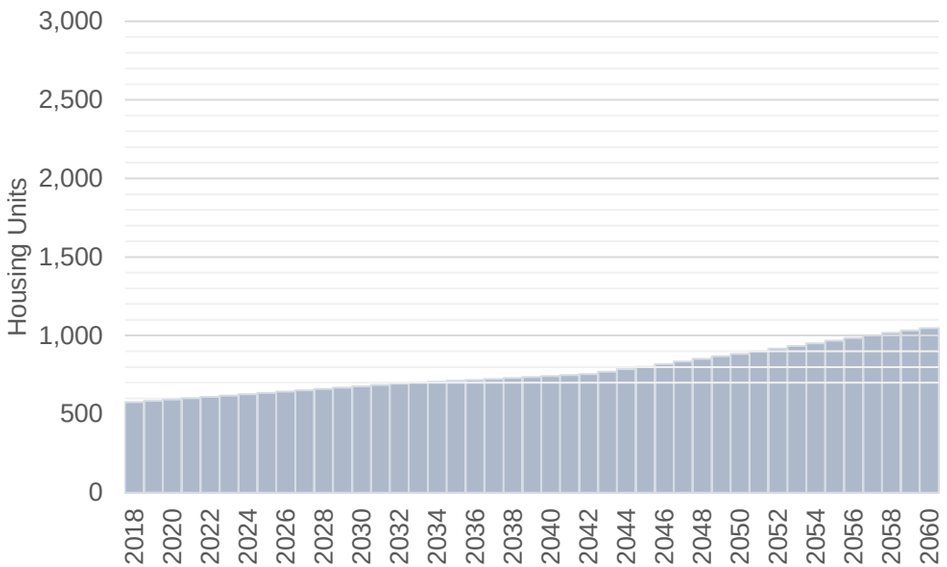
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,093	367	325	0	0	0	0	0	0	0	411	36
2019	1,117	365	325	0	0	0	0	0	0	0	412	38
2020	1,143	361	324	0	0	0	0	0	0	0	412	44
2021	1,171	359	323	0	0	0	0	0	0	0	412	50
2022	1,195	356	323	0	0	0	0	0	0	0	411	57
2023	1,211	353	322	0	0	0	0	0	0	0	409	63
2024	1,226	349	321	0	0	0	0	0	0	0	407	67
2025	1,241	347	321	0	0	0	0	0	0	0	405	70
2026	1,257	345	320	0	0	0	0	0	0	0	404	74
2027	1,273	342	320	0	0	0	0	0	0	0	402	78
2028	1,288	338	319	0	0	0	0	0	0	0	400	82
2029	1,303	336	318	0	0	0	0	0	0	0	398	86
2030	1,318	334	318	0	0	0	0	0	0	0	396	90
2031	1,333	331	317	0	0	0	0	0	0	0	394	93
2032	1,348	328	316	0	0	0	0	0	0	0	393	97
2033	1,358	326	316	0	0	0	0	0	0	0	390	101
2034	1,368	323	315	0	0	0	0	0	0	0	388	103
2035	1,377	321	314	0	0	0	0	0	0	0	381	110
2036	1,387	317	314	0	0	0	0	0	0	0	365	126
2037	1,396	315	313	0	0	0	0	0	0	0	363	128
2038	1,405	313	313	0	0	0	0	0	0	0	360	131
2039	1,413	312	312	0	0	0	0	0	0	0	360	133
2040	1,421	312	311	0	0	0	0	0	0	0	361	135
2041	1,430	312	311	0	0	0	0	0	0	0	361	137
2042	1,438	312	310	0	0	0	0	0	0	0	362	139
2043	1,451	312	309	0	0	0	0	0	0	0	363	141
2044	1,459	312	309	0	0	0	0	0	0	0	364	144
2045	1,466	312	309	0	0	0	0	0	0	0	364	146
2046	1,474	312	309	0	0	0	0	0	0	0	365	148
2047	1,481	312	309	0	0	0	0	0	0	0	366	150
2048	1,488	312	309	0	0	0	0	0	0	0	367	151
2049	1,495	312	309	0	0	0	0	0	0	0	367	153
2050	1,502	312	309	0	0	0	0	0	0	0	368	155
2051	1,508	312	309	0	0	0	0	0	0	0	368	157
2052	1,515	312	309	0	0	0	0	0	0	0	370	158
2053	1,522	312	309	0	0	0	0	0	0	0	370	160
2054	1,529	312	309	0	0	0	0	0	0	0	371	162
2055	1,536	312	309	0	0	0	0	0	0	0	371	163
2056	1,544	312	309	0	0	0	0	0	0	0	373	165
2057	1,551	312	309	0	0	0	0	0	0	0	373	167
2058	1,557	312	309	0	0	0	0	0	0	0	373	169
2059	1,564	312	309	0	0	0	0	0	0	0	374	170
2060	1,571	312	309	0	0	0	0	0	0	0	375	172

LosCerros

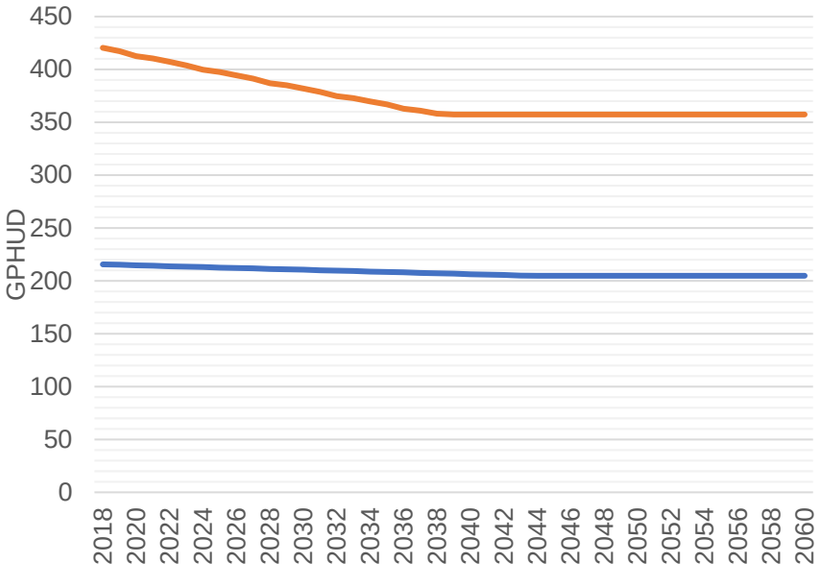
Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]

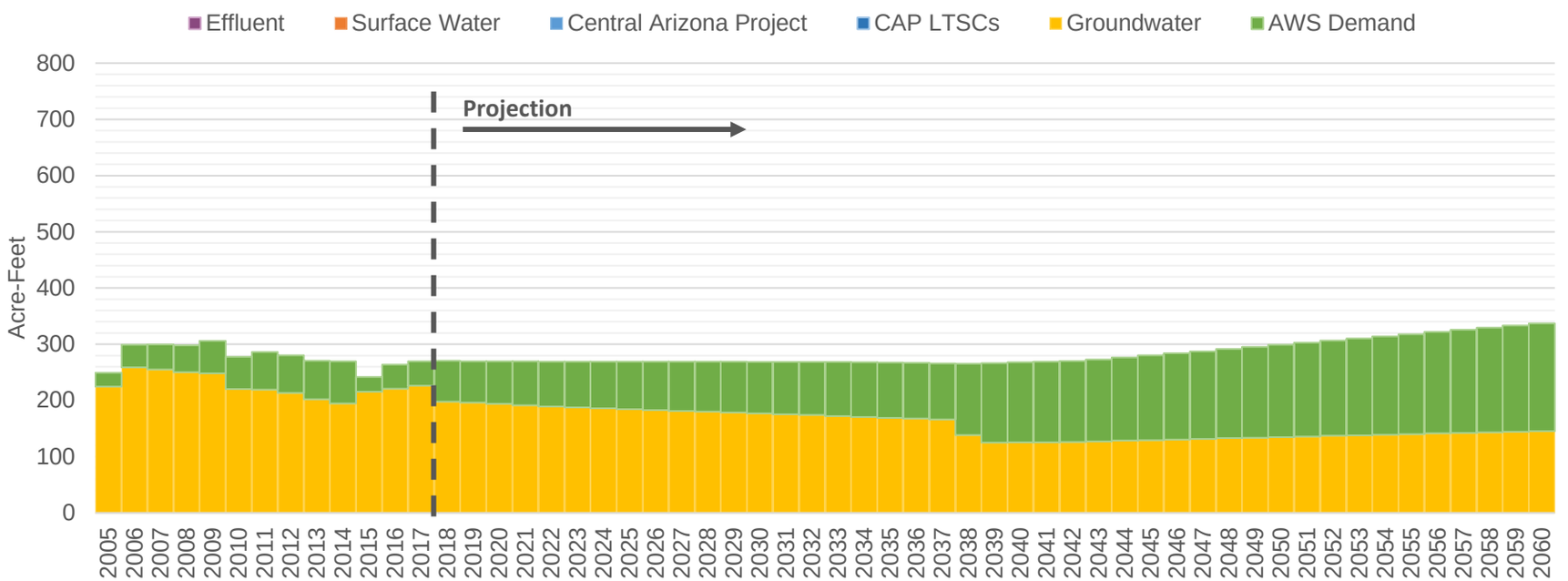
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

LosCerros

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

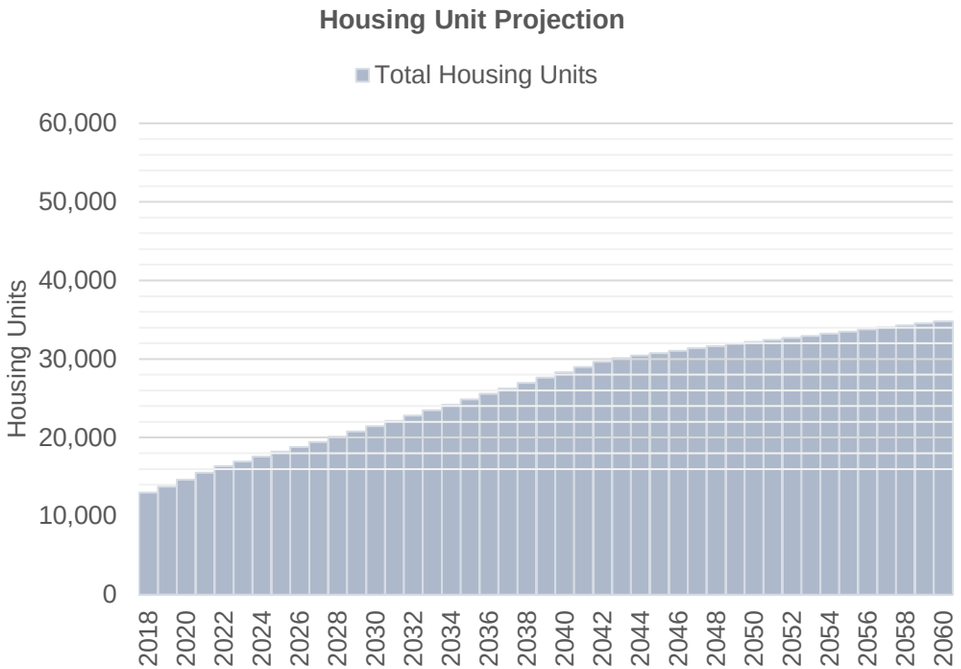
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

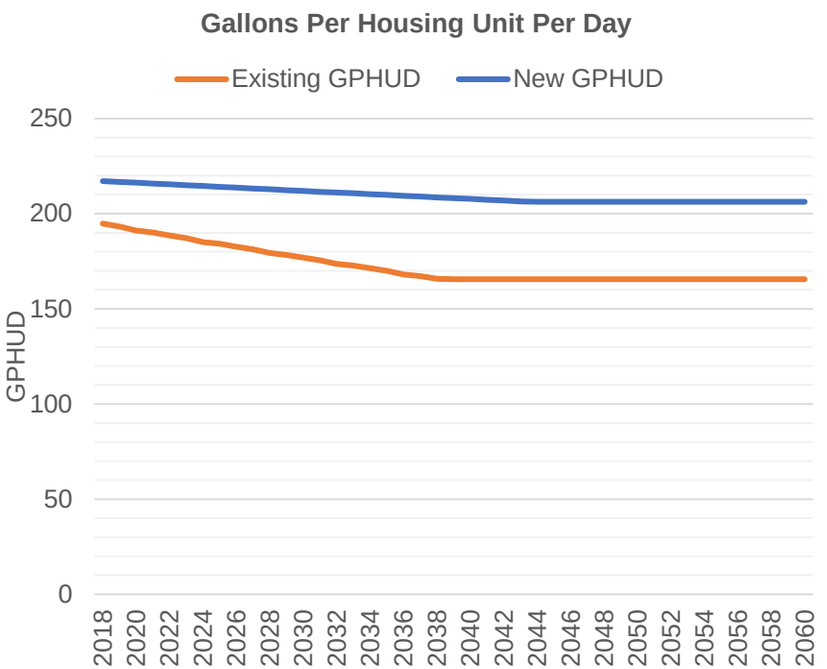
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	577	420	216	0	0	0	0	0	0	0	198	73
2019	585	417	215	0	0	0	0	0	0	0	196	74
2020	593	413	215	0	0	0	0	0	0	0	194	76
2021	602	410	214	0	0	0	0	0	0	0	192	78
2022	610	407	214	0	0	0	0	0	0	0	190	80
2023	619	404	213	0	0	0	0	0	0	0	188	82
2024	627	400	213	0	0	0	0	0	0	0	186	83
2025	635	397	213	0	0	0	0	0	0	0	184	85
2026	644	394	212	0	0	0	0	0	0	0	183	86
2027	652	391	212	0	0	0	0	0	0	0	181	88
2028	661	387	211	0	0	0	0	0	0	0	180	89
2029	669	385	211	0	0	0	0	0	0	0	178	90
2030	677	382	210	0	0	0	0	0	0	0	177	92
2031	686	379	210	0	0	0	0	0	0	0	176	93
2032	694	375	210	0	0	0	0	0	0	0	174	95
2033	700	373	209	0	0	0	0	0	0	0	172	96
2034	706	370	209	0	0	0	0	0	0	0	171	97
2035	712	367	208	0	0	0	0	0	0	0	169	98
2036	718	363	208	0	0	0	0	0	0	0	168	99
2037	724	361	208	0	0	0	0	0	0	0	166	100
2038	730	358	207	0	0	0	0	0	0	0	138	127
2039	736	357	207	0	0	0	0	0	0	0	125	141
2040	742	357	206	0	0	0	0	0	0	0	126	142
2041	748	357	206	0	0	0	0	0	0	0	126	143
2042	754	357	205	0	0	0	0	0	0	0	126	144
2043	769	357	205	0	0	0	0	0	0	0	127	145
2044	786	357	205	0	0	0	0	0	0	0	129	148
2045	802	357	205	0	0	0	0	0	0	0	130	151
2046	818	357	205	0	0	0	0	0	0	0	131	153
2047	834	357	205	0	0	0	0	0	0	0	132	156
2048	851	357	205	0	0	0	0	0	0	0	133	158
2049	868	357	205	0	0	0	0	0	0	0	134	161
2050	884	357	205	0	0	0	0	0	0	0	135	164
2051	901	357	205	0	0	0	0	0	0	0	136	167
2052	917	357	205	0	0	0	0	0	0	0	137	170
2053	933	357	205	0	0	0	0	0	0	0	138	172
2054	951	357	205	0	0	0	0	0	0	0	139	175
2055	967	357	205	0	0	0	0	0	0	0	140	178
2056	984	357	205	0	0	0	0	0	0	0	142	180
2057	1,000	357	205	0	0	0	0	0	0	0	142	183
2058	1,017	357	205	0	0	0	0	0	0	0	143	186
2059	1,033	357	205	0	0	0	0	0	0	0	144	189
2060	1,048	357	205	0	0	0	0	0	0	0	146	191

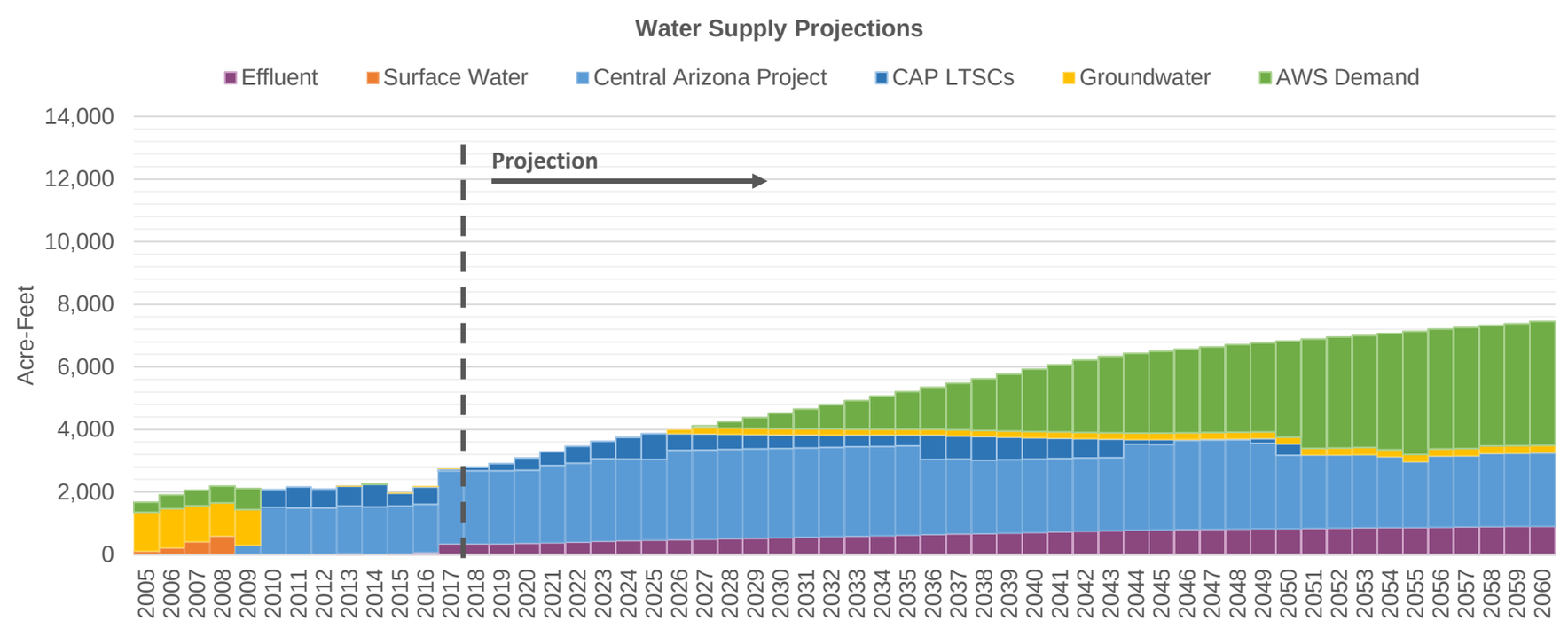
Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]

Marana







Central Arizona Project Service Area Model

Marana

A. Official, Historic Climate [LSCRBS]

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Demand Assumptions

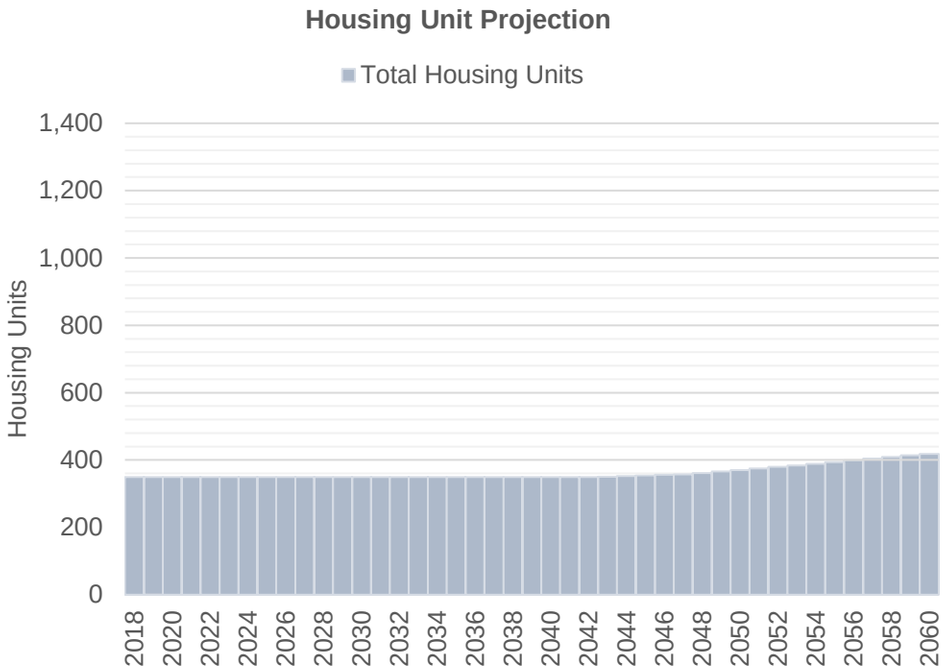
Water Supply Projections (Acre-Feet)

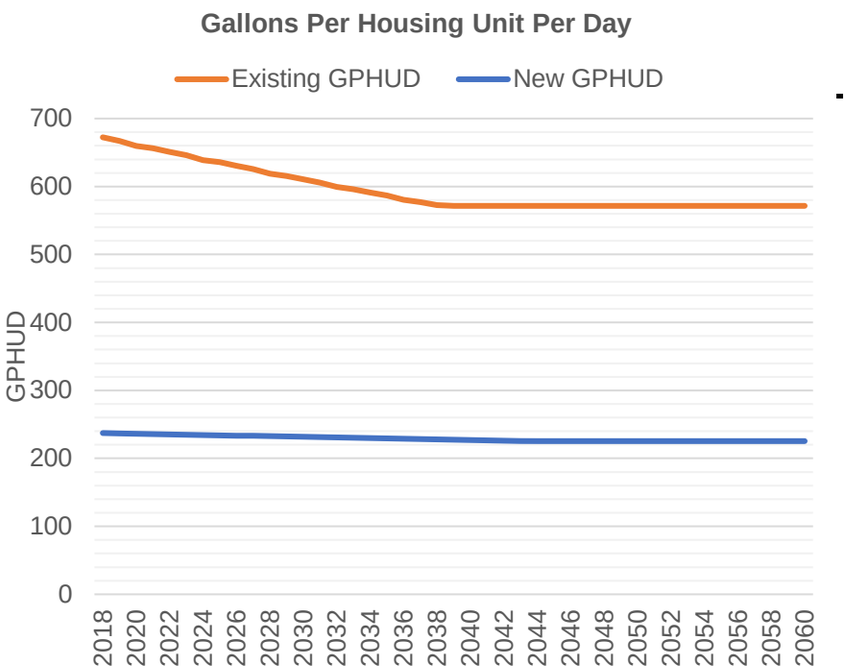
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	12,985	195	217	345	0	0	0	2,336	0	115	0	0
2019	13,761	193	217	345	0	0	0	2,336	0	234	0	0
2020	14,619	191	216	359	0	0	0	2,336	0	397	0	0
2021	15,522	190	216	381	0	0	0	2,463	0	437	0	0
2022	16,350	189	215	405	0	0	0	2,519	0	544	0	0
2023	16,964	187	215	428	0	0	0	2,636	0	554	0	0
2024	17,582	185	215	446	0	0	0	2,608	0	692	0	0
2025	18,201	184	214	462	0	0	0	2,583	0	824	0	0
2026	18,822	183	214	477	0	0	0	2,851	0	540	125	0
2027	19,451	181	213	492	0	0	0	2,851	0	513	197	65
2028	20,117	179	213	508	0	0	0	2,851	0	488	195	213
2029	20,785	178	212	525	0	0	0	2,851	0	463	194	352
2030	21,454	177	212	541	0	0	0	2,851	0	440	193	495
2031	22,123	175	212	557	0	0	0	2,851	0	418	192	636
2032	22,793	174	211	574	0	0	0	2,851	0	397	191	781
2033	23,489	173	211	591	0	0	0	2,851	0	377	191	915
2034	24,183	171	210	607	0	0	0	2,851	0	358	191	1,057
2035	24,877	170	210	624	0	0	0	2,851	0	341	191	1,196
2036	25,569	168	209	642	0	0	0	2,404	0	770	192	1,341
2037	26,260	167	209	660	0	0	0	2,391	0	745	193	1,489
2038	26,948	166	209	675	0	0	0	2,336	0	763	194	1,646
2039	27,634	166	208	692	0	0	0	2,336	0	725	195	1,815
2040	28,317	166	208	711	0	0	0	2,336	0	688	196	1,994
2041	28,996	166	207	731	0	0	0	2,336	0	654	198	2,148
2042	29,672	166	207	748	0	0	0	2,336	0	621	200	2,310
2043	30,123	166	207	766	0	0	0	2,336	0	590	202	2,444
2044	30,435	166	206	782	0	0	0	2,747	0	150	205	2,550
2045	30,746	166	206	793	0	0	0	2,726	0	163	207	2,604
2046	31,053	166	206	801	0	0	0	2,851	0	30	210	2,674
2047	31,359	166	206	809	0	0	0	2,851	0	29	212	2,735
2048	31,641	166	206	818	0	0	0	2,851	0	27	215	2,805
2049	31,906	166	206	828	0	0	0	2,726	0	151	217	2,845
2050	32,168	166	206	834	0	0	0	2,336	0	364	220	3,074
2051	32,427	166	206	842	0	0	0	2,336	0	0	222	3,488
2052	32,683	166	206	849	0	0	0	2,336	0	0	225	3,550
2053	32,949	166	206	858	0	0	0	2,336	0	0	227	3,586
2054	33,224	166	206	864	0	0	0	2,261	0	0	230	3,716
2055	33,496	166	206	872	0	0	0	2,098	0	0	232	3,931
2056	33,765	166	206	880	0	0	0	2,261	0	0	235	3,834
2057	34,029	166	206	889	0	0	0	2,261	0	0	237	3,871
2058	34,290	166	206	895	0	0	0	2,336	0	0	240	3,847
2059	34,546	166	206	902	0	0	0	2,336	0	0	243	3,897
2060	34,798	166	206	910	0	0	0	2,336	0	0	245	3,960

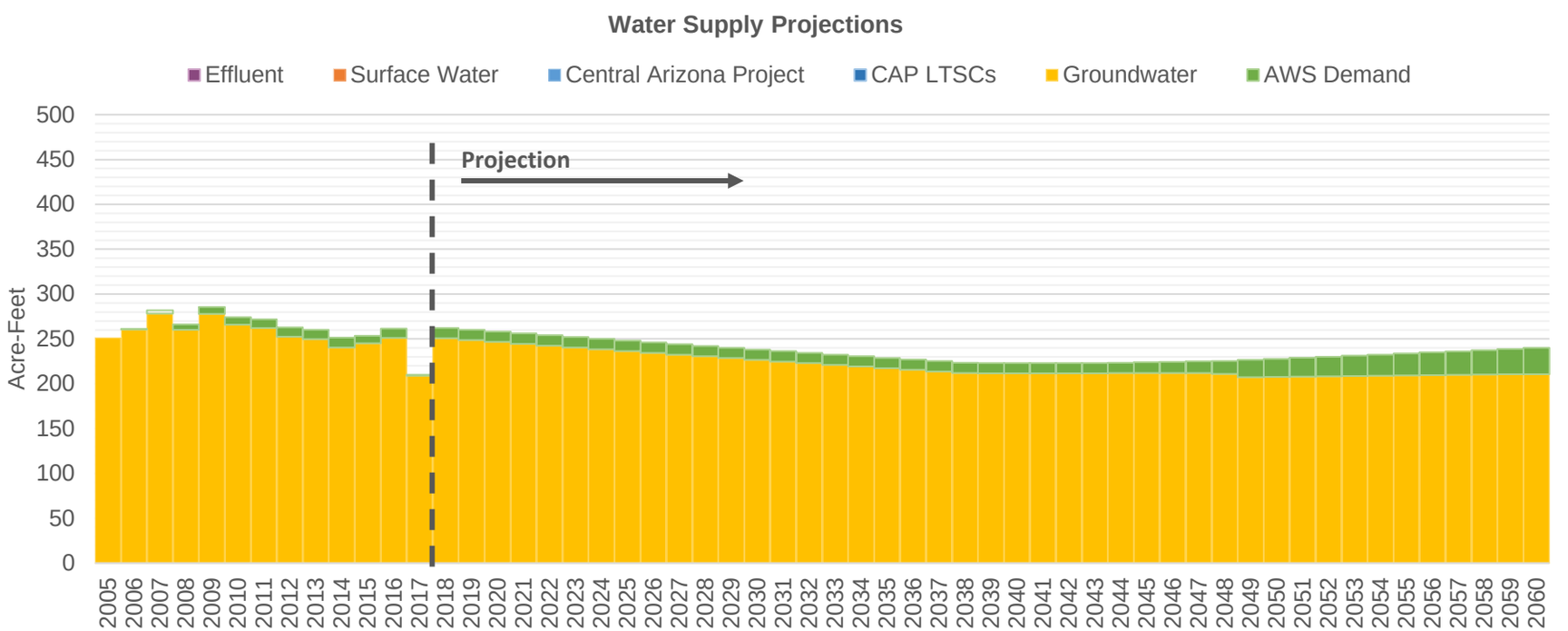
Central Arizona Project Service Area Model

MaranaDomestic

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

MaranaDomesti

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

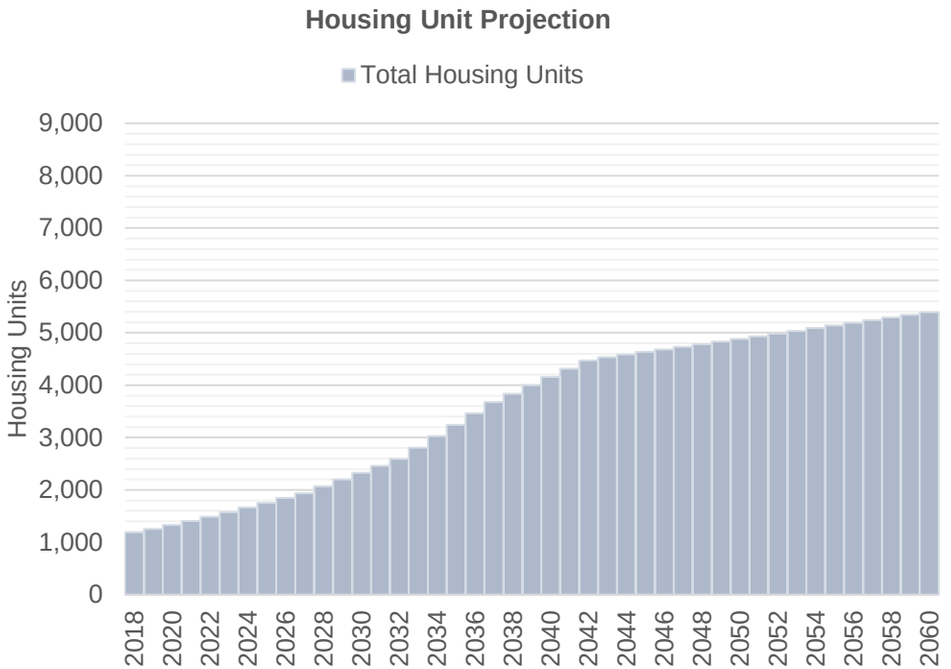
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

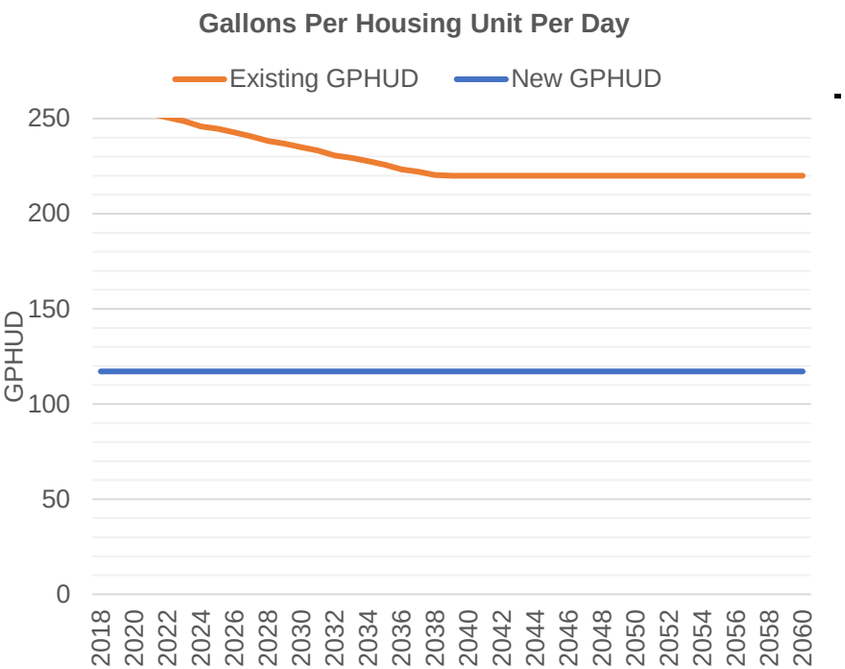
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	349	672	237	0	0	0	0	0	0	0	251	11
2019	349	667	237	0	0	0	0	0	0	0	249	11
2020	349	660	236	0	0	0	0	0	0	0	247	11
2021	349	656	236	0	0	0	0	0	0	0	245	11
2022	349	651	235	0	0	0	0	0	0	0	243	11
2023	349	646	235	0	0	0	0	0	0	0	241	11
2024	349	639	234	0	0	0	0	0	0	0	239	11
2025	349	636	234	0	0	0	0	0	0	0	237	11
2026	349	631	234	0	0	0	0	0	0	0	235	11
2027	349	626	233	0	0	0	0	0	0	0	233	11
2028	349	619	233	0	0	0	0	0	0	0	231	11
2029	349	616	232	0	0	0	0	0	0	0	229	11
2030	349	611	232	0	0	0	0	0	0	0	227	11
2031	349	606	231	0	0	0	0	0	0	0	225	11
2032	349	599	231	0	0	0	0	0	0	0	223	11
2033	349	596	230	0	0	0	0	0	0	0	221	11
2034	349	591	230	0	0	0	0	0	0	0	219	11
2035	349	587	229	0	0	0	0	0	0	0	217	11
2036	349	580	229	0	0	0	0	0	0	0	216	11
2037	349	577	228	0	0	0	0	0	0	0	214	11
2038	349	573	228	0	0	0	0	0	0	0	212	11
2039	349	572	228	0	0	0	0	0	0	0	212	11
2040	349	572	227	0	0	0	0	0	0	0	212	11
2041	349	572	227	0	0	0	0	0	0	0	212	11
2042	349	572	226	0	0	0	0	0	0	0	212	11
2043	350	572	226	0	0	0	0	0	0	0	212	11
2044	352	572	225	0	0	0	0	0	0	0	212	12
2045	354	572	225	0	0	0	0	0	0	0	212	12
2046	356	572	225	0	0	0	0	0	0	0	212	12
2047	357	572	225	0	0	0	0	0	0	0	212	13
2048	361	572	225	0	0	0	0	0	0	0	211	15
2049	366	572	225	0	0	0	0	0	0	0	207	19
2050	370	572	225	0	0	0	0	0	0	0	208	20
2051	375	572	225	0	0	0	0	0	0	0	208	21
2052	380	572	225	0	0	0	0	0	0	0	208	22
2053	384	572	225	0	0	0	0	0	0	0	209	23
2054	389	572	225	0	0	0	0	0	0	0	209	24
2055	394	572	225	0	0	0	0	0	0	0	209	24
2056	399	572	225	0	0	0	0	0	0	0	210	25
2057	404	572	225	0	0	0	0	0	0	0	210	26
2058	409	572	225	0	0	0	0	0	0	0	210	27
2059	414	572	225	0	0	0	0	0	0	0	211	28
2060	418	572	225	0	0	0	0	0	0	0	211	29

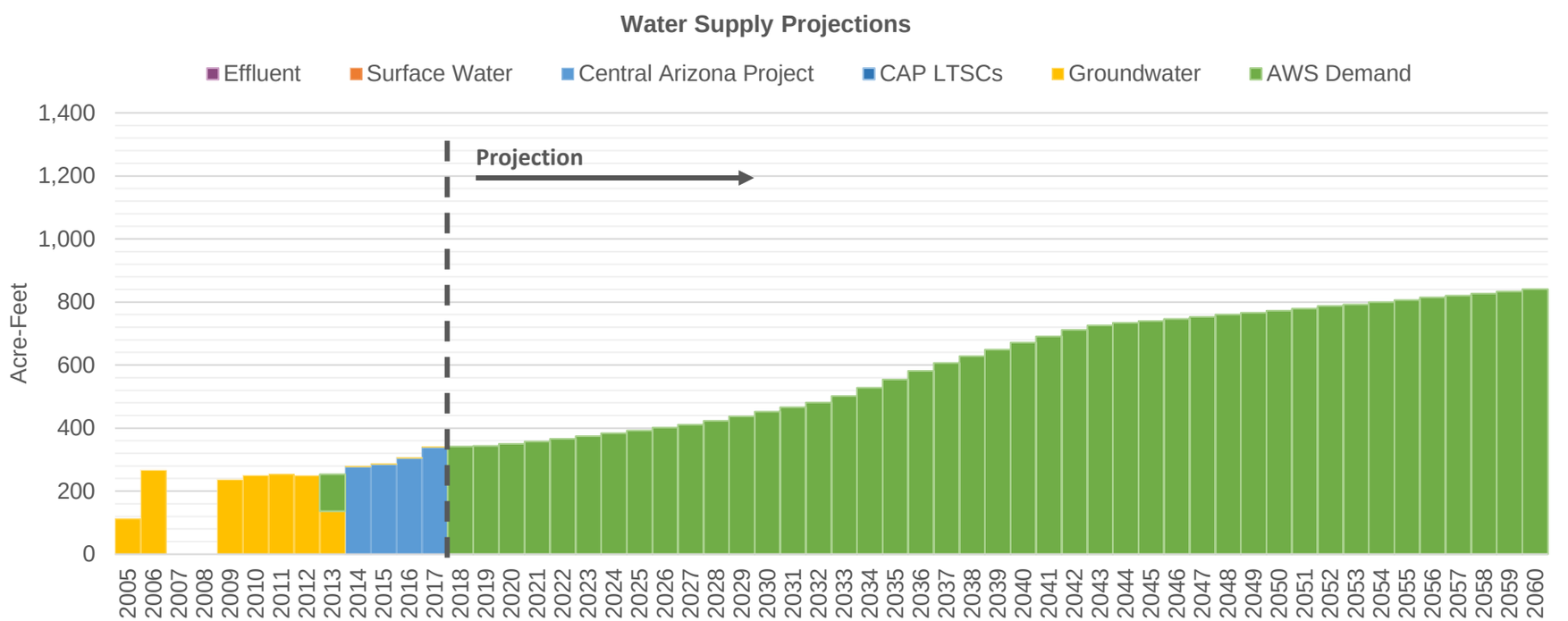
Central Arizona Project Service Area Model

MetroDiablo

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroDiablo

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

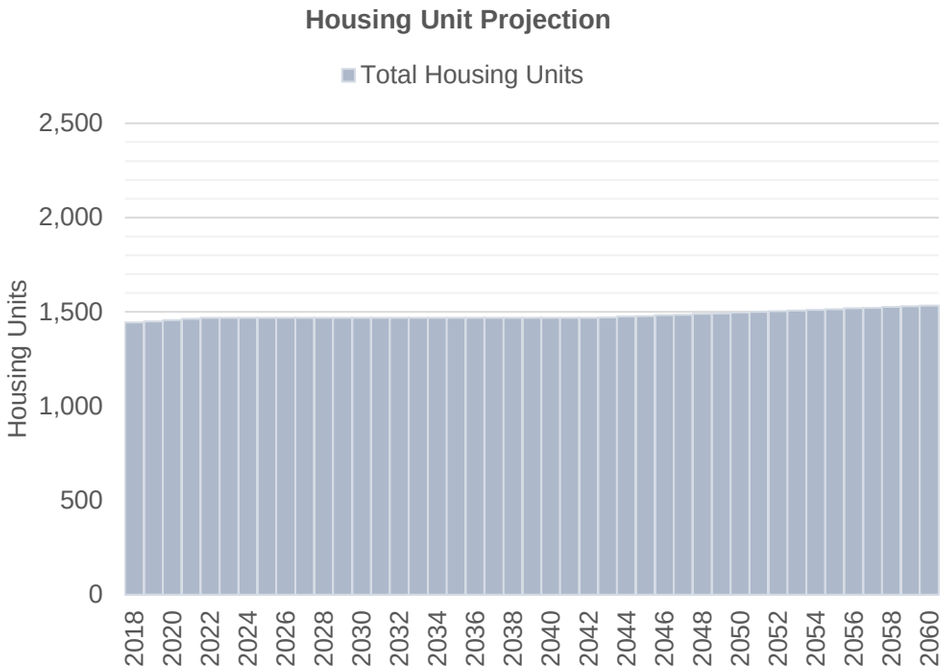
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

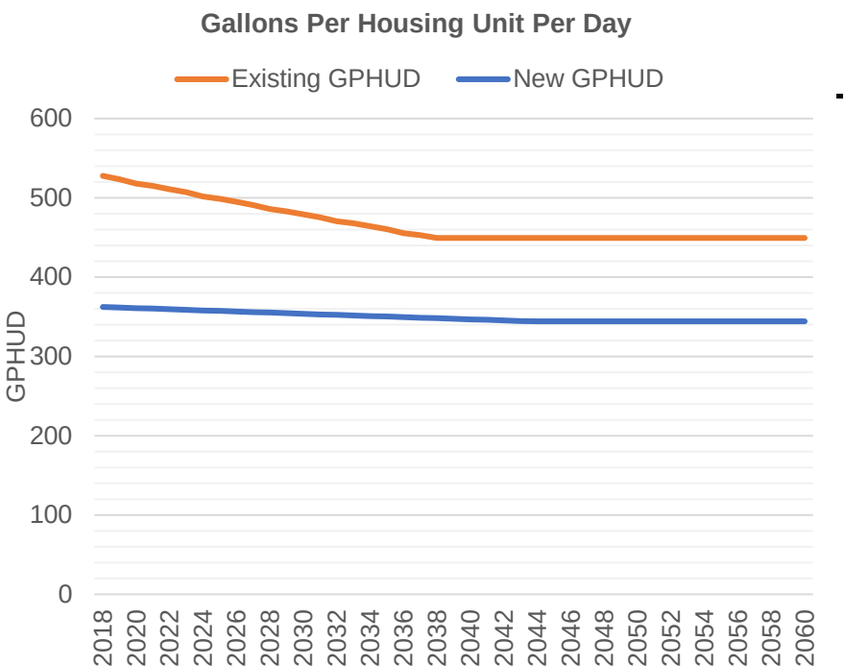
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,192	259	117	0	0	0	0	0	0	0	0	341
2019	1,254	257	117	0	0	0	0	0	0	0	0	344
2020	1,329	254	117	0	0	0	0	0	0	0	0	350
2021	1,409	253	117	0	0	0	0	0	0	0	0	358
2022	1,492	251	117	0	0	0	0	0	0	0	0	366
2023	1,580	249	117	0	0	0	0	0	0	0	0	374
2024	1,668	246	117	0	0	0	0	0	0	0	0	383
2025	1,757	245	117	0	0	0	0	0	0	0	0	392
2026	1,846	243	117	0	0	0	0	0	0	0	0	401
2027	1,940	241	117	0	0	0	0	0	0	0	0	411
2028	2,070	238	117	0	0	0	0	0	0	0	0	423
2029	2,199	237	117	0	0	0	0	0	0	0	0	437
2030	2,328	235	117	0	0	0	0	0	0	0	0	452
2031	2,458	233	117	0	0	0	0	0	0	0	0	466
2032	2.591	231	117	0	0	0	0	0	0	0	0	482
2033	2,809	229	117	0	0	0	0	0	0	0	0	502
2034	3,027	228	117	0	0	0	0	0	0	0	0	528
2035	3,245	226	117	0	0	0	0	0	0	0	0	554
2036	3,462	223	117	0	0	0	0	0	0	0	0	581
2037	3,678	222	117	0	0	0	0	0	0	0	0	606
2038	3,838	220	117	0	0	0	0	0	0	0	0	629
2039	3,997	220	117	0	0	0	0	0	0	0	0	649
2040	4,156	220	117	0	0	0	0	0	0	0	0	671
2041	4,313	220	117	0	0	0	0	0	0	0	0	691
2042	4,470	220	117	0	0	0	0	0	0	0	0	711
2043	4,534	220	117	0	0	0	0	0	0	0	0	726
2044	4,584	220	117	0	0	0	0	0	0	0	0	734
2045	4,634	220	117	0	0	0	0	0	0	0	0	740
2046	4,683	220	117	0	0	0	0	0	0	0	0	746
2047	4,731	220	117	0	0	0	0	0	0	0	0	753
2048	4,782	220	117	0	0	0	0	0	0	0	0	760
2049	4,833	220	117	0	0	0	0	0	0	0	0	766
2050	4,884	220	117	0	0	0	0	0	0	0	0	773
2051	4,934	220	117	0	0	0	0	0	0	0	0	779
2052	4,984	220	117	0	0	0	0	0	0	0	0	787
2053	5,035	220	117	0	0	0	0	0	0	0	0	792
2054	5,089	220	117	0	0	0	0	0	0	0	0	799
2055	5,142	220	117	0	0	0	0	0	0	0	0	806
2056	5,193	220	117	0	0	0	0	0	0	0	0	814
2057	5,245	220	117	0	0	0	0	0	0	0	0	820
2058	5,295	220	117	0	0	0	0	0	0	0	0	826
2059	5,345	220	117	0	0	0	0	0	0	0	0	833
2060	5,394	220	117	0	0	0	0	0	0	0	0	841

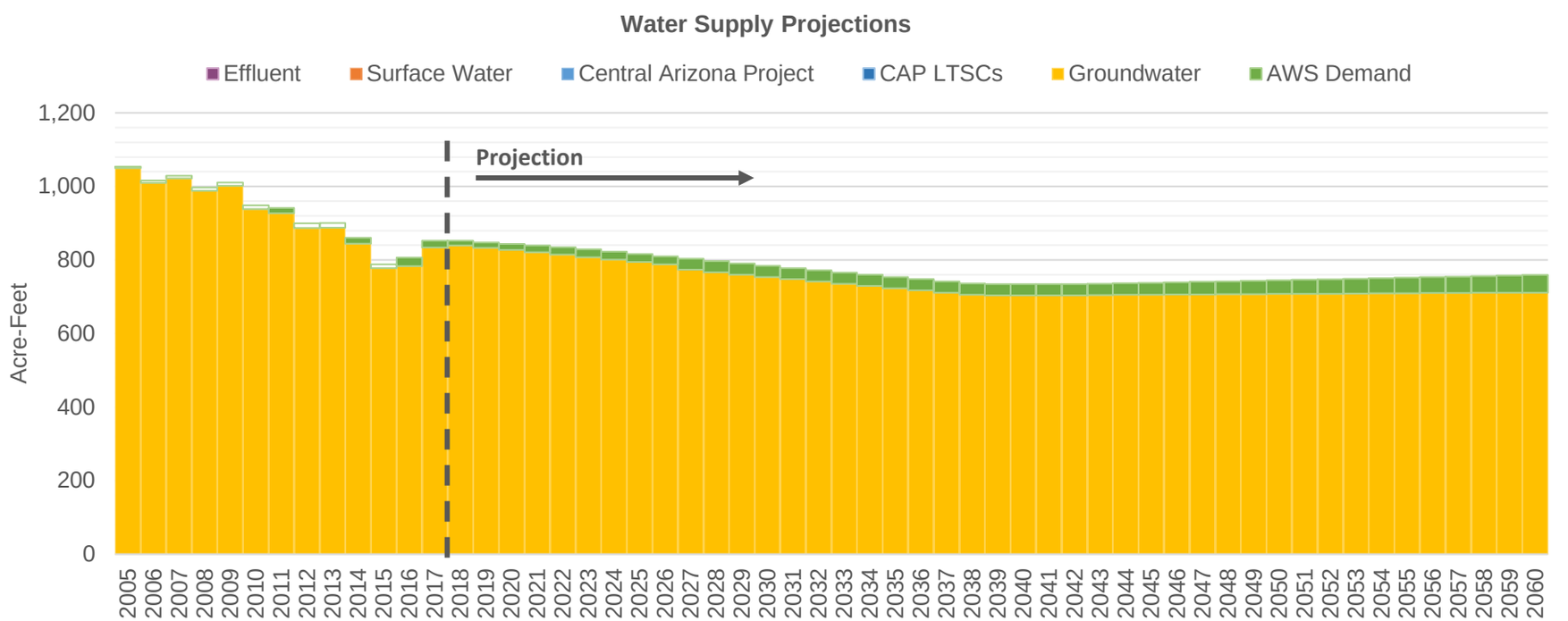
Central Arizona Project Service Area Model

MetroHub

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroHub

A. Official, Historic Climate [LSCRBS]

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Demand Assumptions

Water Supply Projections (Acre-Feet)

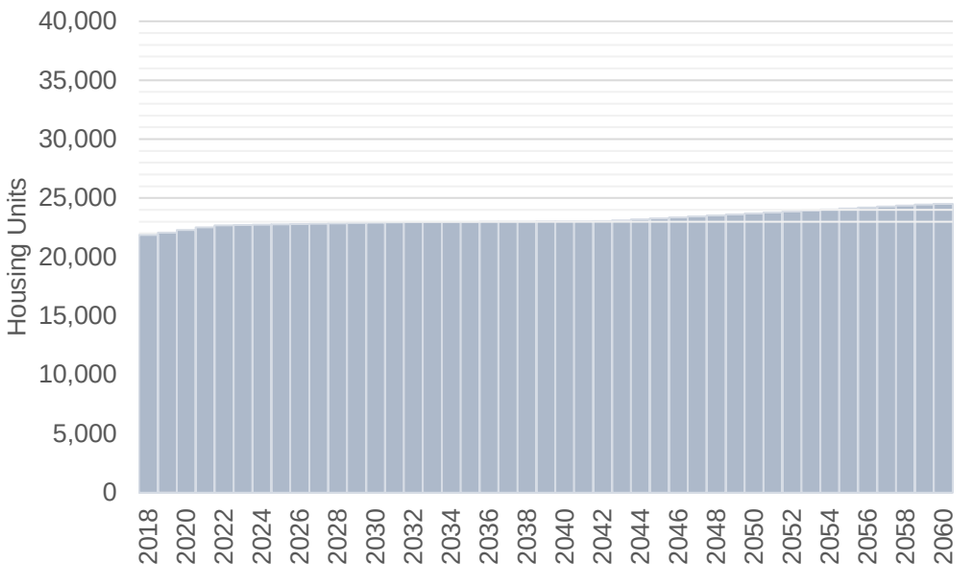
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,444	528	362	0	0	0	0	0	0	0	839	13
2019	1,450	524	362	0	0	0	0	0	0	0	833	14
2020	1,457	518	361	0	0	0	0	0	0	0	827	16
2021	1,463	515	360	0	0	0	0	0	0	0	821	18
2022	1,468	511	360	0	0	0	0	0	0	0	815	20
2023	1,468	507	359	0	0	0	0	0	0	0	808	21
2024	1,468	502	358	0	0	0	0	0	0	0	801	21
2025	1,468	499	357	0	0	0	0	0	0	0	795	21
2026	1,468	495	357	0	0	0	0	0	0	0	788	21
2027	1,468	491	356	0	0	0	0	0	0	0	774	30
2028	1,468	486	355	0	0	0	0	0	0	0	767	30
2029	1,468	483	355	0	0	0	0	0	0	0	760	30
2030	1,468	479	354	0	0	0	0	0	0	0	754	30
2031	1,468	475	353	0	0	0	0	0	0	0	748	30
2032	1,468	470	352	0	0	0	0	0	0	0	742	30
2033	1,468	468	352	0	0	0	0	0	0	0	735	30
2034	1,468	464	351	0	0	0	0	0	0	0	729	30
2035	1,468	460	350	0	0	0	0	0	0	0	723	30
2036	1,468	455	350	0	0	0	0	0	0	0	717	30
2037	1,468	453	349	0	0	0	0	0	0	0	712	30
2038	1,468	449	348	0	0	0	0	0	0	0	706	30
2039	1,468	449	347	0	0	0	0	0	0	0	704	30
2040	1,468	449	347	0	0	0	0	0	0	0	704	30
2041	1,468	449	346	0	0	0	0	0	0	0	704	30
2042	1,468	449	345	0	0	0	0	0	0	0	704	30
2043	1,471	449	345	0	0	0	0	0	0	0	705	30
2044	1,475	449	344	0	0	0	0	0	0	0	705	31
2045	1,478	449	344	0	0	0	0	0	0	0	705	32
2046	1,482	449	344	0	0	0	0	0	0	0	706	33
2047	1,485	449	344	0	0	0	0	0	0	0	706	34
2048	1,489	449	344	0	0	0	0	0	0	0	707	35
2049	1,492	449	344	0	0	0	0	0	0	0	707	36
2050	1,496	449	344	0	0	0	0	0	0	0	708	37
2051	1,500	449	344	0	0	0	0	0	0	0	708	38
2052	1,503	449	344	0	0	0	0	0	0	0	708	39
2053	1,507	449	344	0	0	0	0	0	0	0	709	40
2054	1,511	449	344	0	0	0	0	0	0	0	709	41
2055	1,515	449	344	0	0	0	0	0	0	0	710	42
2056	1,519	449	344	0	0	0	0	0	0	0	710	43
2057	1,522	449	344	0	0	0	0	0	0	0	710	45
2058	1,526	449	344	0	0	0	0	0	0	0	711	45
2059	1,530	449	344	0	0	0	0	0	0	0	711	46
2060	1,533	449	344	0	0	0	0	0	0	0	712	48

Central Arizona Project Service Area Model

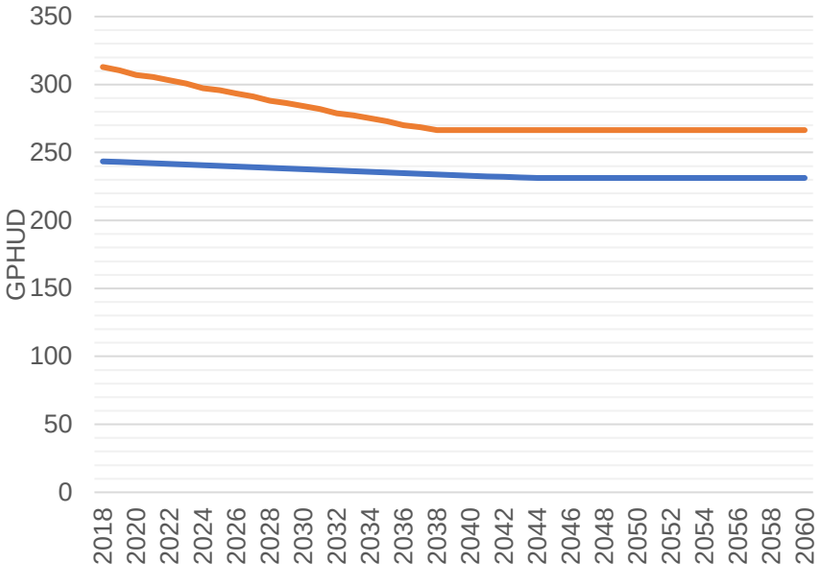
MetroMain

A. Official, Historic Climate [LSCRBS]

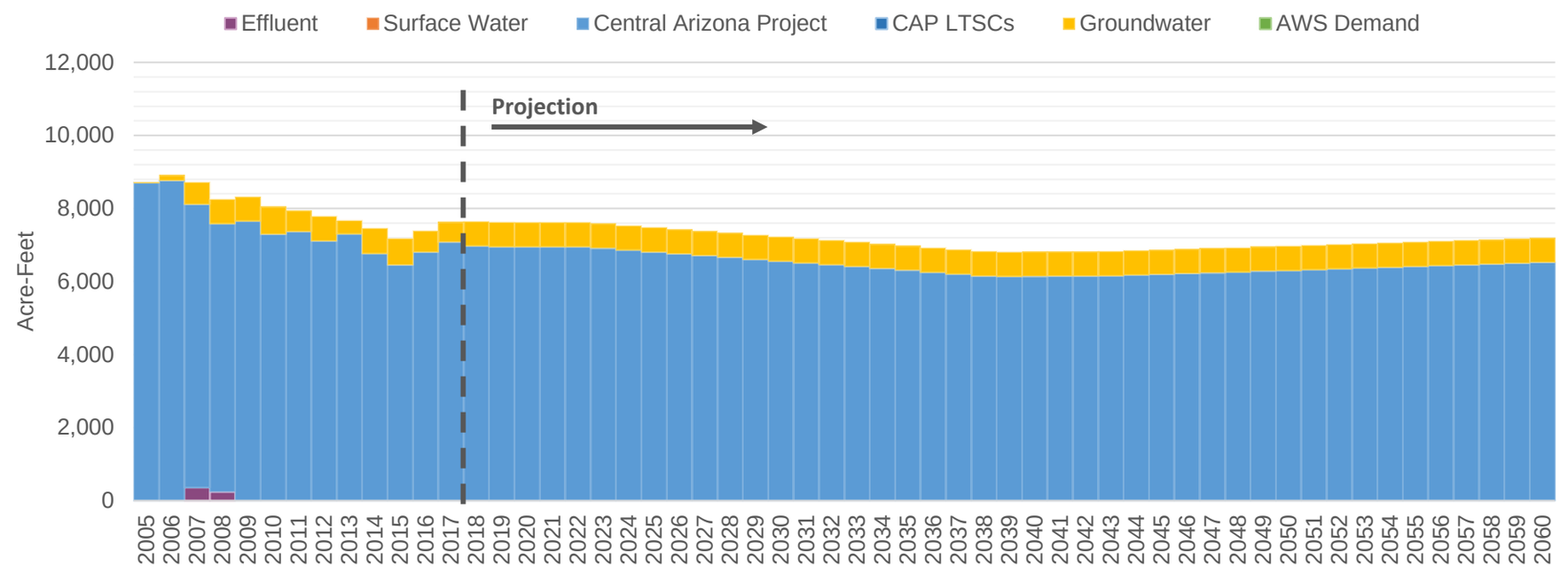
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

MetroMain

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions

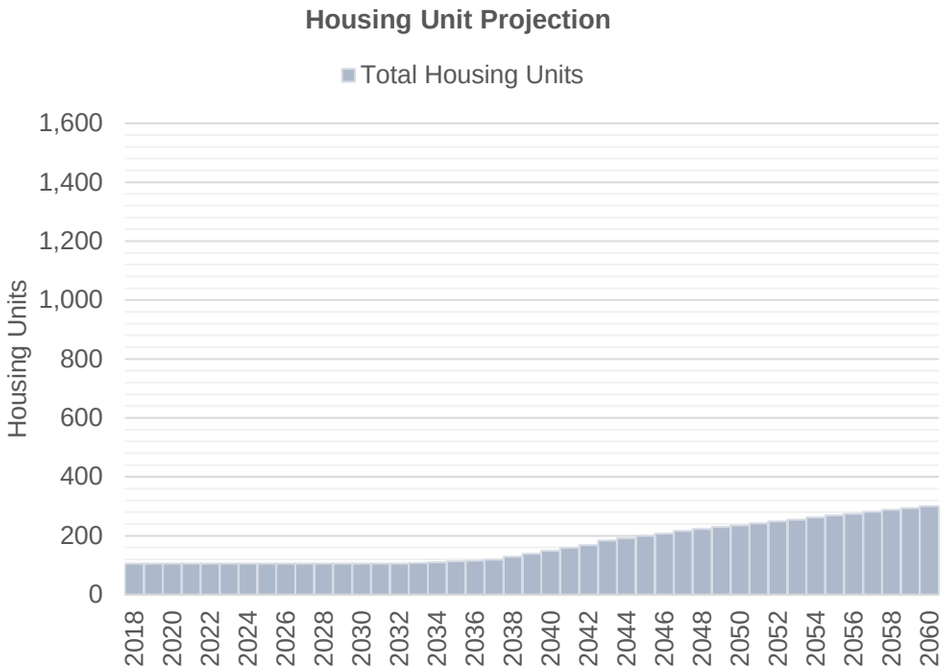
Water Supply Projections (Acre-Feet)

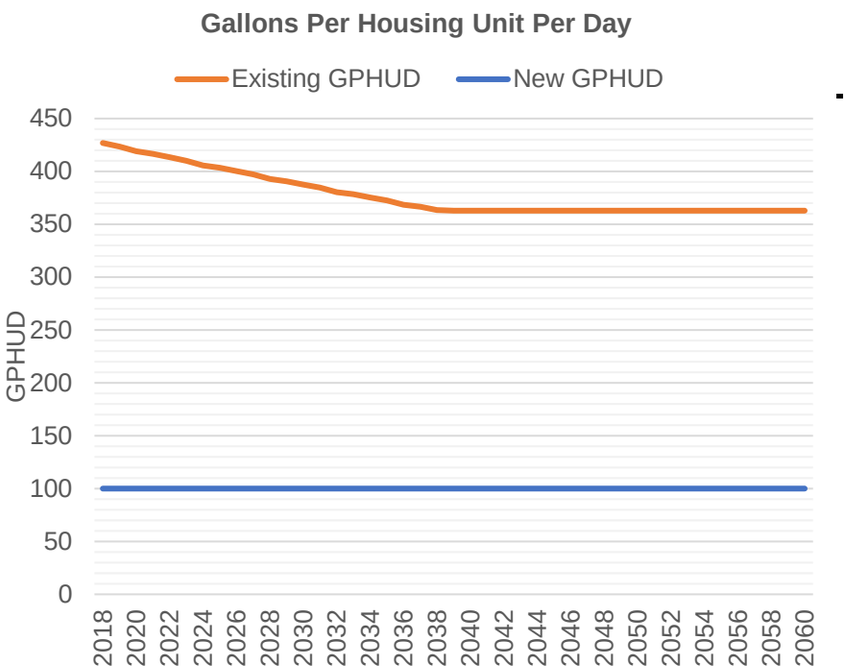
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	21,865	313	243	0	0	0	0	6,974	6,486	0	668	0
2019	22,066	310	243	0	0	0	0	6,954	6,506	0	668	0
2020	22,287	307	242	0	0	0	0	6,951	6,509	0	668	0
2021	22,520	305	242	0	0	0	0	6,952	6,508	0	668	0
2022	22,693	303	241	0	0	0	0	6,947	6,513	0	668	0
2023	22,718	301	241	0	0	0	0	6,914	6,546	0	668	0
2024	22,743	297	241	0	0	0	0	6,862	6,598	0	668	0
2025	22,768	296	240	0	0	0	0	6,810	6,650	0	668	0
2026	22,794	293	240	0	0	0	0	6,758	6,702	0	668	0
2027	22,819	291	239	0	0	0	0	6,707	6,753	0	668	0
2028	22,846	288	239	0	0	0	0	6,658	6,802	0	668	0
2029	22,872	286	238	0	0	0	0	6,607	6,853	0	668	0
2030	22,899	284	238	0	0	0	0	6,558	6,902	0	668	0
2031	22,925	282	237	0	0	0	0	6,509	6,951	0	668	0
2032	22,951	279	237	0	0	0	0	6,461	6,999	0	668	0
2033	22,959	277	236	0	0	0	0	6,410	7,050	0	668	0
2034	22,968	275	236	0	0	0	0	6,357	7,103	0	668	0
2035	22,976	273	235	0	0	0	0	6,305	7,155	0	668	0
2036	22,984	270	235	0	0	0	0	6,254	7,206	0	668	0
2037	22,993	269	234	0	0	0	0	6,202	7,258	0	668	0
2038	23,002	266	234	0	0	0	0	6,151	7,309	0	668	0
2039	23,011	266	233	0	0	0	0	6,141	7,319	0	668	0
2040	23,020	266	233	0	0	0	0	6,144	7,316	0	668	0
2041	23,029	266	232	0	0	0	0	6,144	7,316	0	668	0
2042	23,038	266	232	0	0	0	0	6,146	7,314	0	668	0
2043	23,111	266	232	0	0	0	0	6,156	7,304	0	668	0
2044	23,194	266	231	0	0	0	0	6,177	7,283	0	668	0
2045	23,276	266	231	0	0	0	0	6,197	7,263	0	668	0
2046	23,358	266	231	0	0	0	0	6,218	7,242	0	668	0
2047	23,439	266	231	0	0	0	0	6,240	7,220	0	668	0
2048	23,522	266	231	0	0	0	0	6,262	7,198	0	668	0
2049	23,606	266	231	0	0	0	0	6,282	7,178	0	668	0
2050	23,690	266	231	0	0	0	0	6,304	7,156	0	668	0
2051	23,773	266	231	0	0	0	0	6,326	7,134	0	668	0
2052	23,855	266	231	0	0	0	0	6,349	7,111	0	668	0
2053	23,939	266	231	0	0	0	0	6,369	7,091	0	668	0
2054	24,025	266	231	0	0	0	0	6,391	6,634	0	668	0
2055	24,110	266	231	0	0	0	0	6,413	5,678	0	668	0
2056	24,194	266	231	0	0	0	0	6,436	6,589	0	668	0
2057	24,277	266	231	0	0	0	0	6,456	6,569	0	668	0
2058	24,358	266	231	0	0	0	0	6,478	6,982	0	668	0
2059	24,439	266	231	0	0	0	0	6,499	6,961	0	668	0
2060	24,518	266	231	0	0	0	0	6,521	6,939	0	668	0

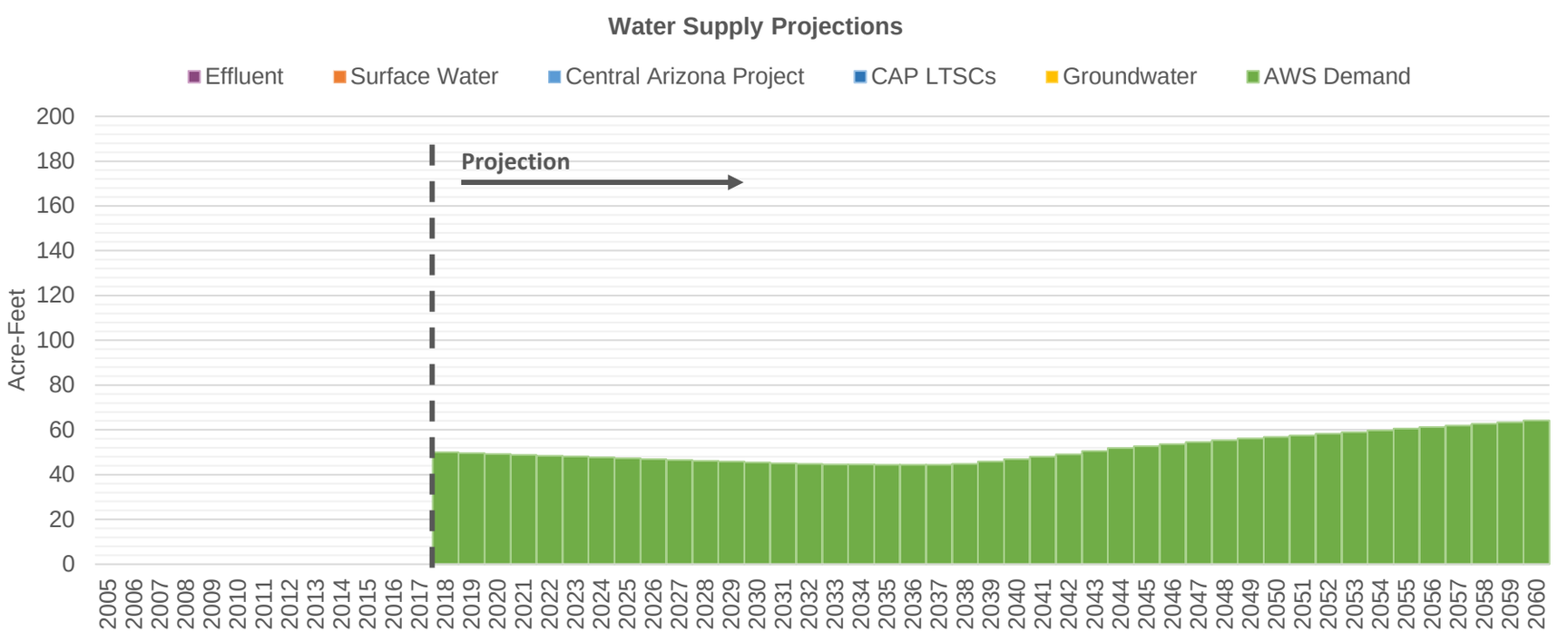
Central Arizona Project Service Area Model

MetroWest

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroWest

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

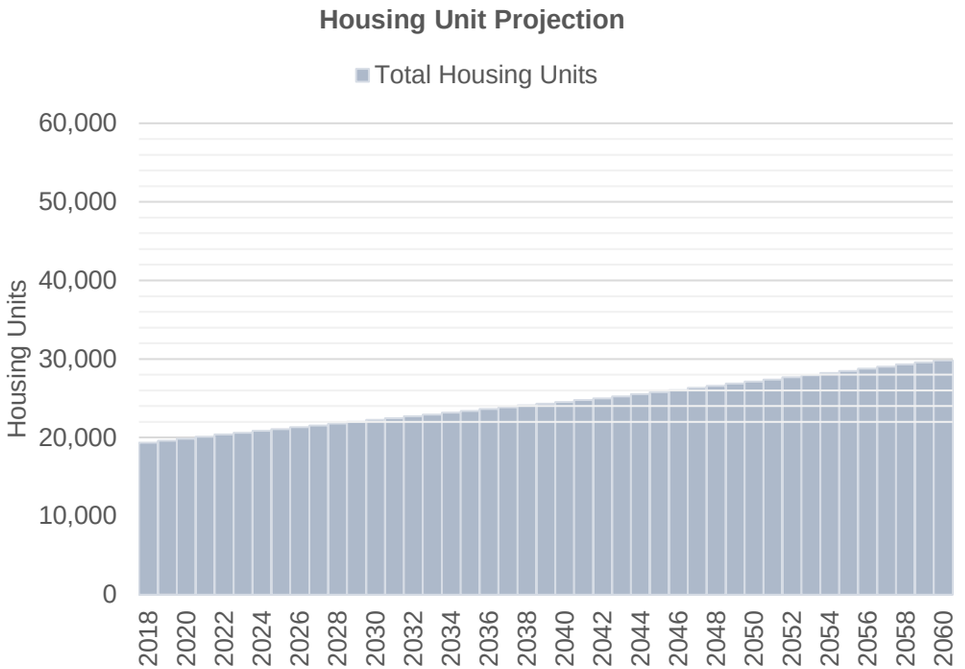
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

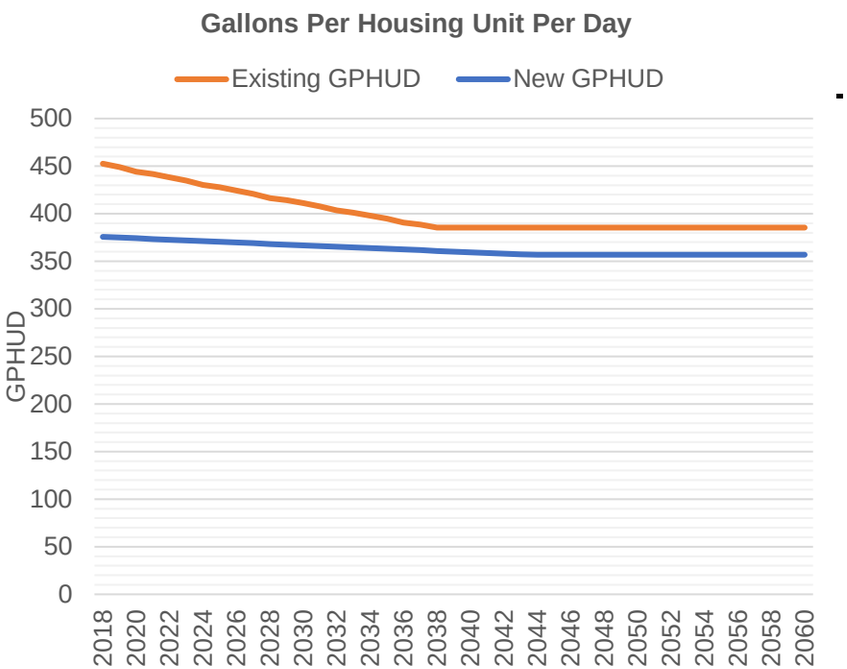
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	105	427	100	0	0	0	0	0	0	0	0	50
2019	105	423	100	0	0	0	0	0	0	0	0	50
2020	105	419	100	0	0	0	0	0	0	0	0	49
2021	105	417	100	0	0	0	0	0	0	0	0	49
2022	105	413	100	0	0	0	0	0	0	0	0	48
2023	105	410	100	0	0	0	0	0	0	0	0	48
2024	105	406	100	0	0	0	0	0	0	0	0	48
2025	105	404	100	0	0	0	0	0	0	0	0	47
2026	105	400	100	0	0	0	0	0	0	0	0	47
2027	105	397	100	0	0	0	0	0	0	0	0	47
2028	105	393	100	0	0	0	0	0	0	0	0	46
2029	105	391	100	0	0	0	0	0	0	0	0	46
2030	105	388	100	0	0	0	0	0	0	0	0	45
2031	105	385	100	0	0	0	0	0	0	0	0	45
2032	105	380	100	0	0	0	0	0	0	0	0	45
2033	108	378	100	0	0	0	0	0	0	0	0	45
2034	110	375	100	0	0	0	0	0	0	0	0	44
2035	113	372	100	0	0	0	0	0	0	0	0	44
2036	116	368	100	0	0	0	0	0	0	0	0	44
2037	119	366	100	0	0	0	0	0	0	0	0	44
2038	129	364	100	0	0	0	0	0	0	0	0	45
2039	139	363	100	0	0	0	0	0	0	0	0	46
2040	149	363	100	0	0	0	0	0	0	0	0	47
2041	159	363	100	0	0	0	0	0	0	0	0	48
2042	168	363	100	0	0	0	0	0	0	0	0	49
2043	184	363	100	0	0	0	0	0	0	0	0	51
2044	192	363	100	0	0	0	0	0	0	0	0	52
2045	200	363	100	0	0	0	0	0	0	0	0	53
2046	208	363	100	0	0	0	0	0	0	0	0	54
2047	216	363	100	0	0	0	0	0	0	0	0	55
2048	223	363	100	0	0	0	0	0	0	0	0	55
2049	230	363	100	0	0	0	0	0	0	0	0	56
2050	236	363	100	0	0	0	0	0	0	0	0	57
2051	242	363	100	0	0	0	0	0	0	0	0	58
2052	249	363	100	0	0	0	0	0	0	0	0	58
2053	255	363	100	0	0	0	0	0	0	0	0	59
2054	262	363	100	0	0	0	0	0	0	0	0	60
2055	269	363	100	0	0	0	0	0	0	0	0	61
2056	275	363	100	0	0	0	0	0	0	0	0	61
2057	282	363	100	0	0	0	0	0	0	0	0	62
2058	288	363	100	0	0	0	0	0	0	0	0	63
2059	294	363	100	0	0	0	0	0	0	0	0	63
2060	301	363	100	0	0	0	0	0	0	0	0	64

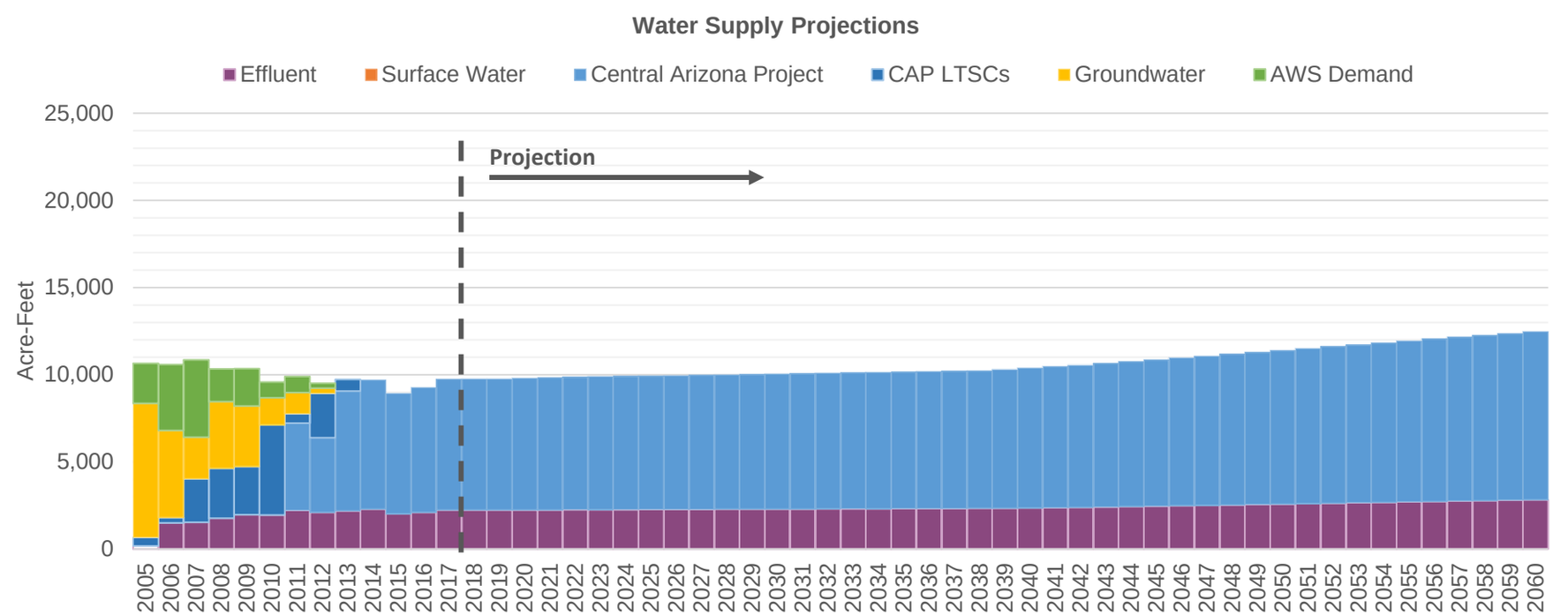
OroValley

Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

OroValley

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

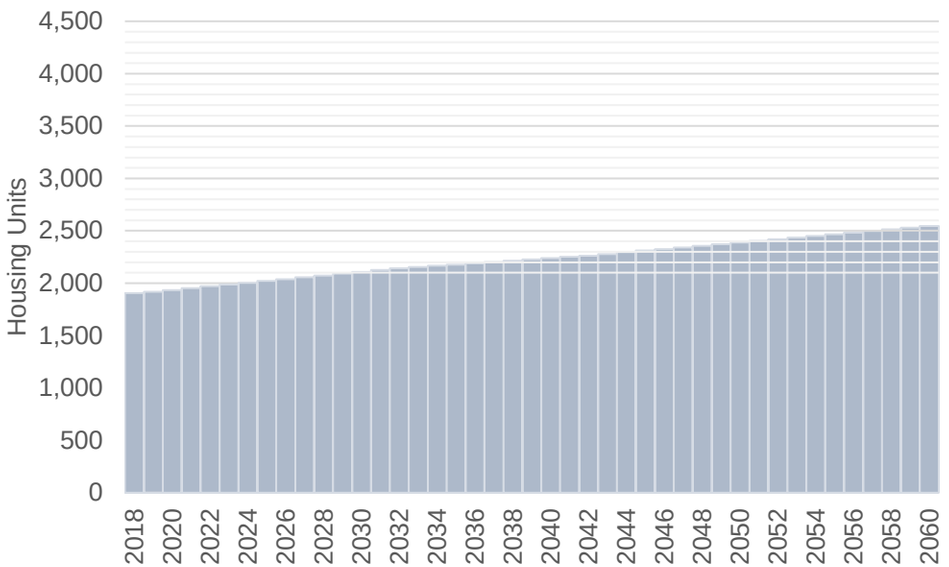
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	19,342	453	376	2,232	0	0	0	7,537	2,768	0	0	0
2019	19,581	449	375	2,232	0	0	0	7,535	2,770	0	0	0
2020	19,843	444	374	2,232	0	0	0	7,563	2,742	0	0	0
2021	20,119	442	373	2,238	0	0	0	7,592	2,713	0	0	0
2022	20,384	438	373	2,246	0	0	0	7,620	2,685	0	0	0
2023	20,613	435	372	2,254	0	0	0	7,639	2,666	0	0	0
2024	20,843	430	371	2,260	0	0	0	7,654	2,651	0	0	0
2025	21,074	428	370	2,265	0	0	0	7,667	2,638	0	0	0
2026	21,306	424	370	2,269	0	0	0	7,684	2,621	0	0	0
2027	21,538	421	369	2,274	0	0	0	7,700	2,605	0	0	0
2028	21,772	417	368	2,279	0	0	0	7,720	2,585	0	0	0
2029	22,007	414	367	2,284	0	0	0	7,734	2,571	0	0	0
2030	22,242	411	367	2,289	0	0	0	7,752	2,553	0	0	0
2031	22,477	408	366	2,294	0	0	0	7,771	2,534	0	0	0
2032	22,712	403	365	2,300	0	0	0	7,792	2,513	0	0	0
2033	22,942	401	365	2,306	0	0	0	7,805	2,500	0	0	0
2034	23,172	398	364	2,310	0	0	0	7,822	2,483	0	0	0
2035	23,401	395	363	2,315	0	0	0	7,839	2,466	0	0	0
2036	23,630	391	362	2,320	0	0	0	7,860	2,445	0	0	0
2037	23,858	389	362	2,326	0	0	0	7,871	2,434	0	0	0
2038	24,086	385	361	2,330	0	0	0	7,889	2,416	0	0	0
2039	24,313	385	360	2,335	0	0	0	7,956	2,349	0	0	0
2040	24,539	385	359	2,351	0	0	0	8,033	2,272	0	0	0
2041	24,764	385	359	2,373	0	0	0	8,092	2,213	0	0	0
2042	24,988	385	358	2,391	0	0	0	8,159	2,146	0	0	0
2043	25,251	385	357	2,411	0	0	0	8,233	2,072	0	0	0
2044	25,520	385	357	2,432	0	0	0	8,322	1,983	0	0	0
2045	25,787	385	357	2,457	0	0	0	8,397	1,908	0	0	0
2046	26,052	385	357	2,480	0	0	0	8,480	1,825	0	0	0
2047	26,314	385	357	2,504	0	0	0	8,562	1,743	0	0	0
2048	26,584	385	357	2,528	0	0	0	8,652	1,653	0	0	0
2049	26,858	385	357	2,554	0	0	0	8,727	1,578	0	0	0
2050	27,129	385	357	2,577	0	0	0	8,813	1,492	0	0	0
2051	27,398	385	357	2,602	0	0	0	8,896	1,409	0	0	0
2052	27,663	385	357	2,627	0	0	0	8,986	1,319	0	0	0
2053	27,936	385	357	2,653	0	0	0	9,059	1,246	0	0	0
2054	28,215	385	357	2,676	0	0	0	9,146	826	0	0	0
2055	28,491	385	357	2,701	0	0	0	9,232	25	0	0	0
2056	28,763	385	357	2,726	0	0	0	9,327	645	0	0	0
2057	29,032	385	357	2,754	0	0	0	9,397	575	0	0	0
2058	29,296	385	357	2,776	0	0	0	9,481	824	0	0	0
2059	29,556	385	357	2,801	0	0	0	9,561	744	0	0	0
2060	29,812	385	357	2,824	0	0	0	9,653	652	0	0	0

QuailCreek

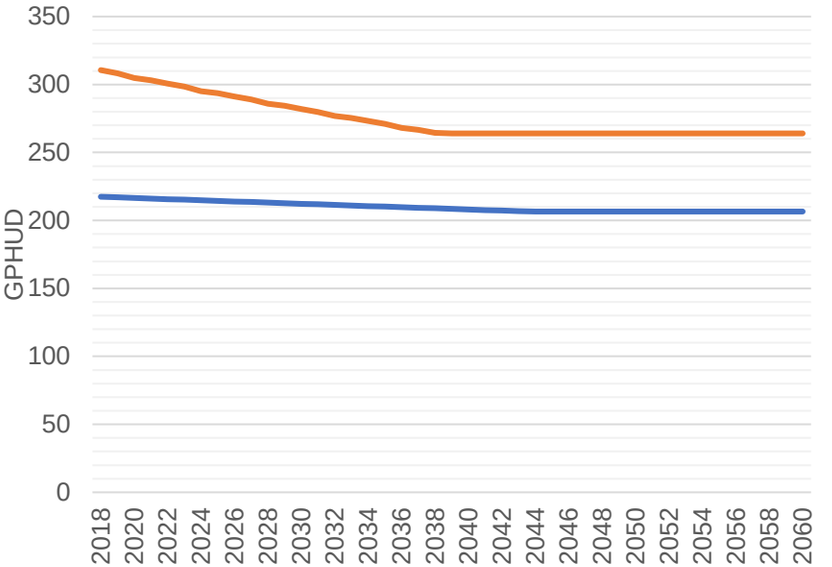
Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]

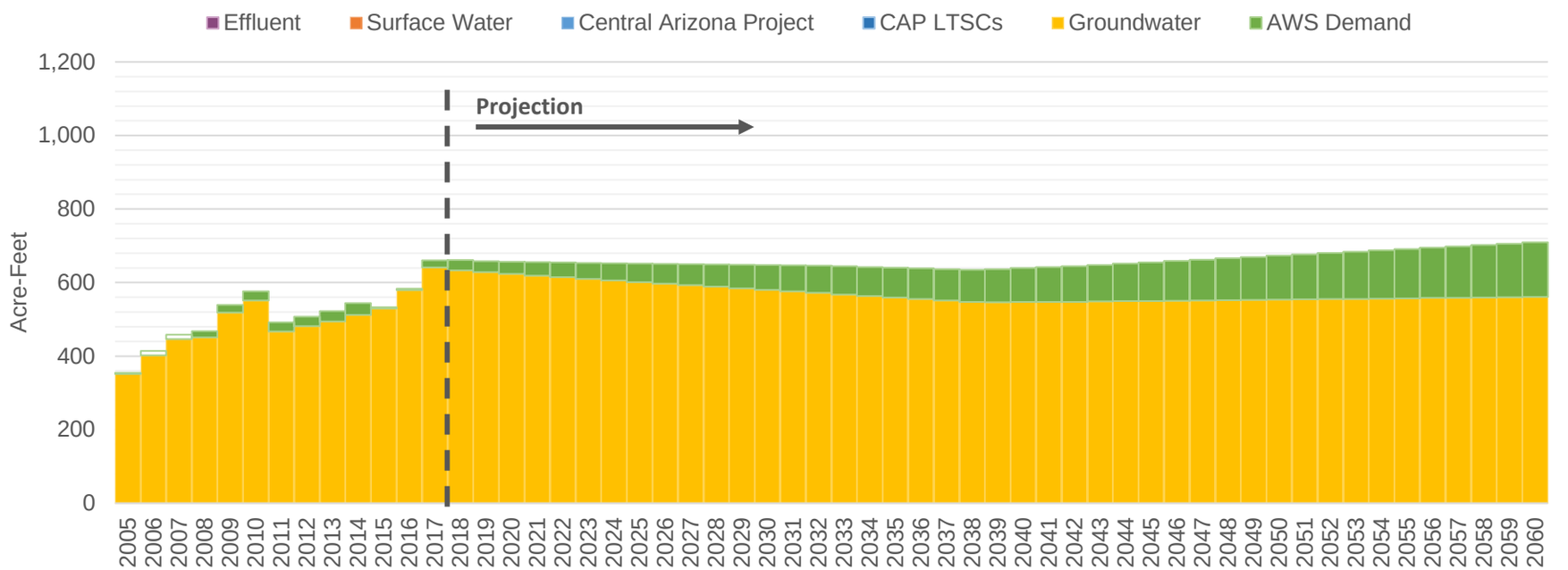
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

QuailCreek

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

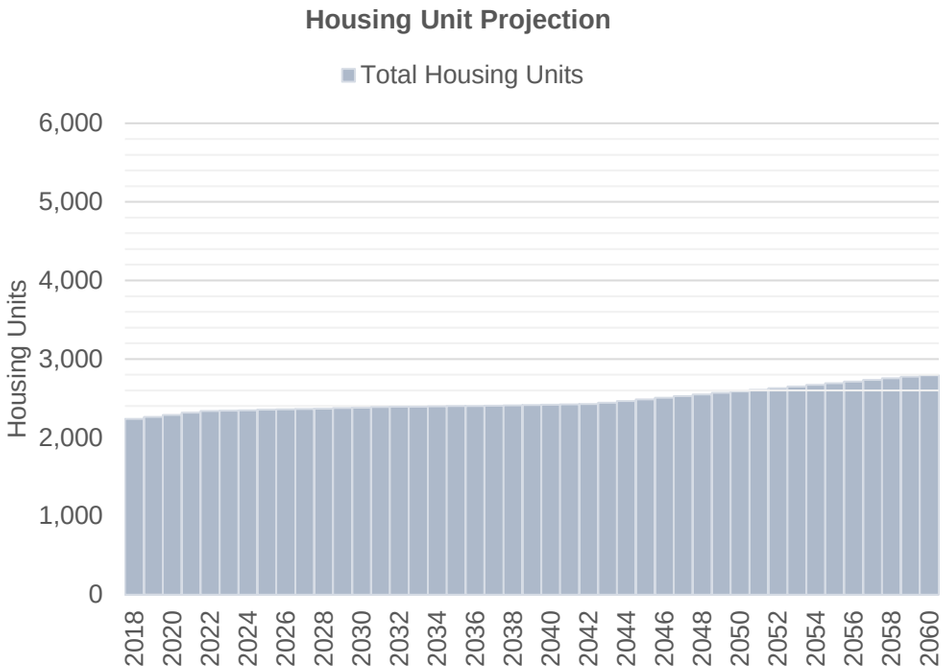
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

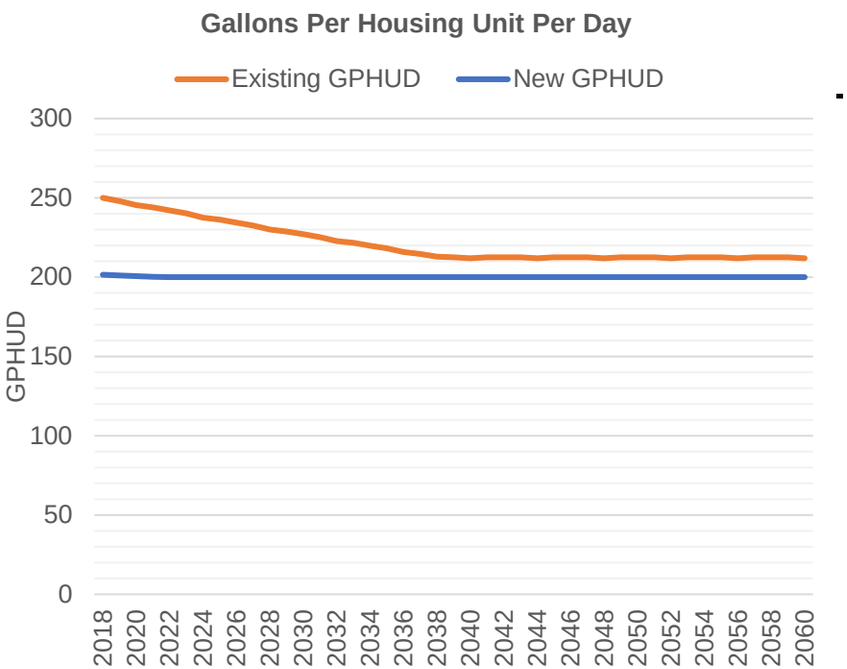
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,905	311	217	0	0	0	0	0	0	0	633	28
2019	1,919	308	217	0	0	0	0	0	0	0	628	30
2020	1,935	305	217	0	0	0	0	0	0	0	624	33
2021	1,952	303	216	0	0	0	0	0	0	0	619	37
2022	1,970	301	216	0	0	0	0	0	0	0	615	40
2023	1,987	298	215	0	0	0	0	0	0	0	610	44
2024	2,004	295	215	0	0	0	0	0	0	0	606	47
2025	2,021	294	214	0	0	0	0	0	0	0	601	51
2026	2,039	291	214	0	0	0	0	0	0	0	597	54
2027	2,056	289	214	0	0	0	0	0	0	0	593	57
2028	2,073	286	213	0	0	0	0	0	0	0	589	60
2029	2,090	284	213	0	0	0	0	0	0	0	584	64
2030	2,108	282	212	0	0	0	0	0	0	0	581	67
2031	2,125	280	212	0	0	0	0	0	0	0	576	70
2032	2,142	277	211	0	0	0	0	0	0	0	573	73
2033	2,154	275	211	0	0	0	0	0	0	0	568	77
2034	2,166	273	211	0	0	0	0	0	0	0	564	79
2035	2,178	271	210	0	0	0	0	0	0	0	559	81
2036	2,190	268	210	0	0	0	0	0	0	0	555	83
2037	2,202	267	209	0	0	0	0	0	0	0	551	86
2038	2,214	265	209	0	0	0	0	0	0	0	547	88
2039	2,227	264	208	0	0	0	0	0	0	0	547	90
2040	2,239	264	208	0	0	0	0	0	0	0	547	92
2041	2,251	264	208	0	0	0	0	0	0	0	547	95
2042	2,263	264	207	0	0	0	0	0	0	0	548	97
2043	2,279	264	207	0	0	0	0	0	0	0	549	99
2044	2,295	264	207	0	0	0	0	0	0	0	549	102
2045	2,311	264	207	0	0	0	0	0	0	0	550	105
2046	2,326	264	207	0	0	0	0	0	0	0	551	108
2047	2,341	264	207	0	0	0	0	0	0	0	551	111
2048	2,357	264	207	0	0	0	0	0	0	0	552	114
2049	2,373	264	207	0	0	0	0	0	0	0	553	116
2050	2,389	264	207	0	0	0	0	0	0	0	554	119
2051	2,404	264	207	0	0	0	0	0	0	0	554	122
2052	2,420	264	207	0	0	0	0	0	0	0	555	125
2053	2,436	264	207	0	0	0	0	0	0	0	556	128
2054	2,452	264	207	0	0	0	0	0	0	0	557	131
2055	2,468	264	207	0	0	0	0	0	0	0	557	134
2056	2,484	264	207	0	0	0	0	0	0	0	558	137
2057	2,499	264	207	0	0	0	0	0	0	0	559	140
2058	2,515	264	207	0	0	0	0	0	0	0	559	143
2059	2,530	264	207	0	0	0	0	0	0	0	560	146
2060	2,545	264	207	0	0	0	0	0	0	0	561	148

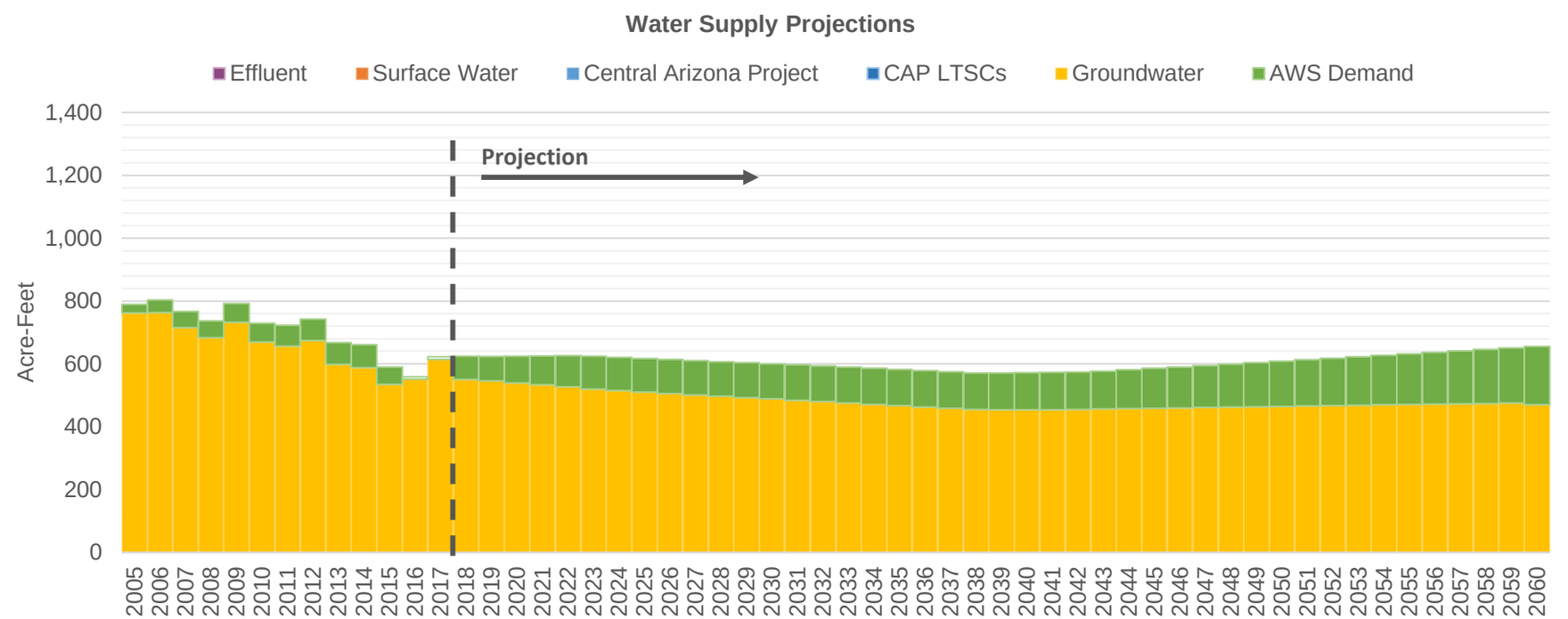
Central Arizona Project Service Area Model

RayWC

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

RayWC

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions

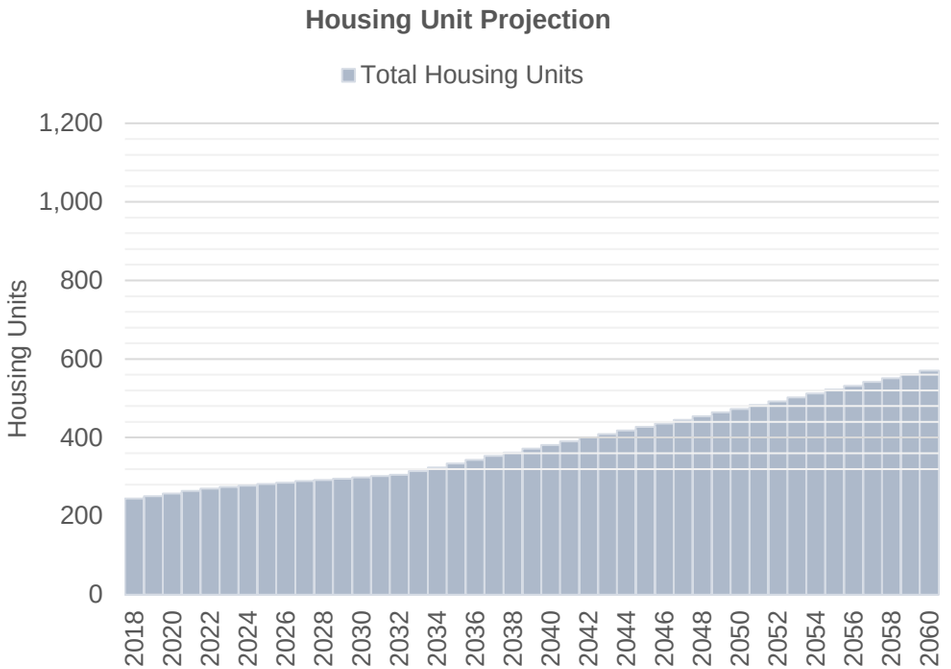
Water Supply Projections (Acre-Feet)

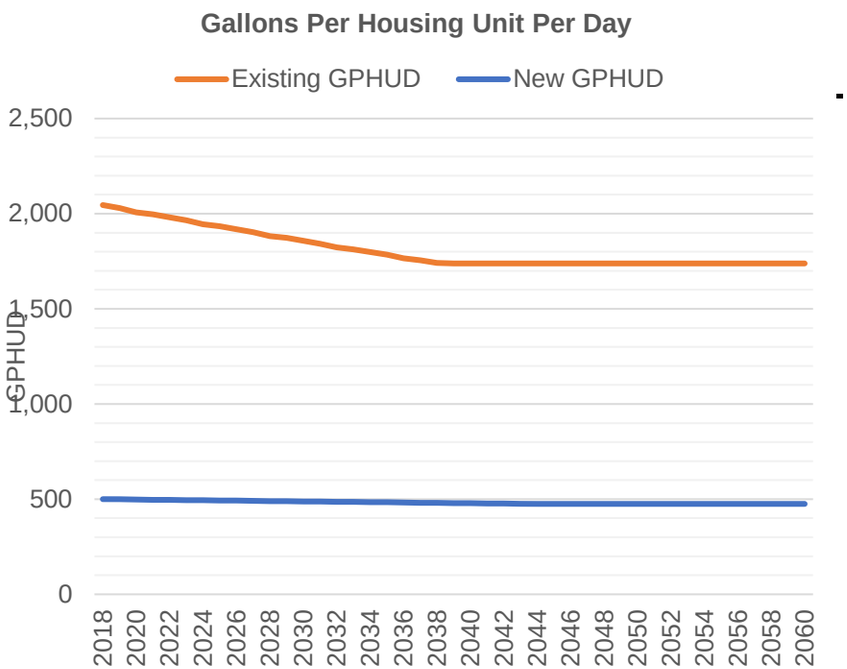
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,238	250	202	0	0	0	0	0	0	0	551	74
2019	2,263	248	201	0	0	0	0	0	0	0	546	78
2020	2,289	245	201	0	0	0	0	0	0	0	540	85
2021	2,316	244	200	0	0	0	0	0	0	0	533	92
2022	2,337	242	200	0	0	0	0	0	0	0	527	99
2023	2,343	240	200	0	0	0	0	0	0	0	520	104
2024	2,348	238	200	0	0	0	0	0	0	0	515	106
2025	2,354	236	200	0	0	0	0	0	0	0	510	107
2026	2,359	234	200	0	0	0	0	0	0	0	505	108
2027	2,365	233	200	0	0	0	0	0	0	0	501	109
2028	2,370	230	200	0	0	0	0	0	0	0	497	110
2029	2,376	229	200	0	0	0	0	0	0	0	493	111
2030	2,381	227	200	0	0	0	0	0	0	0	488	112
2031	2,387	225	200	0	0	0	0	0	0	0	484	113
2032	2,392	223	200	0	0	0	0	0	0	0	480	114
2033	2,395	222	200	0	0	0	0	0	0	0	475	115
2034	2,397	220	200	0	0	0	0	0	0	0	471	115
2035	2,400	218	200	0	0	0	0	0	0	0	467	115
2036	2,403	216	200	0	0	0	0	0	0	0	463	116
2037	2,405	215	200	0	0	0	0	0	0	0	459	116
2038	2,409	213	200	0	0	0	0	0	0	0	455	117
2039	2,413	212	200	0	0	0	0	0	0	0	454	117
2040	2,418	212	200	0	0	0	0	0	0	0	454	118
2041	2,422	212	200	0	0	0	0	0	0	0	454	119
2042	2,426	212	200	0	0	0	0	0	0	0	455	120
2043	2,445	212	200	0	0	0	0	0	0	0	456	120
2044	2,466	212	200	0	0	0	0	0	0	0	458	123
2045	2,486	212	200	0	0	0	0	0	0	0	459	127
2046	2,506	212	200	0	0	0	0	0	0	0	460	130
2047	2,526	212	200	0	0	0	0	0	0	0	461	134
2048	2,547	212	200	0	0	0	0	0	0	0	463	137
2049	2,568	212	200	0	0	0	0	0	0	0	464	140
2050	2,588	212	200	0	0	0	0	0	0	0	465	144
2051	2,609	212	200	0	0	0	0	0	0	0	466	147
2052	2,629	212	200	0	0	0	0	0	0	0	467	151
2053	2,650	212	200	0	0	0	0	0	0	0	468	154
2054	2,671	212	200	0	0	0	0	0	0	0	470	158
2055	2,692	212	200	0	0	0	0	0	0	0	471	161
2056	2,713	212	200	0	0	0	0	0	0	0	472	165
2057	2,734	212	200	0	0	0	0	0	0	0	473	168
2058	2,754	212	200	0	0	0	0	0	0	0	474	172
2059	2,774	212	200	0	0	0	0	0	0	0	475	175
2060	2,793	212	200	0	0	0	0	0	0	0	470	185

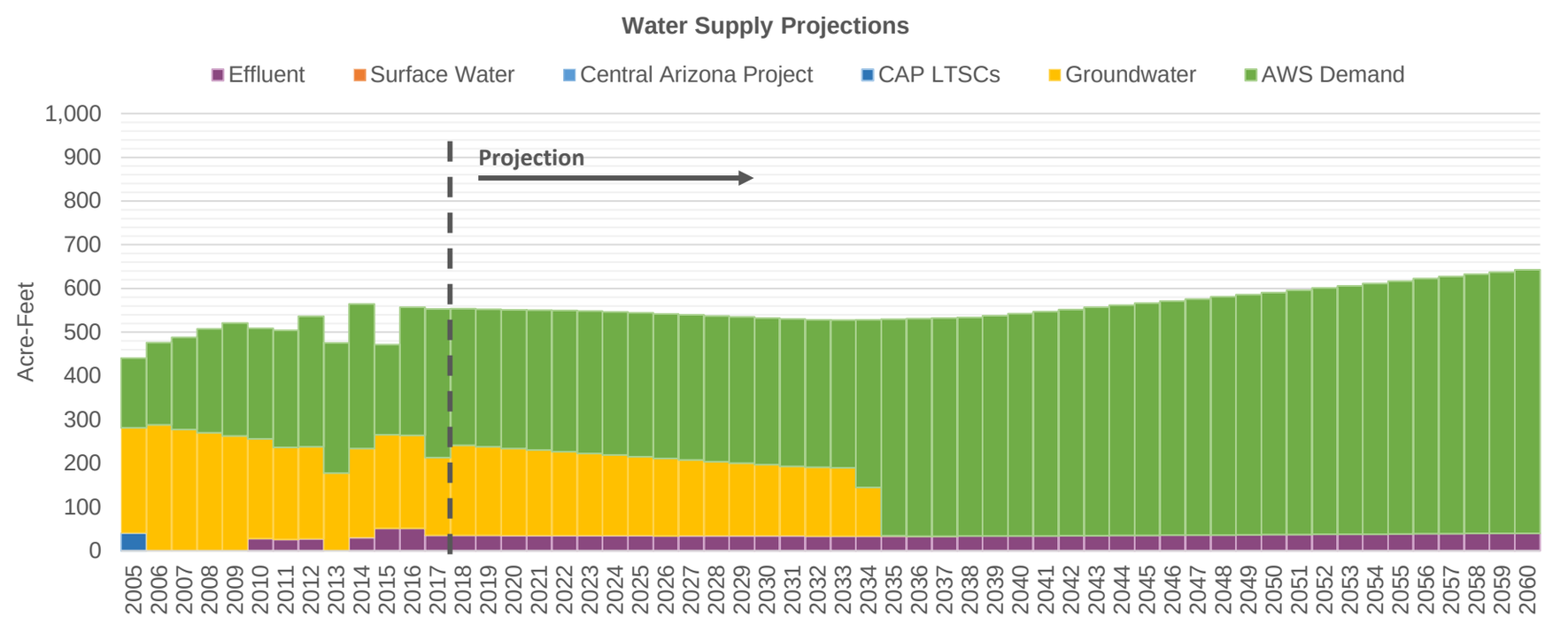
RidgeView

Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

RidgeView

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions

Water Supply Projections (Acre-Feet)

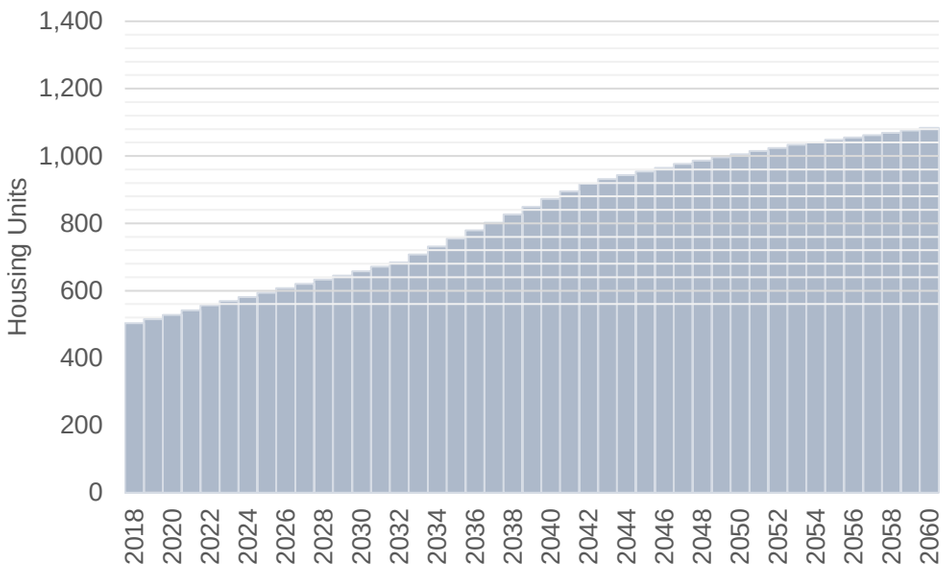
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	245	2,045	500	35	0	0	0	0	0	0	206	313
2019	251	2,029	499	35	0	0	0	0	0	0	203	314
2020	257	2,007	498	35	0	0	0	0	0	0	199	317
2021	264	1,997	497	35	0	0	0	0	0	0	196	320
2022	270	1,981	496	35	0	0	0	0	0	0	192	323
2023	274	1,965	495	35	0	0	0	0	0	0	188	326
2024	278	1,944	494	35	0	0	0	0	0	0	184	327
2025	282	1,934	493	35	0	0	0	0	0	0	181	329
2026	285	1,918	492	34	0	0	0	0	0	0	177	331
2027	289	1,903	491	34	0	0	0	0	0	0	174	332
2028	292	1,882	490	34	0	0	0	0	0	0	170	333
2029	295	1,872	489	34	0	0	0	0	0	0	166	334
2030	299	1,857	488	34	0	0	0	0	0	0	163	336
2031	302	1,843	487	34	0	0	0	0	0	0	160	337
2032	305	1.823	486	34	0	0	0	0	0	0	157	337
2033	315	1,813	485	33	0	0	0	0	0	0	157	337
2034	324	1,799	484	33	0	0	0	0	0	0	112	384
2035	334	1,784	483	33	0	0	0	0	0	0	1	495
2036	343	1,765	482	33	0	0	0	0	0	0	0	498
2037	353	1,756	481	34	0	0	0	0	0	0	0	499
2038	362	1,742	480	34	0	0	0	0	0	0	0	500
2039	372	1,739	479	34	0	0	0	0	0	0	0	504
2040	381	1,739	478	34	0	0	0	0	0	0	0	509
2041	390	1,739	477	34	0	0	0	0	0	0	0	513
2042	400	1,739	477	35	0	0	0	0	0	0	0	517
2043	409	1,739	476	35	0	0	0	0	0	0	0	522
2044	418	1,739	475	35	0	0	0	0	0	0	0	527
2045	427	1,739	475	35	0	0	0	0	0	0	0	531
2046	436	1,739	475	36	0	0	0	0	0	0	0	535
2047	445	1,739	475	36	0	0	0	0	0	0	0	540
2048	454	1,739	475	36	0	0	0	0	0	0	0	545
2049	464	1,739	475	37	0	0	0	0	0	0	0	549
2050	473	1,739	475	37	0	0	0	0	0	0	0	554
2051	483	1,739	475	37	0	0	0	0	0	0	0	559
2052	492	1,739	475	38	0	0	0	0	0	0	0	564
2053	502	1,739	475	38	0	0	0	0	0	0	0	568
2054	512	1,739	475	38	0	0	0	0	0	0	0	573
2055	522	1,739	475	39	0	0	0	0	0	0	0	578
2056	532	1,739	475	39	0	0	0	0	0	0	0	583
2057	542	1,739	475	39	0	0	0	0	0	0	0	588
2058	551	1,739	475	40	0	0	0	0	0	0	0	593
2059	561	1,739	475	40	0	0	0	0	0	0	0	598
2060	570	1,739	475	40	0	0	0	0	0	0	0	603

Central Arizona Project Service Area Model

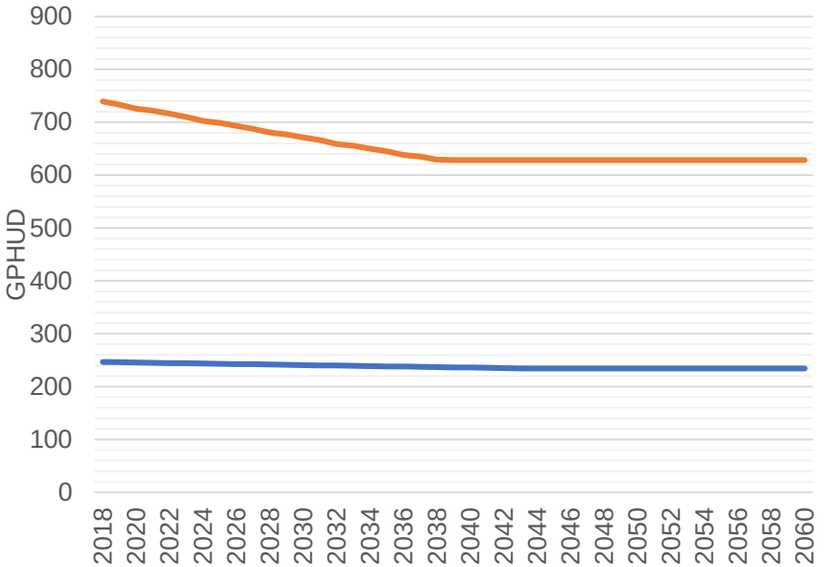
A. Official, Historic Climate [LSCRBS]

Saguaro

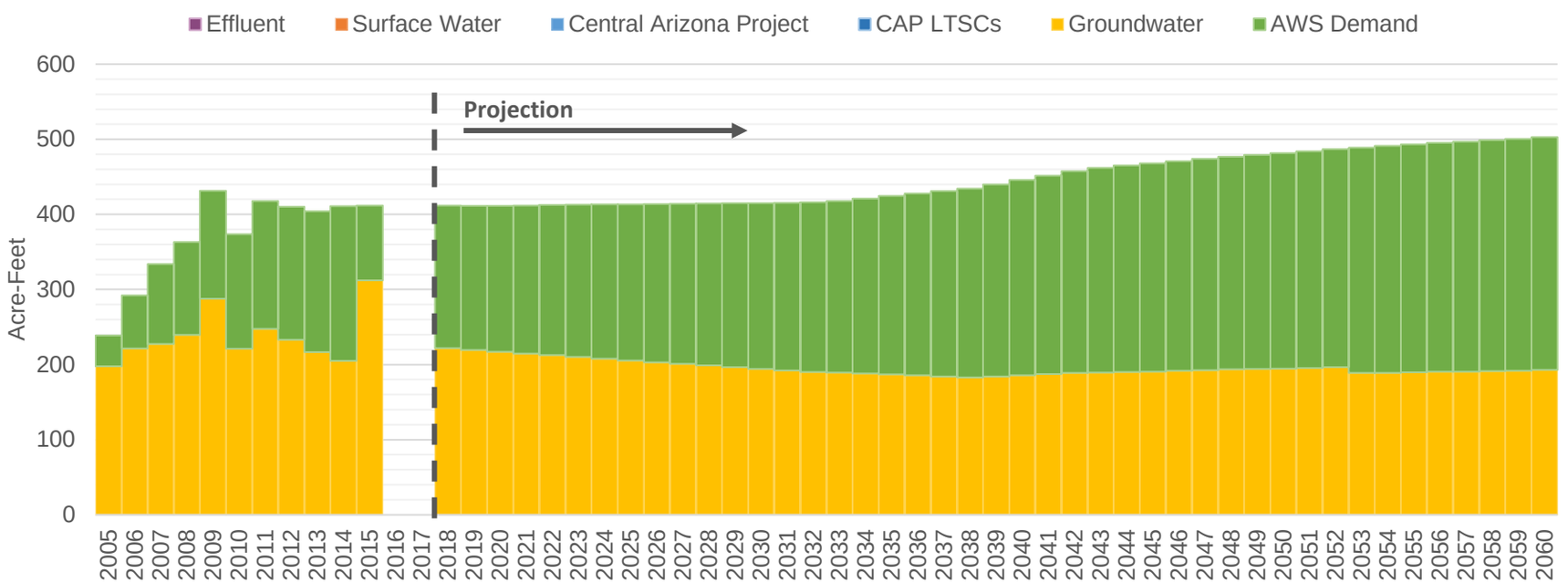
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

Saguaro

A. Official, Historic Climate [LSCRBS]

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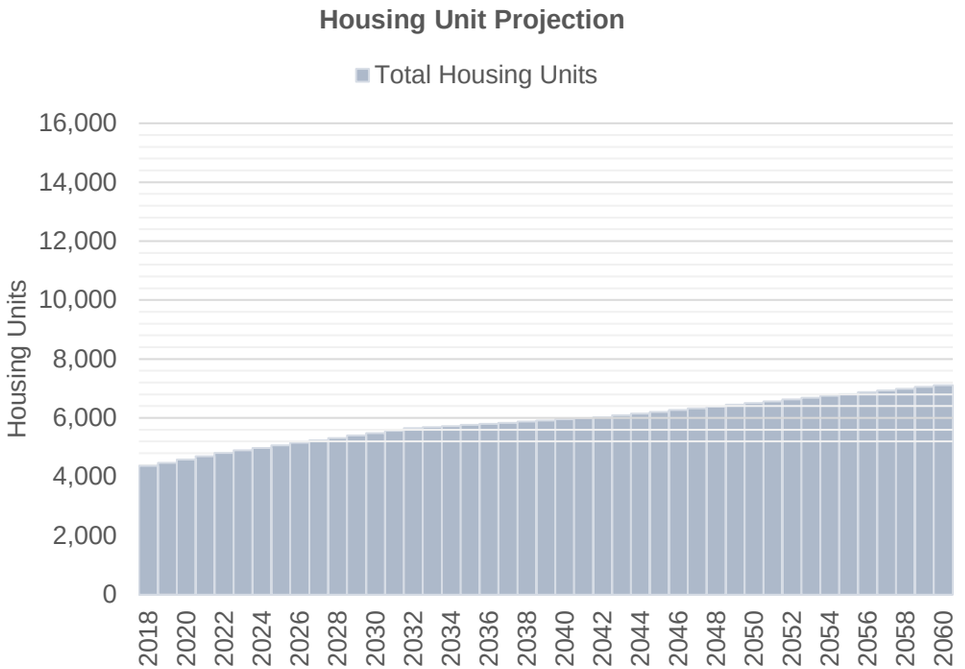
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

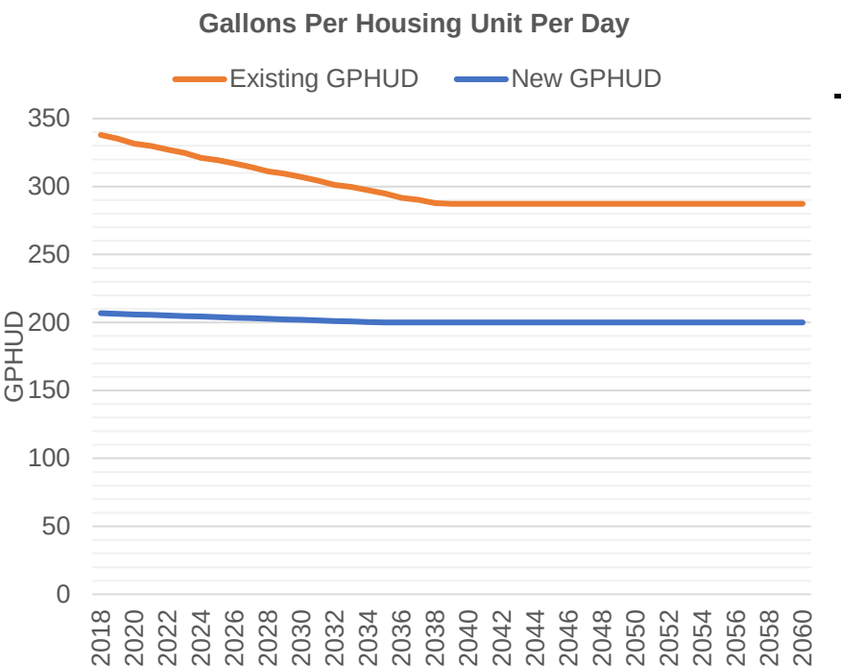
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	503	739	247	0	0	0	0	0	0	0	222	190
2019	515	733	246	0	0	0	0	0	0	0	220	192
2020	528	726	246	0	0	0	0	0	0	0	217	194
2021	542	722	245	0	0	0	0	0	0	0	215	197
2022	556	716	245	0	0	0	0	0	0	0	213	200
2023	569	710	244	0	0	0	0	0	0	0	210	203
2024	581	703	244	0	0	0	0	0	0	0	208	206
2025	594	699	243	0	0	0	0	0	0	0	205	208
2026	607	693	243	0	0	0	0	0	0	0	203	211
2027	620	688	242	0	0	0	0	0	0	0	201	213
2028	633	680	242	0	0	0	0	0	0	0	199	216
2029	645	677	241	0	0	0	0	0	0	0	196	218
2030	658	671	241	0	0	0	0	0	0	0	194	221
2031	671	666	240	0	0	0	0	0	0	0	192	223
2032	684	659	240	0	0	0	0	0	0	0	190	226
2033	708	655	239	0	0	0	0	0	0	0	190	228
2034	731	650	239	0	0	0	0	0	0	0	188	233
2035	755	645	238	0	0	0	0	0	0	0	187	237
2036	779	638	238	0	0	0	0	0	0	0	186	242
2037	802	635	237	0	0	0	0	0	0	0	184	247
2038	826	630	237	0	0	0	0	0	0	0	183	251
2039	849	628	236	0	0	0	0	0	0	0	184	256
2040	872	628	236	0	0	0	0	0	0	0	186	260
2041	895	628	235	0	0	0	0	0	0	0	187	264
2042	918	628	235	0	0	0	0	0	0	0	189	268
2043	931	628	235	0	0	0	0	0	0	0	189	273
2044	943	628	234	0	0	0	0	0	0	0	190	275
2045	954	628	234	0	0	0	0	0	0	0	191	277
2046	965	628	234	0	0	0	0	0	0	0	192	279
2047	976	628	234	0	0	0	0	0	0	0	193	281
2048	986	628	234	0	0	0	0	0	0	0	194	283
2049	996	628	234	0	0	0	0	0	0	0	194	285
2050	1,005	628	234	0	0	0	0	0	0	0	195	287
2051	1,015	628	234	0	0	0	0	0	0	0	196	289
2052	1,024	628	234	0	0	0	0	0	0	0	197	290
2053	1,033	628	234	0	0	0	0	0	0	0	189	300
2054	1,040	628	234	0	0	0	0	0	0	0	189	302
2055	1,048	628	234	0	0	0	0	0	0	0	190	303
2056	1,055	628	234	0	0	0	0	0	0	0	191	305
2057	1,062	628	234	0	0	0	0	0	0	0	191	306
2058	1,069	628	234	0	0	0	0	0	0	0	191	307
2059	1,076	628	234	0	0	0	0	0	0	0	192	309
2060	1,083	628	234	0	0	0	0	0	0	0	193	310

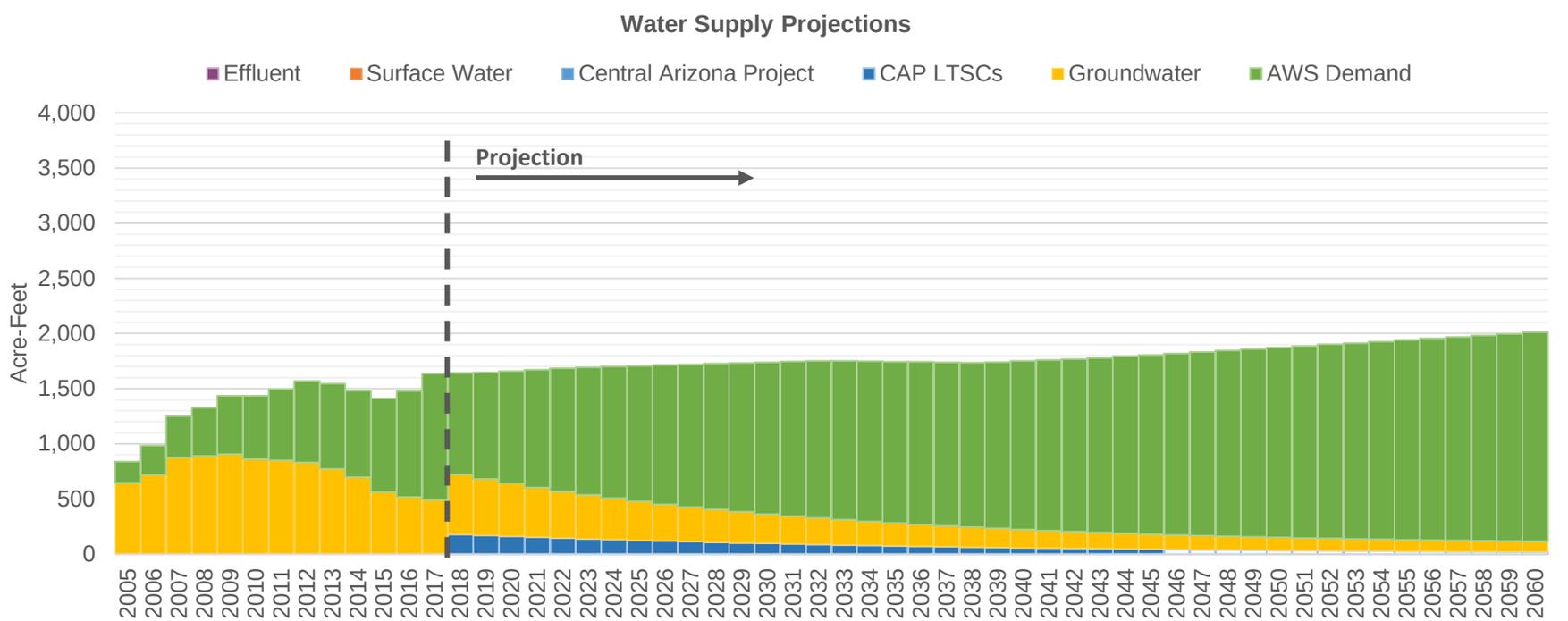
Central Arizona Project Service Area Model

Sahuarita

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

Sahuarita

A. Official, Historic Climate [LSCRBS]

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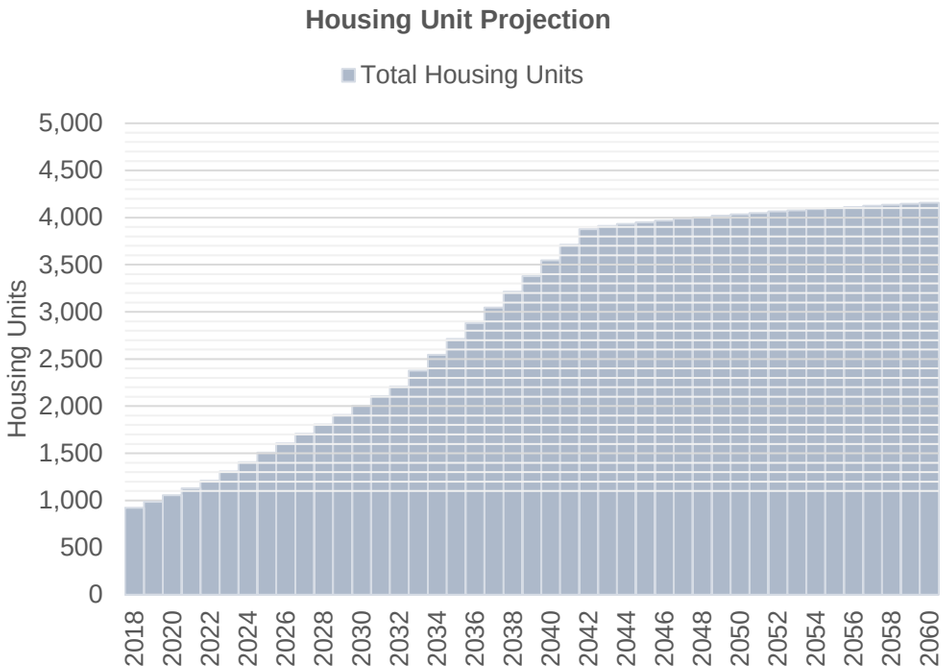
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

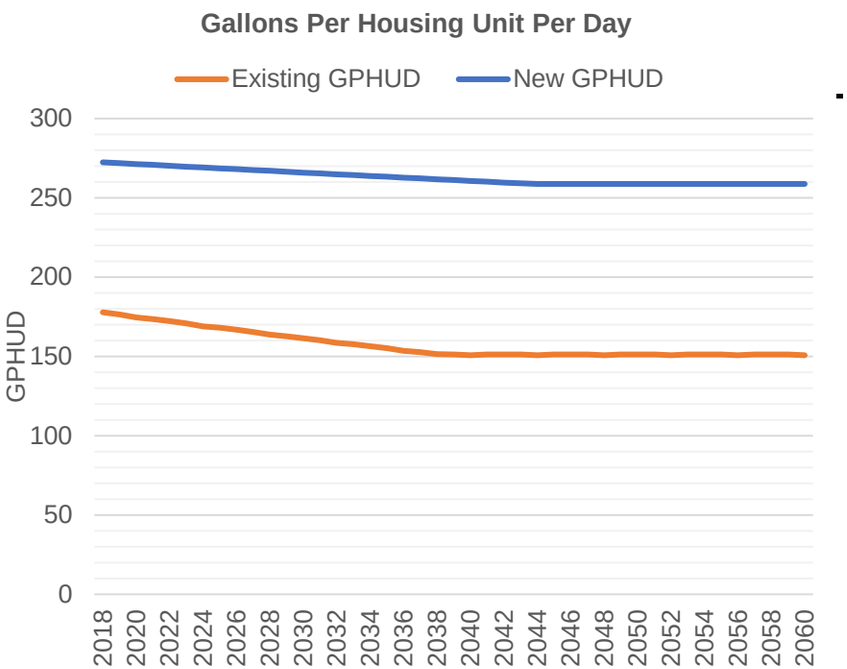
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,376	338	207	0	0	0	0	0	0	179	544	919
2019	4,478	335	206	0	0	0	0	0	0	171	510	967
2020	4,589	332	206	0	0	0	0	0	0	162	479	1,018
2021	4,705	330	206	0	0	0	0	0	0	154	450	1,068
2022	4,814	327	205	0	0	0	0	0	0	146	423	1,115
2023	4,898	325	205	0	0	0	0	0	0	139	398	1,157
2024	4,983	321	204	0	0	0	0	0	0	132	375	1,194
2025	5,069	319	204	0	0	0	0	0	0	125	354	1,228
2026	5,154	317	204	0	0	0	0	0	0	119	334	1,261
2027	5,239	314	203	0	0	0	0	0	0	113	315	1,293
2028	5,321	311	203	0	0	0	0	0	0	107	298	1,323
2029	5,403	309	202	0	0	0	0	0	0	102	282	1,349
2030	5,485	307	202	0	0	0	0	0	0	97	267	1,376
2031	5,567	304	201	0	0	0	0	0	0	92	253	1,400
2032	5.648	301	201	0	0	0	0	0	0	88	240	1.425
2033	5,685	300	201	0	0	0	0	0	0	83	228	1,441
2034	5,723	297	200	0	0	0	0	0	0	79	217	1,453
2035	5,760	295	200	0	0	0	0	0	0	75	207	1,463
2036	5,797	292	200	0	0	0	0	0	0	71	197	1,474
2037	5,834	290	200	0	0	0	0	0	0	68	188	1,483
2038	5,873	288	200	0	0	0	0	0	0	64	180	1,492
2039	5,912	287	200	0	0	0	0	0	0	61	172	1,509
2040	5,951	287	200	0	0	0	0	0	0	58	165	1,529
2041	5,990	287	200	0	0	0	0	0	0	55	158	1,546
2042	6,028	287	200	0	0	0	0	0	0	52	152	1,564
2043	6,089	287	200	0	0	0	0	0	0	50	147	1,583
2044	6,148	287	200	0	0	0	0	0	0	47	141	1,606
2045	6,206	287	200	0	0	0	0	0	0	45	136	1,625
2046	6,265	287	200	0	0	0	0	0	0	43	132	1,645
2047	6,322	287	200	0	0	0	0	0	0	41	128	1,664
2048	6,382	287	200	0	0	0	0	0	0	39	124	1,684
2049	6,444	287	200	0	0	0	0	0	0	37	120	1,702
2050	6,505	287	200	0	0	0	0	0	0	35	117	1,721
2051	6,565	287	200	0	0	0	0	0	0	33	114	1,739
2052	6,625	287	200	0	0	0	0	0	0	31	111	1,759
2053	6,686	287	200	0	0	0	0	0	0	30	109	1,775
2054	6,749	287	200	0	0	0	0	0	0	28	107	1,793
2055	6,812	287	200	0	0	0	0	0	0	27	104	1,810
2056	6,873	287	200	0	0	0	0	0	0	26	102	1,829
2057	6,934	287	200	0	0	0	0	0	0	24	101	1,844
2058	6,993	287	200	0	0	0	0	0	0	23	99	1,860
2059	7,052	287	200	0	0	0	0	0	0	22	98	1,876
2060	7,110	287	200	0	0	0	0	0	0	21	96	1,893

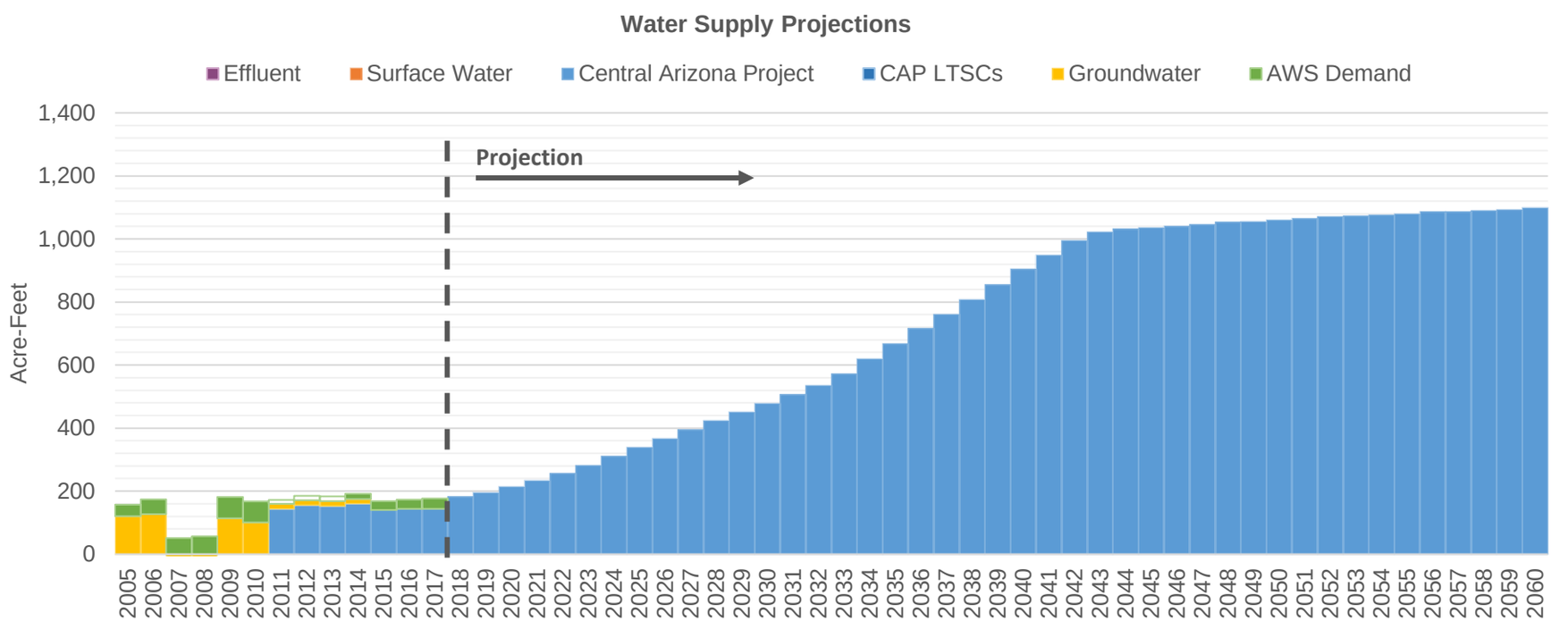
Central Arizona Project Service Area Model

SpanishTrailWC

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

SpanishTrailWC

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

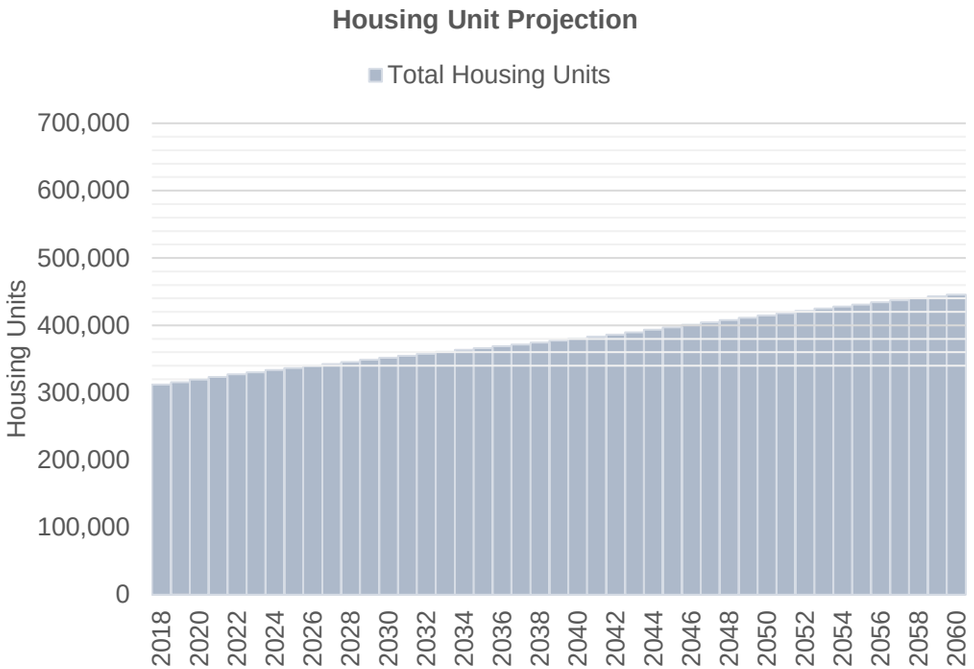
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

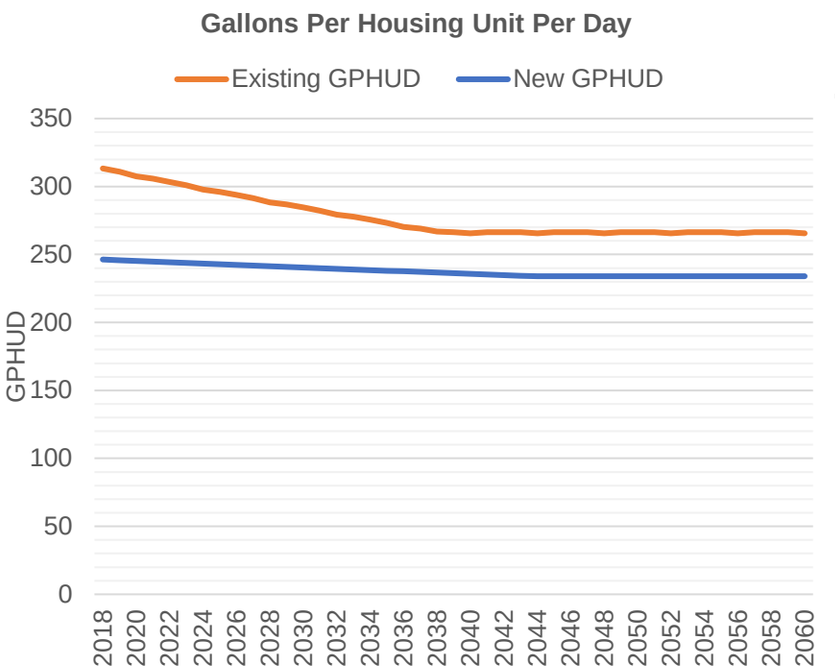
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	921	178	272	0	0	0	0	182	2,855	0	0	0
2019	984	176	272	0	0	0	0	195	2,842	0	0	0
2020	1,054	175	271	0	0	0	0	214	2,823	0	0	0
2021	1,127	174	271	0	0	0	0	234	2,803	0	0	0
2022	1,209	172	270	0	0	0	0	256	2,781	0	0	0
2023	1,307	171	270	0	0	0	0	282	2,755	0	0	0
2024	1,407	169	269	0	0	0	0	310	2,727	0	0	0
2025	1,507	168	269	0	0	0	0	338	2,699	0	0	0
2026	1,607	167	268	0	0	0	0	367	2,670	0	0	0
2027	1,707	165	268	0	0	0	0	395	2,642	0	0	0
2028	1,806	164	267	0	0	0	0	424	2,613	0	0	0
2029	1,906	163	266	0	0	0	0	451	2,586	0	0	0
2030	2,005	162	266	0	0	0	0	479	2,558	0	0	0
2031	2,105	160	265	0	0	0	0	506	2,531	0	0	0
2032	2,207	158	265	0	0	0	0	535	2,502	0	0	0
2033	2,376	158	264	0	0	0	0	572	2,465	0	0	0
2034	2,544	156	264	0	0	0	0	620	2,417	0	0	0
2035	2,712	155	263	0	0	0	0	667	2,370	0	0	0
2036	2,880	153	263	0	0	0	0	716	2,321	0	0	0
2037	3,047	153	262	0	0	0	0	761	2,276	0	0	0
2038	3,214	151	262	0	0	0	0	808	2,229	0	0	0
2039	3,380	151	261	0	0	0	0	855	2,182	0	0	0
2040	3,546	151	261	0	0	0	0	904	2,133	0	0	0
2041	3,711	151	260	0	0	0	0	949	2,088	0	0	0
2042	3,875	151	260	0	0	0	0	995	2,042	0	0	0
2043	3,913	151	259	0	0	0	0	1,023	2,014	0	0	0
2044	3,932	151	259	0	0	0	0	1,032	2,005	0	0	0
2045	3,951	151	259	0	0	0	0	1,035	2,002	0	0	0
2046	3,969	151	259	0	0	0	0	1,041	1,996	0	0	0
2047	3,987	151	259	0	0	0	0	1,046	1,991	0	0	0
2048	4,004	151	259	0	0	0	0	1,054	1,983	0	0	0
2049	4,019	151	259	0	0	0	0	1,056	1,981	0	0	0
2050	4,034	151	259	0	0	0	0	1,060	1,977	0	0	0
2051	4,049	151	259	0	0	0	0	1,064	1,973	0	0	0
2052	4,064	151	259	0	0	0	0	1,071	1,966	0	0	0
2053	4,077	151	259	0	0	0	0	1,073	1,964	0	0	0
2054	4,089	151	259	0	0	0	0	1,076	1,862	0	0	0
2055	4,101	151	259	0	0	0	0	1,080	1,648	0	0	0
2056	4,113	151	259	0	0	0	0	1,086	1,853	0	0	0
2057	4,124	151	259	0	0	0	0	1,087	1,852	0	0	0
2058	4,135	151	259	0	0	0	0	1,090	1,947	0	0	0
2059	4,147	151	259	0	0	0	0	1,093	1,944	0	0	0
2060	4,157	151	259	0	0	0	0	1,099	1,938	0	0	0

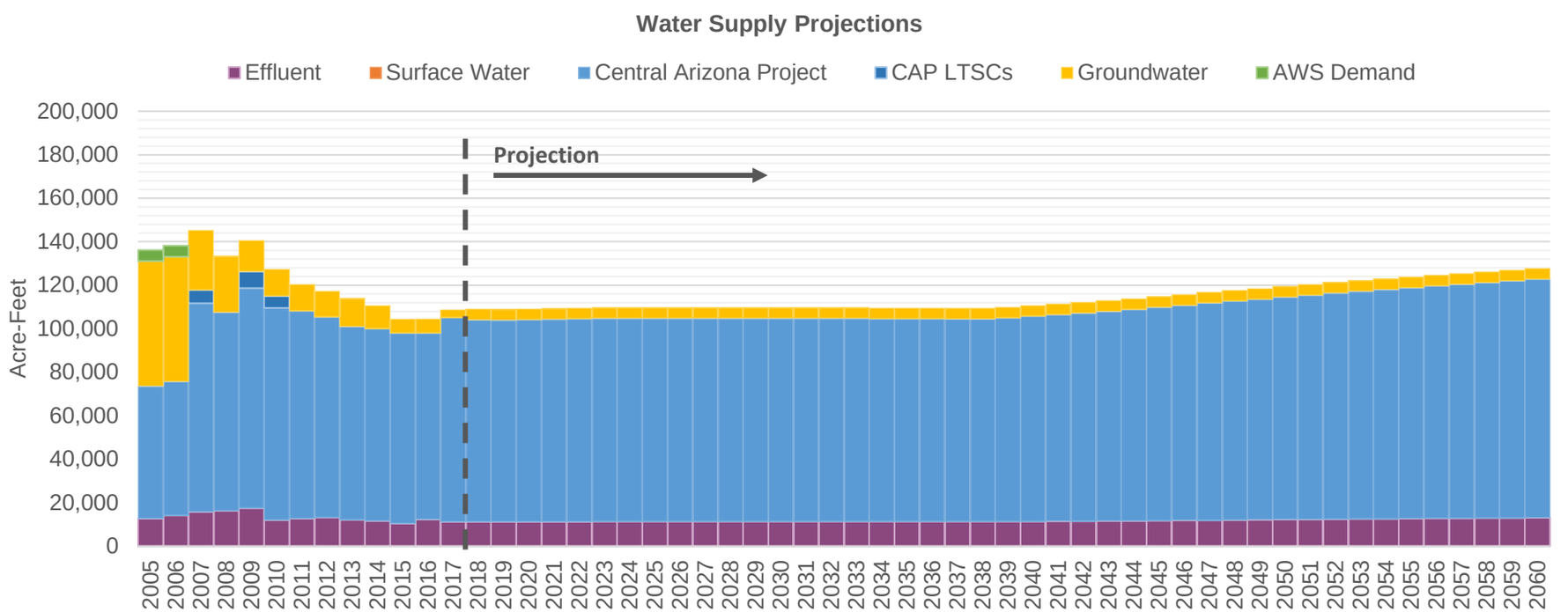
Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]

Tucson







Central Arizona Project Service Area Model

Tucson

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

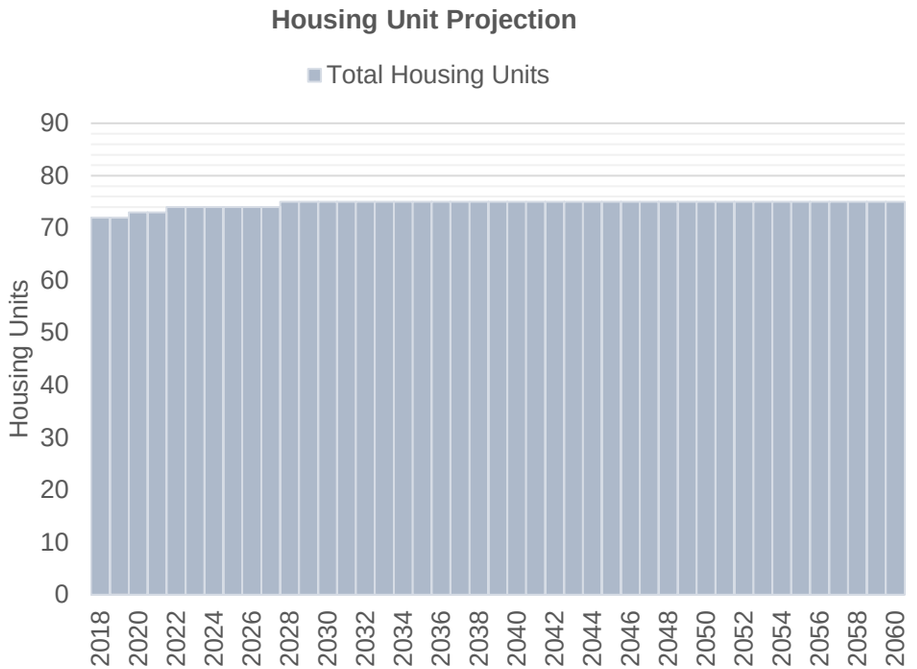
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

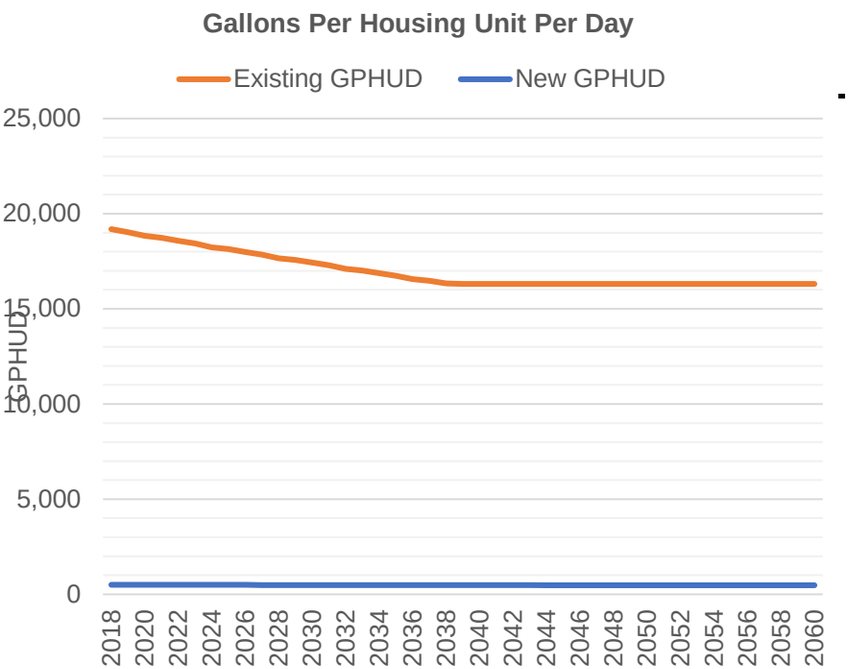
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	311,886	313	246	11,236	0	0	0	92,867	51,305	0	4,951	0
2019	315,484	311	246	11,236	0	0	0	92,751	51,421	0	4,951	0
2020	319,407	307	245	11,224	0	0	0	92,936	51,236	0	4,951	0
2021	323,534	306	245	11,242	0	0	0	93,156	51,016	0	4,951	0
2022	327,386	303	244	11,266	0	0	0	93,368	50,804	0	4,951	0
2023	330,416	301	244	11,291	0	0	0	93,432	50,740	0	4,951	0
2024	333,467	298	243	11,300	0	0	0	93,422	50,750	0	4,951	0
2025	336,525	296	243	11,300	0	0	0	93,395	50,777	0	4,951	0
2026	339,590	294	242	11,297	0	0	0	93,393	50,779	0	4,951	0
2027	342,656	291	242	11,296	0	0	0	93,393	50,779	0	4,951	0
2028	345,692	288	241	11,296	0	0	0	93,417	50,755	0	4,951	0
2029	348,735	287	241	11,299	0	0	0	93,388	50,784	0	4,951	0
2030	351,781	285	240	11,296	0	0	0	93,394	50,778	0	4,951	0
2031	354,829	282	240	11,296	0	0	0	93,401	50,771	0	4,951	0
2032	357,867	279	240	11,297	0	0	0	93,443	50,729	0	4,951	0
2033	360,641	278	239	11,302	0	0	0	93,380	50,792	0	4,951	0
2034	363,412	276	239	11,296	0	0	0	93,329	50,843	0	4,951	0
2035	366,179	273	238	11,290	0	0	0	93,280	50,892	0	4,951	0
2036	368,939	270	238	11,284	0	0	0	93,274	50,898	0	4,951	0
2037	371,692	269	237	11,283	0	0	0	93,182	50,990	0	4,951	0
2038	374,572	267	237	11,273	0	0	0	93,159	51,013	0	4,951	0
2039	377,442	266	236	11,270	0	0	0	93,716	50,456	0	4,951	0
2040	380,298	266	236	11,327	0	0	0	94,430	49,742	0	4,951	0
2041	383,141	266	235	11,406	0	0	0	95,015	49,157	0	4,951	0
2042	385,967	266	235	11,475	0	0	0	95,654	48,518	0	4,951	0
2043	389,602	266	234	11,548	0	0	0	96,390	47,782	0	4,951	0
2044	393,326	266	234	11,631	0	0	0	97,304	46,868	0	4,951	0
2045	397,022	266	234	11,734	0	0	0	98,115	46,057	0	4,951	0
2046	400,689	266	234	11,828	0	0	0	98,986	45,186	0	4,951	0
2047	404,325	266	234	11,927	0	0	0	99,844	44,328	0	4,951	0
2048	407,872	266	234	12,026	0	0	0	100,755	43,417	0	4,951	0
2049	411,341	266	234	12,130	0	0	0	101,502	42,670	0	4,951	0
2050	414,774	266	234	12,218	0	0	0	102,319	41,853	0	4,951	0
2051	418,170	266	234	12,311	0	0	0	103,120	41,052	0	4,951	0
2052	421,527	266	234	12,403	0	0	0	103,992	40,180	0	4,951	0
2053	424,770	266	234	12,503	0	0	0	104,679	39,493	0	4,951	0
2054	427,898	266	234	12,584	0	0	0	105,433	34,081	0	4,951	0
2055	430,986	266	234	12,670	0	0	0	106,162	23,350	0	4,951	0
2056	434,031	266	234	12,753	0	0	0	106,970	32,544	0	4,951	0
2057	437,032	266	234	12,845	0	0	0	107,582	31,931	0	4,951	0
2058	439,989	266	234	12,918	0	0	0	108,290	35,882	0	4,951	0
2059	442,901	266	234	12,998	0	0	0	108,979	35,193	0	4,951	0
2060	445,766	266	234	13,078	0	0	0	109,753	34,419	0	4,951	0

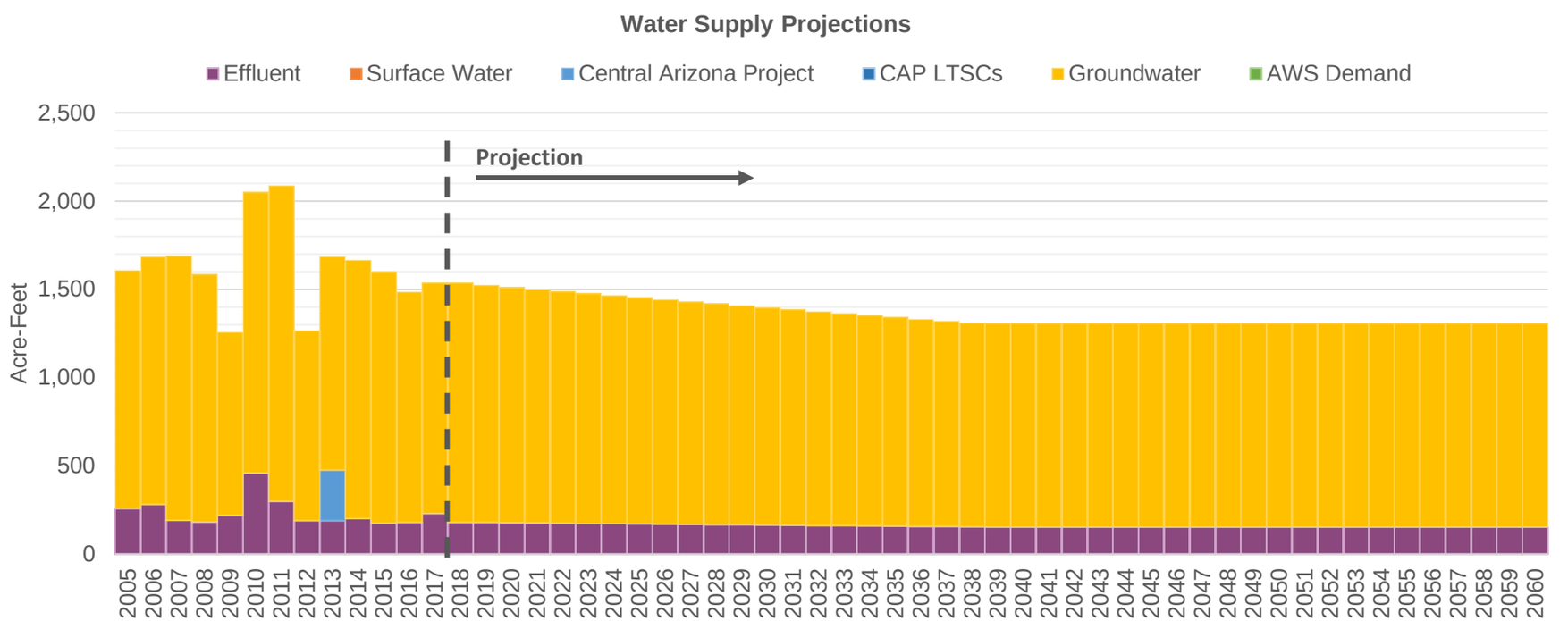
UniversityofAZ

Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

UniversityofAZ

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions

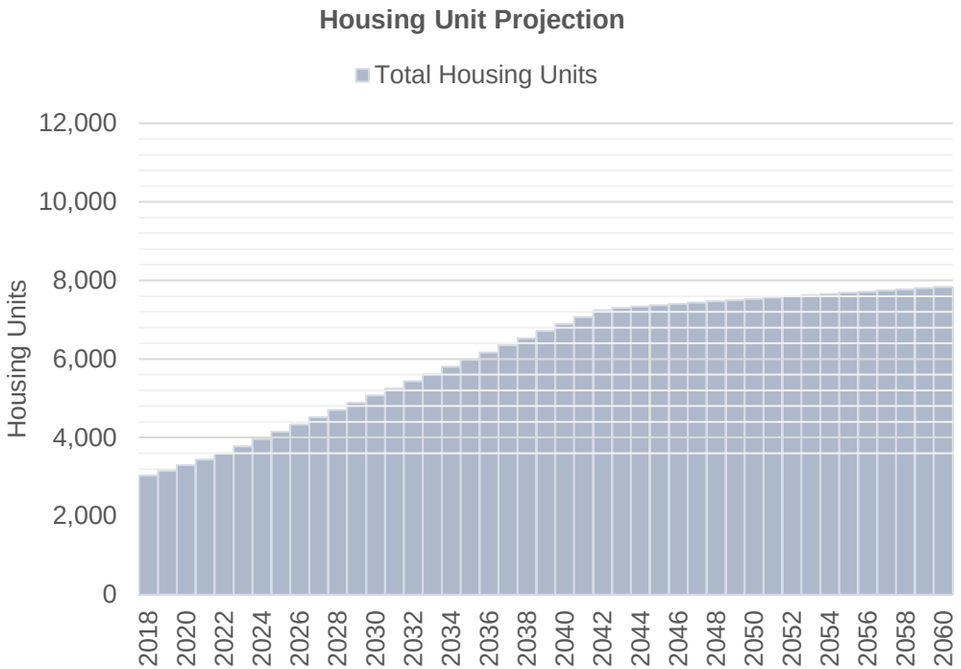
Water Supply Projections (Acre-Feet)

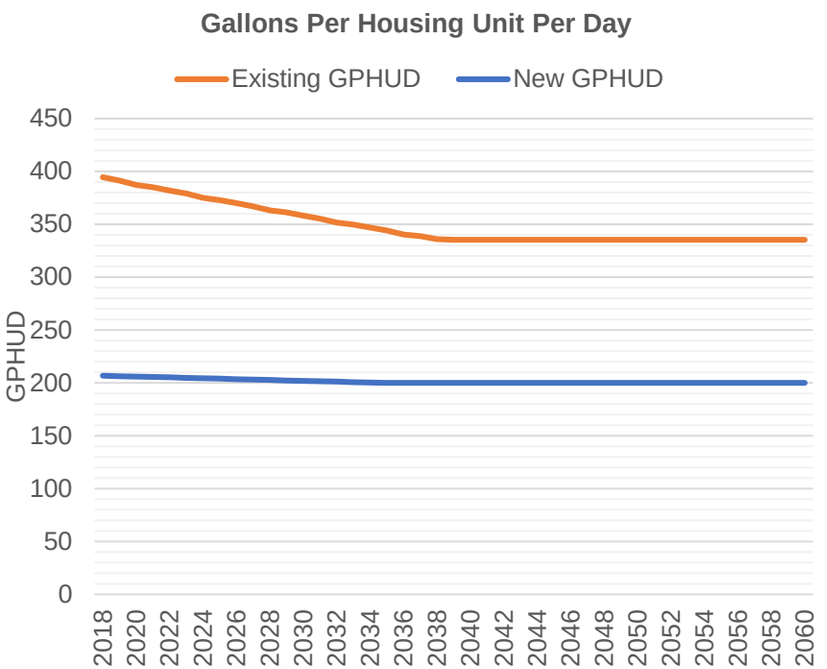
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	72	19,189	500	180	0	0	0	0	0	0	1,356	0
2019	72	19,035	499	180	0	0	0	0	0	0	1,344	0
2020	73	18,831	498	179	0	0	0	0	0	0	1,334	0
2021	73	18,732	497	177	0	0	0	0	0	0	1,323	0
2022	74	18,582	496	176	0	0	0	0	0	0	1,313	0
2023	74	18,433	495	174	0	0	0	0	0	0	1,303	0
2024	74	18,236	494	173	0	0	0	0	0	0	1,292	0
2025	74	18,139	493	172	0	0	0	0	0	0	1,282	0
2026	74	17,994	492	170	0	0	0	0	0	0	1,272	0
2027	74	17,850	491	169	0	0	0	0	0	0	1,261	0
2028	75	17,659	490	168	0	0	0	0	0	0	1,252	0
2029	75	17,566	489	166	0	0	0	0	0	0	1,242	0
2030	75	17,425	488	165	0	0	0	0	0	0	1,232	0
2031	75	17,286	487	164	0	0	0	0	0	0	1,222	0
2032	75	17,101	486	162	0	0	0	0	0	0	1,213	0
2033	75	17,011	485	161	0	0	0	0	0	0	1,203	0
2034	75	16,874	484	160	0	0	0	0	0	0	1,193	0
2035	75	16,739	483	159	0	0	0	0	0	0	1,183	0
2036	75	16,560	482	157	0	0	0	0	0	0	1,174	0
2037	75	16,473	481	156	0	0	0	0	0	0	1,165	0
2038	75	16,341	480	155	0	0	0	0	0	0	1,155	0
2039	75	16,310	479	153	0	0	0	0	0	0	1,155	0
2040	75	16,310	478	153	0	0	0	0	0	0	1,155	0
2041	75	16,310	477	153	0	0	0	0	0	0	1,154	0
2042	75	16,310	477	153	0	0	0	0	0	0	1,154	0
2043	75	16,310	476	153	0	0	0	0	0	0	1,154	0
2044	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2045	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2046	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2047	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2048	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2049	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2050	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2051	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2052	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2053	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2054	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2055	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2056	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2057	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2058	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2059	75	16,310	475	153	0	0	0	0	0	0	1,154	0
2060	75	16,310	475	153	0	0	0	0	0	0	1,154	0

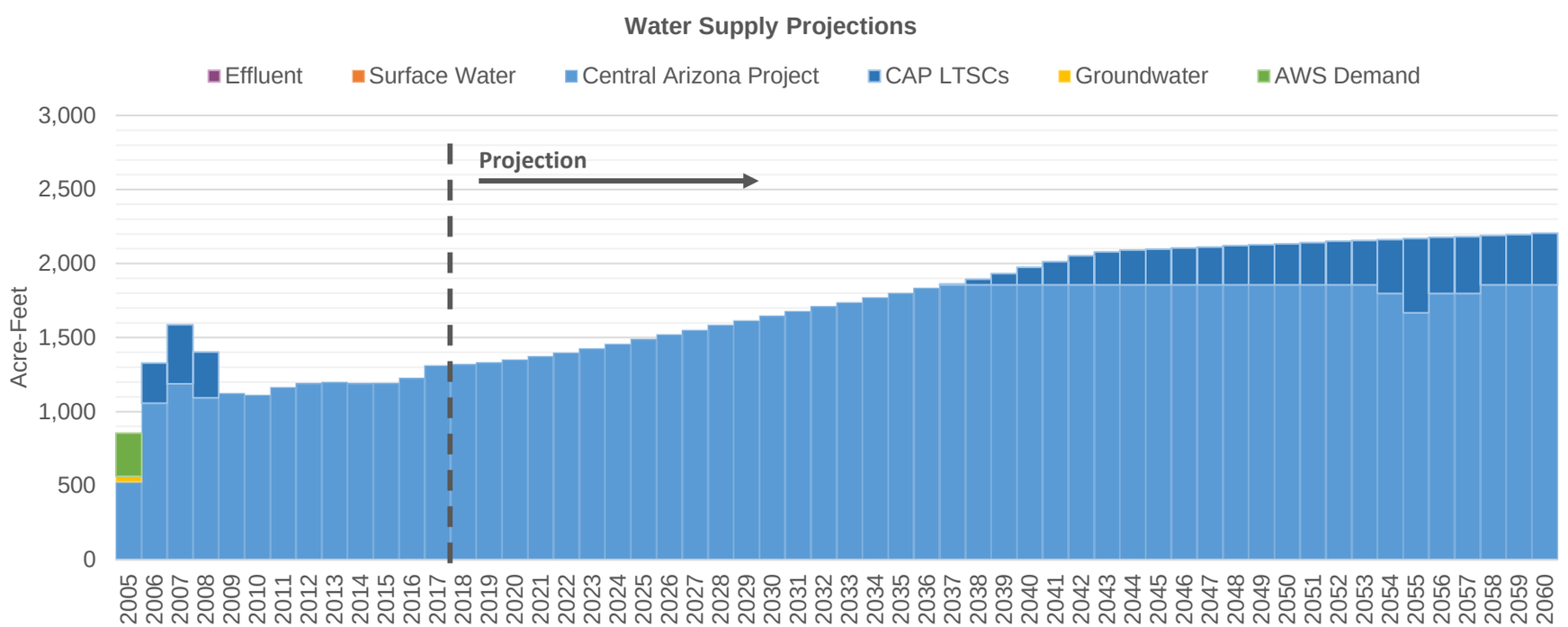
Central Arizona Project Service Area Model

VailWC

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

VailWC

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

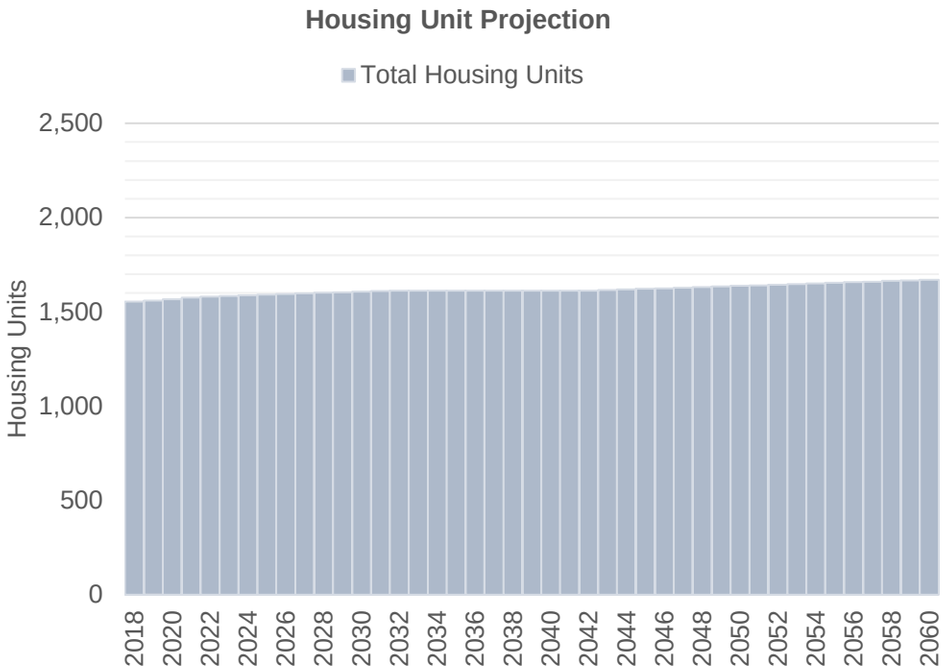
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

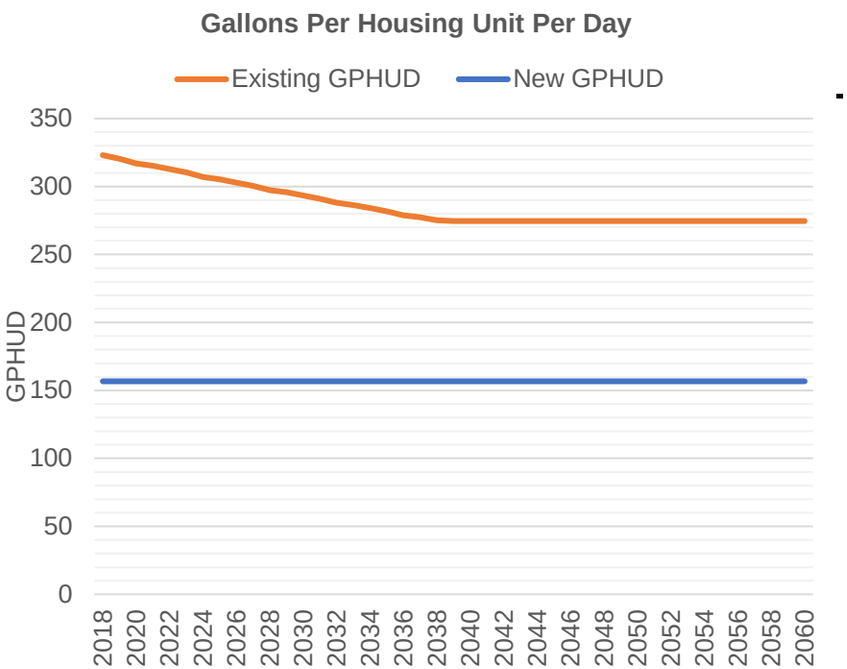
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,033	395	207	0	0	0	0	1,319	538	0	0	0
2019	3,157	391	206	0	0	0	0	1,330	527	0	0	0
2020	3,294	387	206	0	0	0	0	1,350	507	0	0	0
2021	3,438	385	206	0	0	0	0	1,372	485	0	0	0
2022	3,595	382	205	0	0	0	0	1,396	461	0	0	0
2023	3,778	379	205	0	0	0	0	1,425	432	0	0	0
2024	3,963	375	204	0	0	0	0	1,457	400	0	0	0
2025	4,147	373	204	0	0	0	0	1,488	369	0	0	0
2026	4,333	370	204	0	0	0	0	1,520	337	0	0	0
2027	4,518	367	203	0	0	0	0	1,552	305	0	0	0
2028	4,701	363	203	0	0	0	0	1,584	273	0	0	0
2029	4,885	361	202	0	0	0	0	1,614	243	0	0	0
2030	5,069	358	202	0	0	0	0	1,645	212	0	0	0
2031	5,253	355	201	0	0	0	0	1,677	180	0	0	0
2032	5.437	352	201	0	0	0	0	1.709	148	0	0	0
2033	5,620	350	201	0	0	0	0	1,738	119	0	0	0
2034	5,803	347	200	0	0	0	0	1,769	88	0	0	0
2035	5,985	344	200	0	0	0	0	1,800	57	0	0	0
2036	6,167	340	200	0	0	0	0	1,833	24	0	0	0
2037	6,348	339	200	0	0	0	0	1,857	0	6	0	0
2038	6,529	336	200	0	0	0	0	1,857	0	37	0	0
2039	6,709	335	200	0	0	0	0	1,857	0	76	0	0
2040	6,888	335	200	0	0	0	0	1,857	0	118	0	0
2041	7,067	335	200	0	0	0	0	1,857	0	156	0	0
2042	7,244	335	200	0	0	0	0	1,857	0	196	0	0
2043	7,299	335	200	0	0	0	0	1,857	0	222	0	0
2044	7,333	335	200	0	0	0	0	1,857	0	235	0	0
2045	7,367	335	200	0	0	0	0	1,857	0	240	0	0
2046	7,400	335	200	0	0	0	0	1,857	0	247	0	0
2047	7,433	335	200	0	0	0	0	1,857	0	254	0	0
2048	7,466	335	200	0	0	0	0	1,857	0	265	0	0
2049	7,498	335	200	0	0	0	0	1,857	0	269	0	0
2050	7,530	335	200	0	0	0	0	1,857	0	276	0	0
2051	7,561	335	200	0	0	0	0	1,857	0	283	0	0
2052	7,593	335	200	0	0	0	0	1,857	0	293	0	0
2053	7,624	335	200	0	0	0	0	1,857	0	297	0	0
2054	7,655	335	200	0	0	0	0	1,797	0	364	0	0
2055	7,686	335	200	0	0	0	0	1,668	0	500	0	0
2056	7,716	335	200	0	0	0	0	1,797	0	381	0	0
2057	7,746	335	200	0	0	0	0	1,797	0	385	0	0
2058	7,776	335	200	0	0	0	0	1,857	0	332	0	0
2059	7,805	335	200	0	0	0	0	1,857	0	338	0	0
2060	7,834	335	200	0	0	0	0	1,857	0	348	0	0

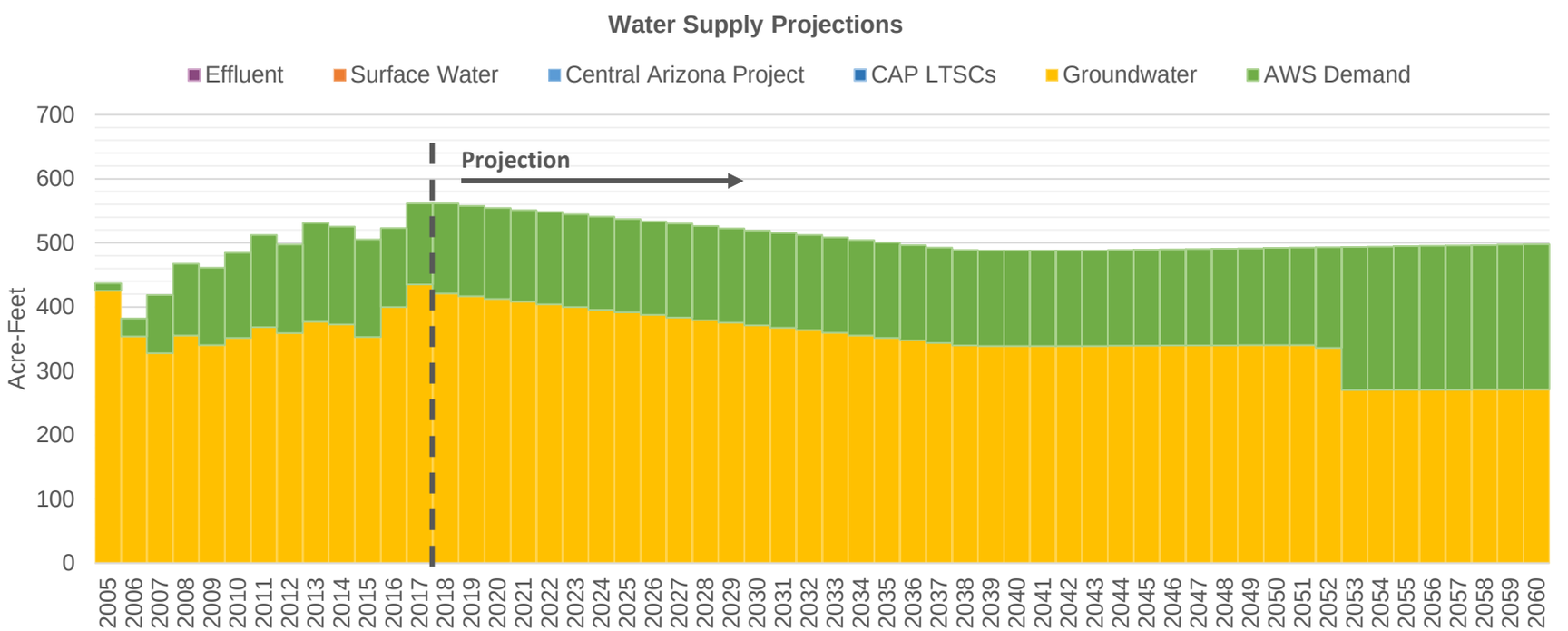
VoyagerWC

Central Arizona Project Service Area Model

A. Official, Historic Climate [LSCRBS]







Central Arizona Project Service Area Model

VoyagerWC

A. Official, Historic Climate [LSCRBS]

6/30/20 11:57 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,554	323	157	0	0	0	0	0	0	0	421	141
2019	1,560	320	157	0	0	0	0	0	0	0	417	141
2020	1,567	317	157	0	0	0	0	0	0	0	413	142
2021	1,575	315	157	0	0	0	0	0	0	0	408	143
2022	1,581	313	157	0	0	0	0	0	0	0	404	144
2023	1,584	310	157	0	0	0	0	0	0	0	400	145
2024	1,588	307	157	0	0	0	0	0	0	0	396	145
2025	1,591	305	157	0	0	0	0	0	0	0	392	146
2026	1,594	303	157	0	0	0	0	0	0	0	387	146
2027	1,598	301	157	0	0	0	0	0	0	0	383	146
2028	1,601	297	157	0	0	0	0	0	0	0	379	147
2029	1,604	296	157	0	0	0	0	0	0	0	375	147
2030	1,607	293	157	0	0	0	0	0	0	0	371	148
2031	1,610	291	157	0	0	0	0	0	0	0	367	148
2032	1,613	288	157	0	0	0	0	0	0	0	364	149
2033	1,613	286	157	0	0	0	0	0	0	0	359	149
2034	1,613	284	157	0	0	0	0	0	0	0	355	149
2035	1,613	282	157	0	0	0	0	0	0	0	352	149
2036	1,613	279	157	0	0	0	0	0	0	0	348	149
2037	1,613	277	157	0	0	0	0	0	0	0	344	149
2038	1,613	275	157	0	0	0	0	0	0	0	340	149
2039	1,613	275	157	0	0	0	0	0	0	0	339	149
2040	1,613	275	157	0	0	0	0	0	0	0	339	149
2041	1,613	275	157	0	0	0	0	0	0	0	339	149
2042	1,613	275	157	0	0	0	0	0	0	0	339	149
2043	1,615	275	157	0	0	0	0	0	0	0	339	149
2044	1,619	275	157	0	0	0	0	0	0	0	339	149
2045	1,622	275	157	0	0	0	0	0	0	0	340	150
2046	1,625	275	157	0	0	0	0	0	0	0	340	150
2047	1,628	275	157	0	0	0	0	0	0	0	340	150
2048	1,631	275	157	0	0	0	0	0	0	0	340	151
2049	1,635	275	157	0	0	0	0	0	0	0	340	151
2050	1,638	275	157	0	0	0	0	0	0	0	340	152
2051	1,641	275	157	0	0	0	0	0	0	0	340	152
2052	1,644	275	157	0	0	0	0	0	0	0	336	157
2053	1,647	275	157	0	0	0	0	0	0	0	270	223
2054	1,651	275	157	0	0	0	0	0	0	0	270	224
2055	1,654	275	157	0	0	0	0	0	0	0	270	224
2056	1,657	275	157	0	0	0	0	0	0	0	271	225
2057	1,660	275	157	0	0	0	0	0	0	0	271	225
2058	1,664	275	157	0	0	0	0	0	0	0	271	226
2059	1,667	275	157	0	0	0	0	0	0	0	271	226
2060	1,670	275	157	0	0	0	0	0	0	0	271	226

CAP:SAM Supply and Demand Projections by Water Provider

Scenario B

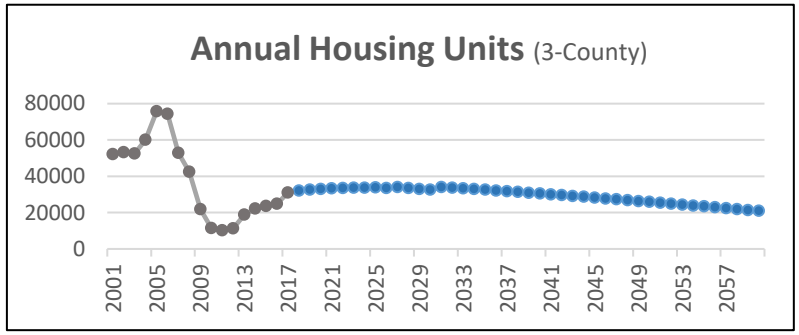
Climate: Best Case
Growth Rate: Slow
Growth Pattern: Compact
Relative Risk: Low

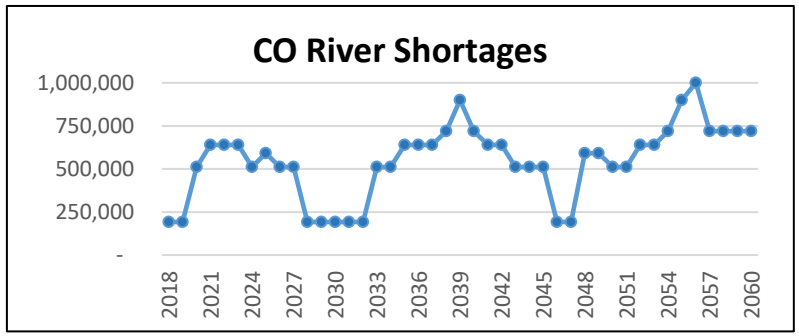
B. Slow, Compact, Dry Climate [LSCRBS]

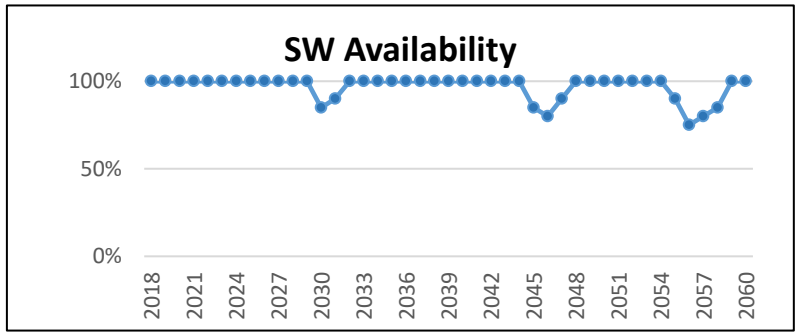
Run Date: 7/6/2020 **Filename:** CAPServiceArea_v3.50_LSCRBS_ACv

Growth rate based on Low growth series from AZ Dept. of Administration, and condensed growth pattern. "Dry" = "Best

Allow Shortages	Yes	
Select CRSS Array	3	*3=Synthetic*
Use Specific Trace	Yes	
Selected Trace	2	*1=Moderate; 2=Deep; 3=Slight*
AWBA Max M&I	20%	
Surface Water Scenario	2	*1=No Reduction; 2=Occational; 3=Frequent*
Use CAP Buildup	Yes	
CAP Buildup Scenario	2	*1=2035; 2=2045*
HU Growth Pattern	5	*1=Baseline*
HU Forecast	2	*1=Use Curve; 2=Eller Forecast*
HU Curve	3	
HU Growth Start Rate	-1%	
HU Ordinary Level	34,000	
HU Rate @ 50 yrs	-3%	
GPHUD Change Existing	-0.6%	*per year*
GPHUD Max Change Existing	-15%	
GPHUD Min Existing	180	
GPHUD Scenario New	1	
GPHUD Change New	-0.2%	*per year*
Ag Climate Adjustment	0.1	
Ag Efficiency Increase	0.1%	*per year*
Ag Efficiency Goal	90%	
Ag Replace Crop CU	2.66	
Ag Intensity Scenario	2	
Ag Develop on Crops	40%	*Perecent of max on active Ag*
Ag Acres Replace Percent	0%	
Ag Replace Crop Year	2025	



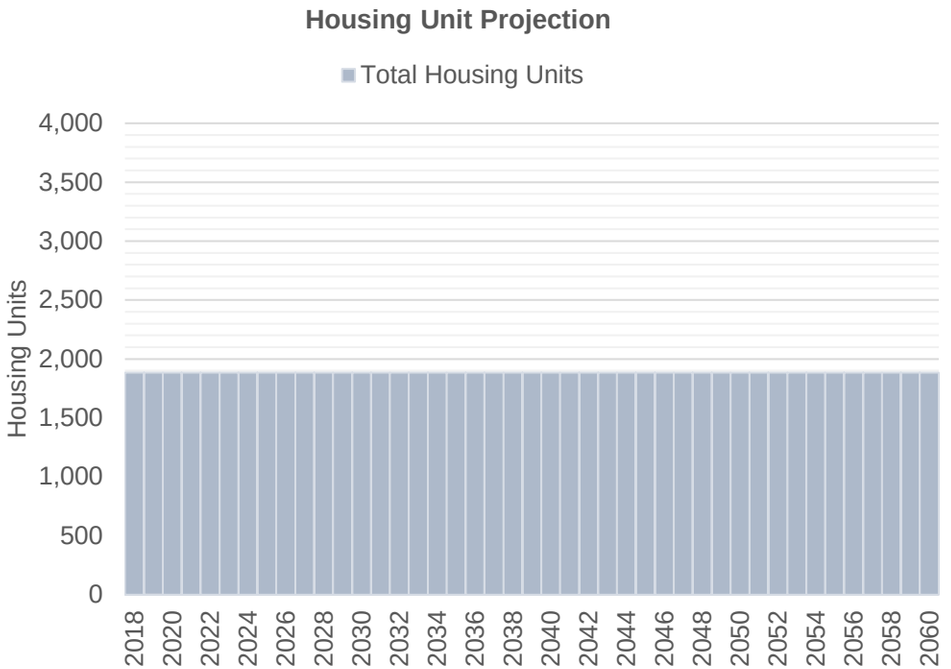


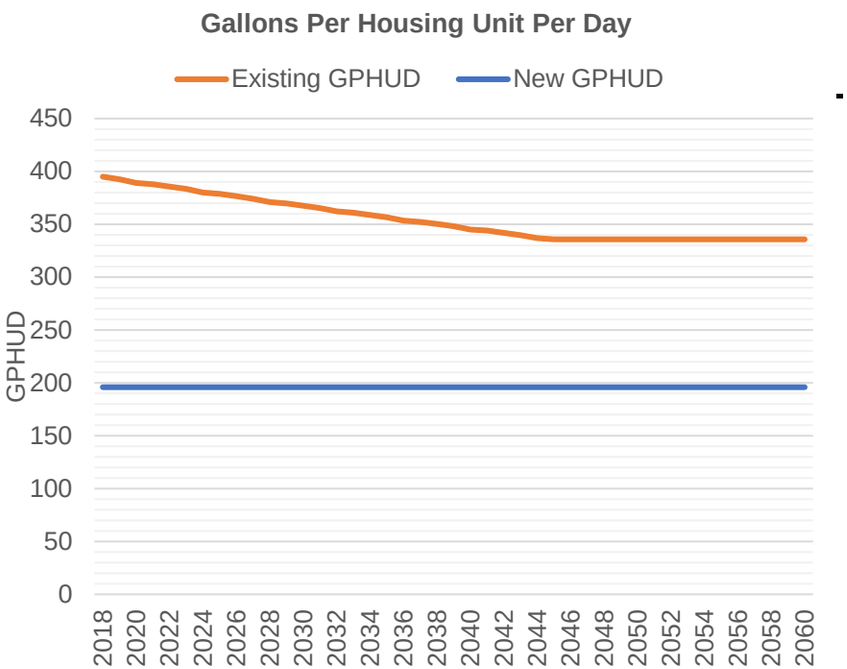


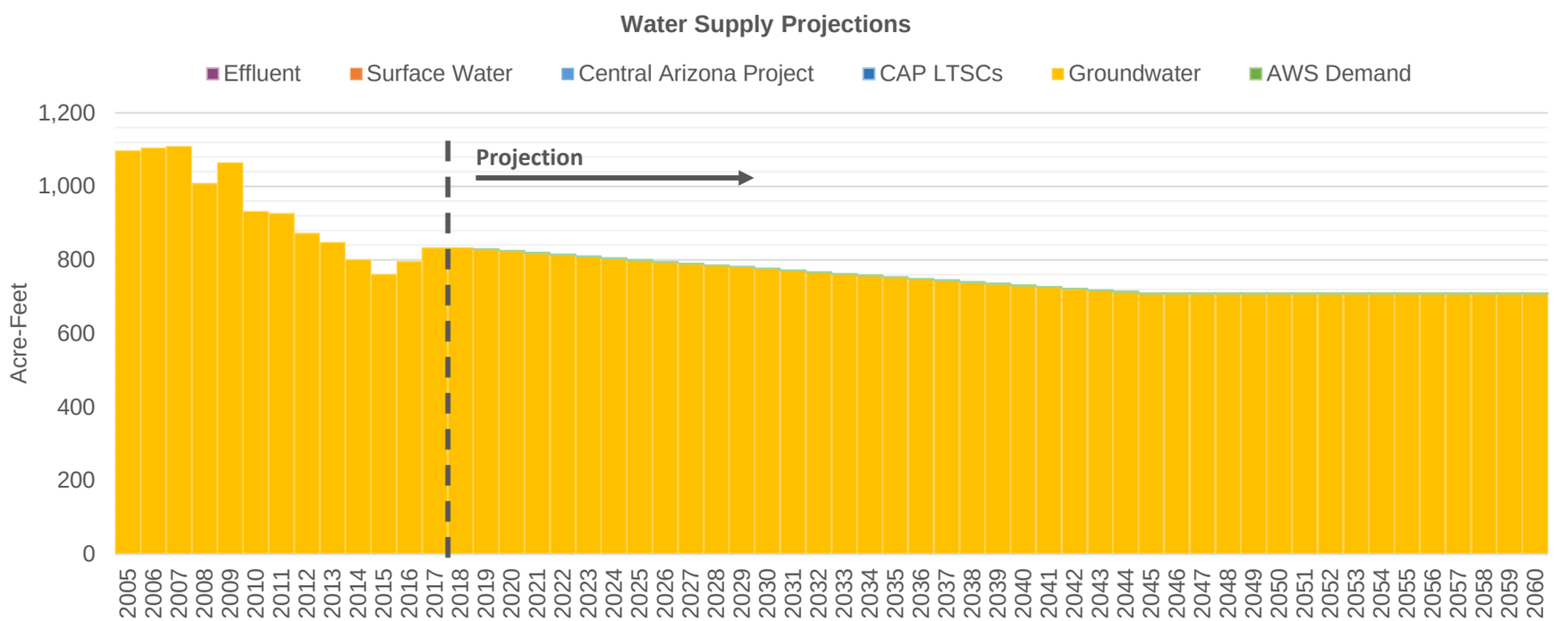
Central Arizona Project Service Area Model

AvraWaterCoop

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

AvraWaterCoop

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

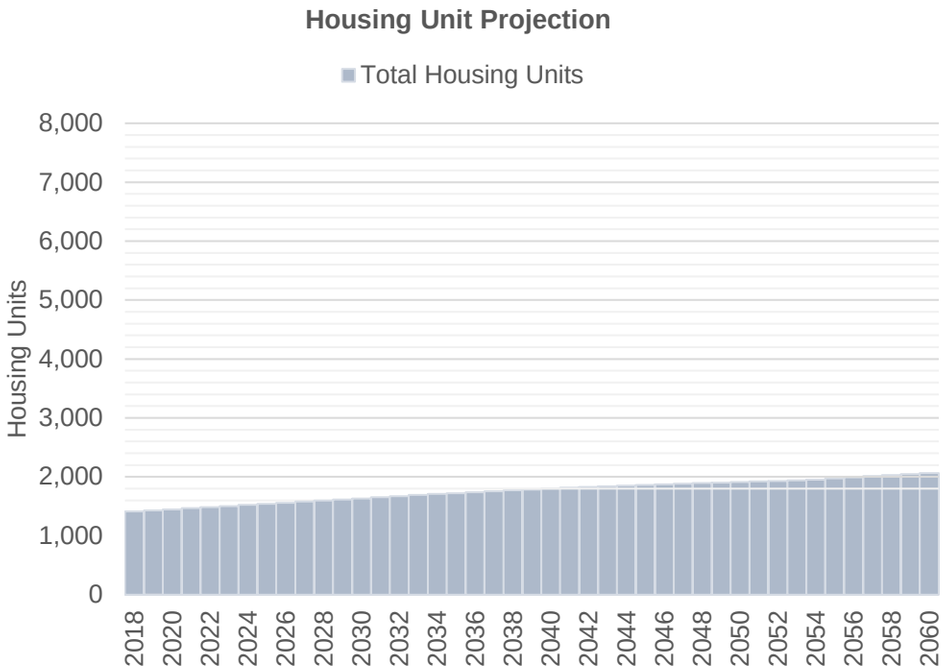
Water Supply Projections (Acre-Feet)

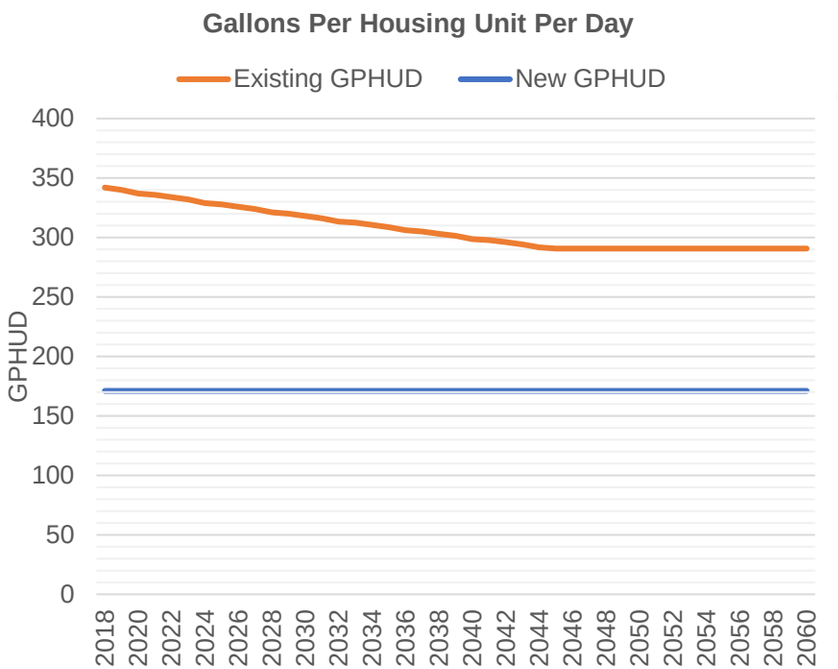
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,885	395	196	0	0	0	0	0	0	0	834	0
2019	1,885	393	196	0	0	0	0	0	0	0	829	0
2020	1,885	389	196	0	0	0	0	0	0	0	824	0
2021	1,885	388	196	0	0	0	0	0	0	0	819	0
2022	1,885	386	196	0	0	0	0	0	0	0	814	0
2023	1,885	383	196	0	0	0	0	0	0	0	809	0
2024	1,885	380	196	0	0	0	0	0	0	0	804	0
2025	1,885	379	196	0	0	0	0	0	0	0	800	0
2026	1,885	376	196	0	0	0	0	0	0	0	795	0
2027	1,885	374	196	0	0	0	0	0	0	0	790	0
2028	1,885	371	196	0	0	0	0	0	0	0	785	0
2029	1,885	370	196	0	0	0	0	0	0	0	781	0
2030	1,885	367	196	0	0	0	0	0	0	0	776	0
2031	1,885	365	196	0	0	0	0	0	0	0	771	0
2032	1,885	362	196	0	0	0	0	0	0	0	767	0
2033	1,885	361	196	0	0	0	0	0	0	0	762	0
2034	1,885	359	196	0	0	0	0	0	0	0	757	0
2035	1,885	357	196	0	0	0	0	0	0	0	753	0
2036	1,885	353	196	0	0	0	0	0	0	0	748	0
2037	1,885	352	196	0	0	0	0	0	0	0	744	0
2038	1,885	350	196	0	0	0	0	0	0	0	739	0
2039	1,885	348	196	0	0	0	0	0	0	0	735	0
2040	1,885	345	196	0	0	0	0	0	0	0	731	0
2041	1,885	344	196	0	0	0	0	0	0	0	726	0
2042	1,885	342	196	0	0	0	0	0	0	0	722	0
2043	1,885	340	196	0	0	0	0	0	0	0	718	0
2044	1,885	337	196	0	0	0	0	0	0	0	713	0
2045	1,885	336	196	0	0	0	0	0	0	0	709	0
2046	1,885	336	196	0	0	0	0	0	0	0	709	0
2047	1,885	336	196	0	0	0	0	0	0	0	709	0
2048	1,885	336	196	0	0	0	0	0	0	0	709	0
2049	1,885	336	196	0	0	0	0	0	0	0	709	0
2050	1,885	336	196	0	0	0	0	0	0	0	709	0
2051	1,885	336	196	0	0	0	0	0	0	0	709	0
2052	1,885	336	196	0	0	0	0	0	0	0	709	0
2053	1,885	336	196	0	0	0	0	0	0	0	709	0
2054	1,885	336	196	0	0	0	0	0	0	0	709	0
2055	1,885	336	196	0	0	0	0	0	0	0	709	0
2056	1,885	336	196	0	0	0	0	0	0	0	709	0
2057	1,885	336	196	0	0	0	0	0	0	0	709	0
2058	1,885	336	196	0	0	0	0	0	0	0	709	0
2059	1,885	336	196	0	0	0	0	0	0	0	709	0
2060	1,885	336	196	0	0	0	0	0	0	0	709	0

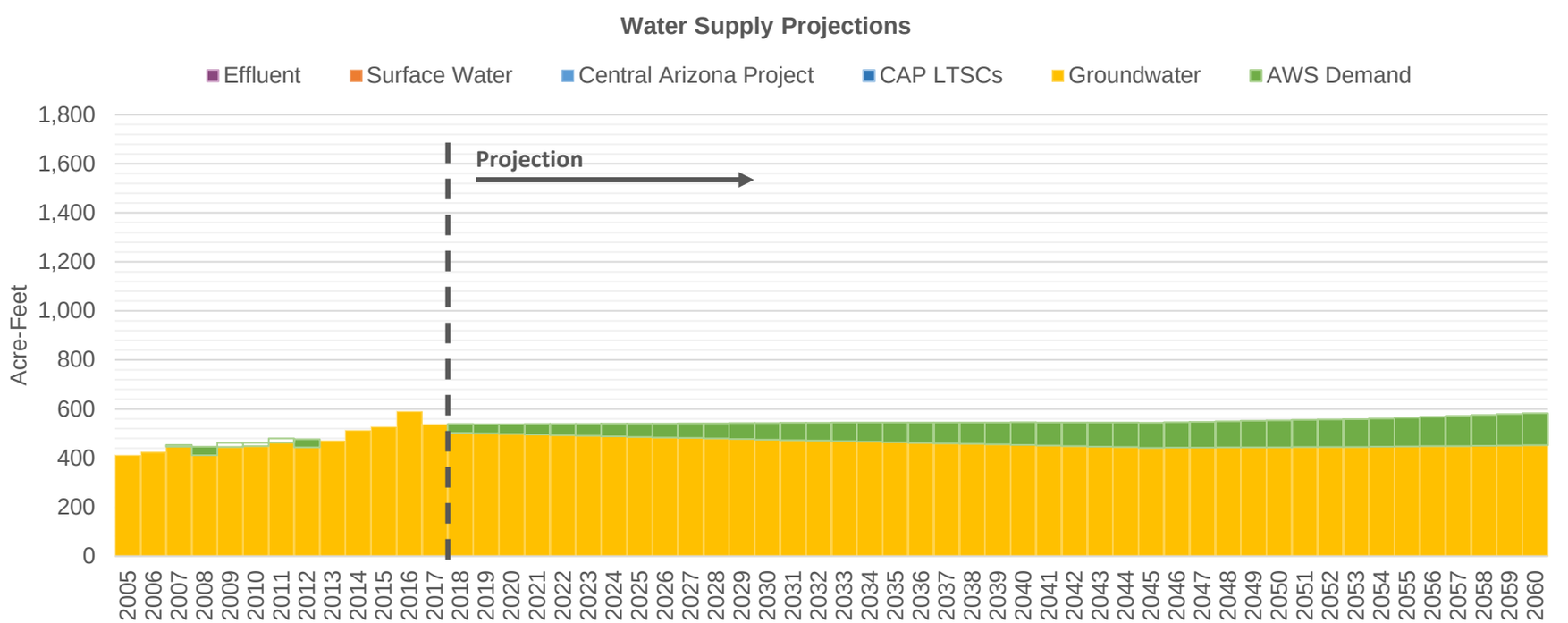
AZWCOracle

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

AZWCOracle

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

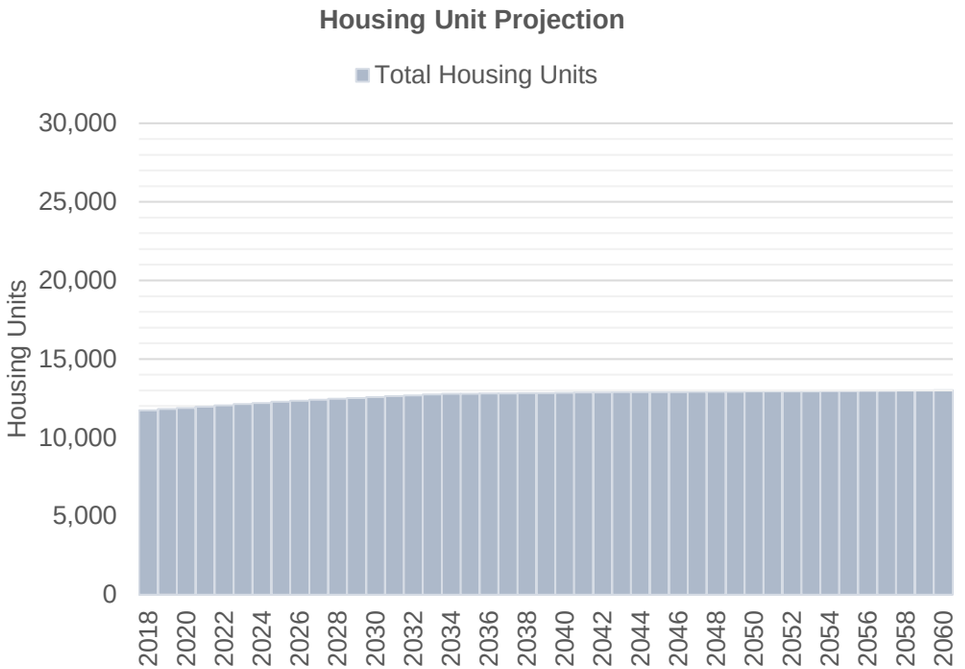
Water Supply Projections (Acre-Feet)

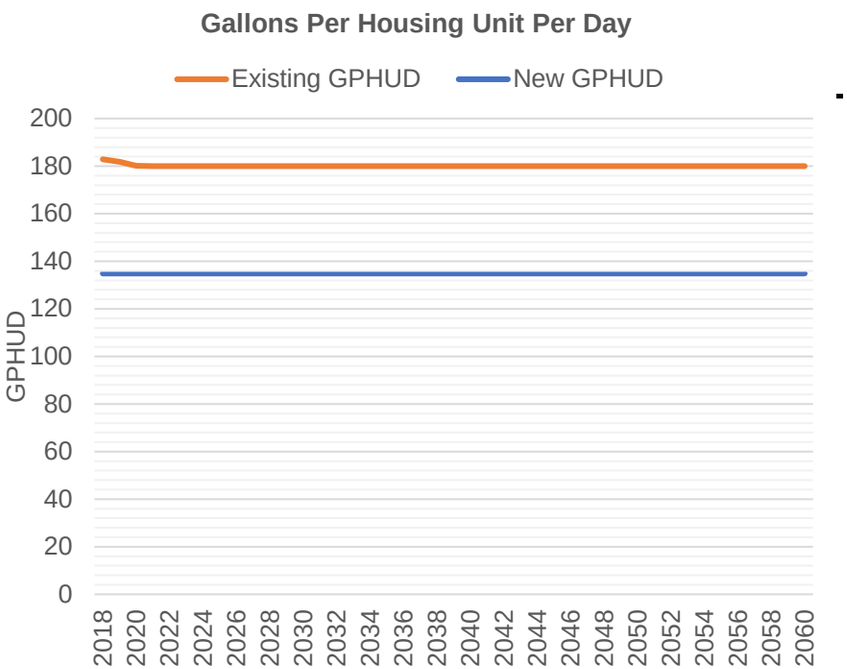
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,412	342	171	0	0	0	0	0	0	0	503	36
2019	1,430	340	171	0	0	0	0	0	0	0	501	37
2020	1,449	337	171	0	0	0	0	0	0	0	499	40
2021	1,467	336	171	0	0	0	0	0	0	0	496	43
2022	1,485	334	171	0	0	0	0	0	0	0	493	45
2023	1,504	332	171	0	0	0	0	0	0	0	491	48
2024	1,523	329	171	0	0	0	0	0	0	0	489	51
2025	1,541	328	171	0	0	0	0	0	0	0	486	54
2026	1,560	326	171	0	0	0	0	0	0	0	484	56
2027	1,579	324	171	0	0	0	0	0	0	0	482	59
2028	1,598	321	171	0	0	0	0	0	0	0	480	62
2029	1,616	320	171	0	0	0	0	0	0	0	478	65
2030	1,634	318	171	0	0	0	0	0	0	0	475	67
2031	1,654	316	171	0	0	0	0	0	0	0	473	70
2032	1,673	313	171	0	0	0	0	0	0	0	471	73
2033	1,691	312	171	0	0	0	0	0	0	0	469	76
2034	1,709	311	171	0	0	0	0	0	0	0	467	78
2035	1,724	309	171	0	0	0	0	0	0	0	465	81
2036	1,740	306	171	0	0	0	0	0	0	0	463	83
2037	1,755	305	171	0	0	0	0	0	0	0	460	85
2038	1,771	303	171	0	0	0	0	0	0	0	458	88
2039	1,786	301	171	0	0	0	0	0	0	0	456	90
2040	1,800	299	171	0	0	0	0	0	0	0	454	92
2041	1,815	298	171	0	0	0	0	0	0	0	451	94
2042	1,829	296	171	0	0	0	0	0	0	0	449	96
2043	1,842	294	171	0	0	0	0	0	0	0	447	98
2044	1,853	292	171	0	0	0	0	0	0	0	445	100
2045	1,863	291	171	0	0	0	0	0	0	0	442	102
2046	1,873	291	171	0	0	0	0	0	0	0	443	103
2047	1,883	291	171	0	0	0	0	0	0	0	443	105
2048	1,893	291	171	0	0	0	0	0	0	0	444	106
2049	1,903	291	171	0	0	0	0	0	0	0	444	108
2050	1,912	291	171	0	0	0	0	0	0	0	444	109
2051	1,922	291	171	0	0	0	0	0	0	0	445	111
2052	1,931	291	171	0	0	0	0	0	0	0	446	112
2053	1,940	291	171	0	0	0	0	0	0	0	446	113
2054	1,953	291	171	0	0	0	0	0	0	0	446	115
2055	1,973	291	171	0	0	0	0	0	0	0	448	117
2056	1,992	291	171	0	0	0	0	0	0	0	449	119
2057	2,011	291	171	0	0	0	0	0	0	0	449	122
2058	2,029	291	171	0	0	0	0	0	0	0	450	125
2059	2,047	291	171	0	0	0	0	0	0	0	451	128
2060	2,064	291	171	0	0	0	0	0	0	0	452	130

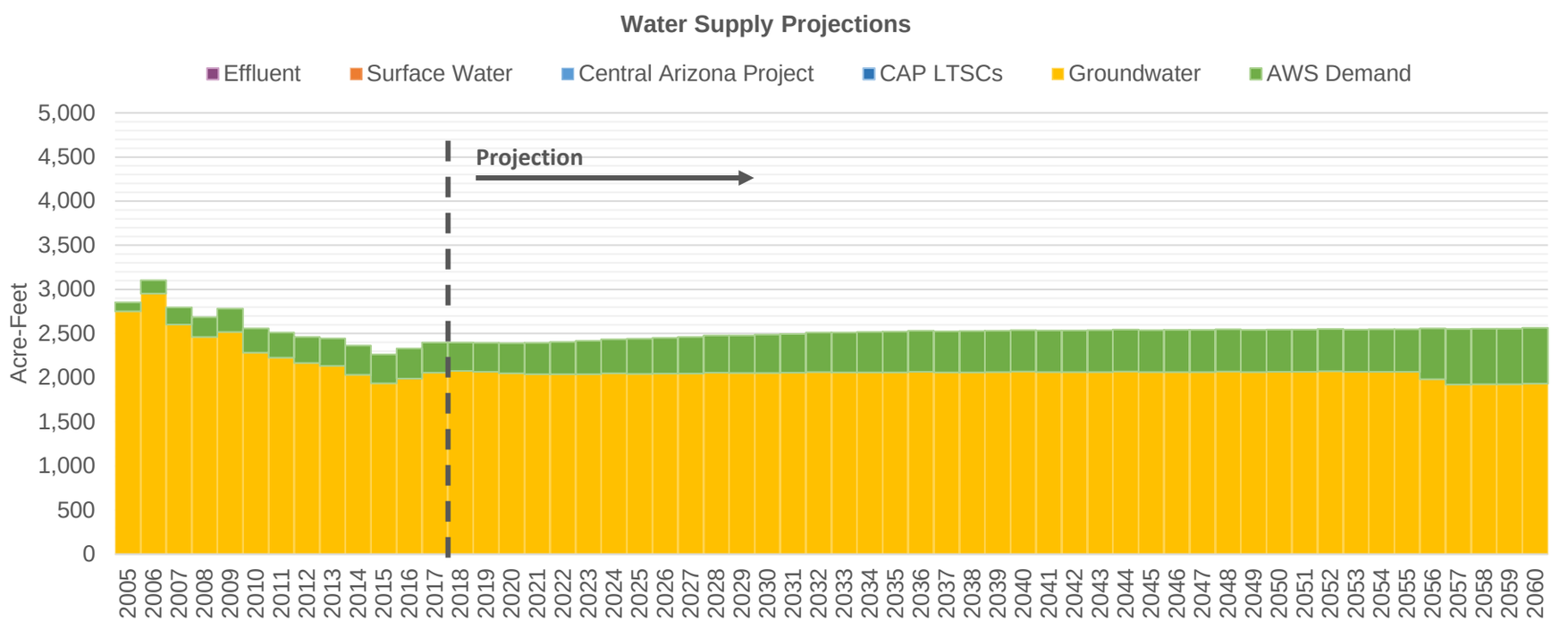
Central Arizona Project Service Area Model

CommWaterGreenVly

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

CommWaterGre

B. Slow, Compact, Dry Climate [LSCRBS]

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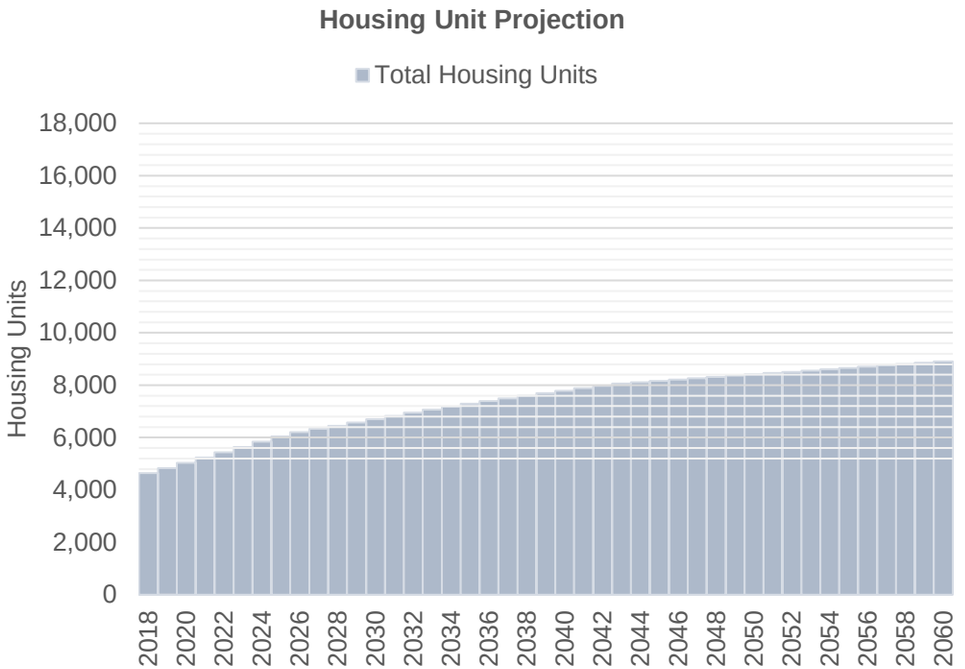
Demand Assumptions **Water Supply Projections** (Acre-Feet)

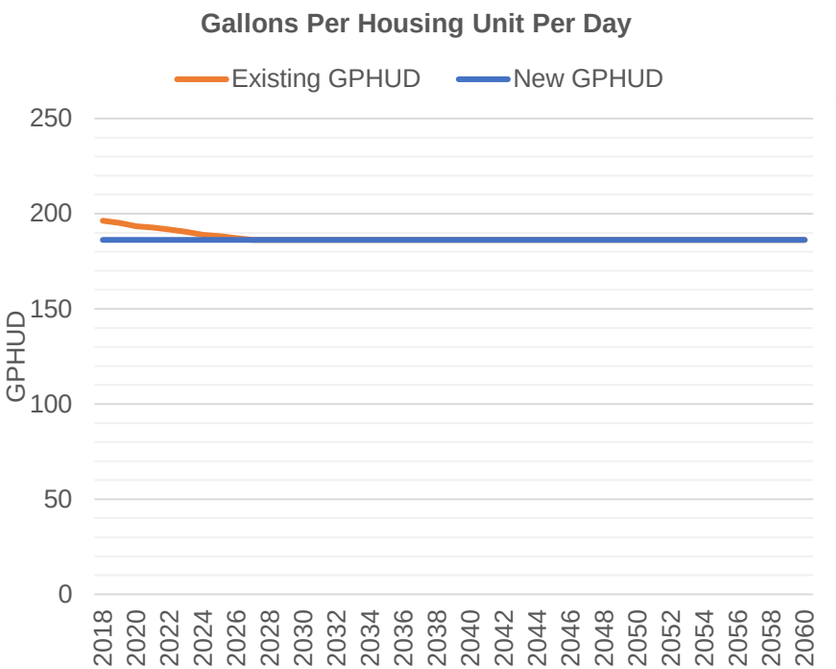
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	11,731	183	135	0	0	0	0	0	0	0	2,077	322
2019	11,809	182	135	0	0	0	0	0	0	0	2,065	328
2020	11,887	180	135	0	0	0	0	0	0	0	2,050	340
2021	11,967	180	135	0	0	0	0	0	0	0	2,040	353
2022	12,046	180	135	0	0	0	0	0	0	0	2,039	366
2023	12,126	180	135	0	0	0	0	0	0	0	2,040	378
2024	12,207	180	135	0	0	0	0	0	0	0	2,049	387
2025	12,287	180	135	0	0	0	0	0	0	0	2,044	397
2026	12,352	180	135	0	0	0	0	0	0	0	2,046	407
2027	12,409	180	135	0	0	0	0	0	0	0	2,047	414
2028	12,464	180	135	0	0	0	0	0	0	0	2,056	421
2029	12,519	180	135	0	0	0	0	0	0	0	2,051	427
2030	12,573	180	135	0	0	0	0	0	0	0	2,053	433
2031	12,630	180	135	0	0	0	0	0	0	0	2,056	439
2032	12,686	180	135	0	0	0	0	0	0	0	2,065	446
2033	12,741	180	135	0	0	0	0	0	0	0	2,060	452
2034	12,779	180	135	0	0	0	0	0	0	0	2,060	459
2035	12,791	180	135	0	0	0	0	0	0	0	2,060	463
2036	12,803	180	135	0	0	0	0	0	0	0	2,067	464
2037	12,815	180	135	0	0	0	0	0	0	0	2,061	466
2038	12,827	180	135	0	0	0	0	0	0	0	2,061	467
2039	12,838	180	135	0	0	0	0	0	0	0	2,062	468
2040	12,850	180	135	0	0	0	0	0	0	0	2,069	470
2041	12,861	180	135	0	0	0	0	0	0	0	2,063	471
2042	12,872	180	135	0	0	0	0	0	0	0	2,063	472
2043	12,882	180	135	0	0	0	0	0	0	0	2,063	473
2044	12,888	180	135	0	0	0	0	0	0	0	2,070	475
2045	12,895	180	135	0	0	0	0	0	0	0	2,064	475
2046	12,901	180	135	0	0	0	0	0	0	0	2,064	476
2047	12,908	180	135	0	0	0	0	0	0	0	2,064	477
2048	12,914	180	135	0	0	0	0	0	0	0	2,071	477
2049	12,920	180	135	0	0	0	0	0	0	0	2,065	478
2050	12,926	180	135	0	0	0	0	0	0	0	2,065	479
2051	12,932	180	135	0	0	0	0	0	0	0	2,065	480
2052	12,938	180	135	0	0	0	0	0	0	0	2,072	480
2053	12,943	180	135	0	0	0	0	0	0	0	2,065	481
2054	12,951	180	135	0	0	0	0	0	0	0	2,066	481
2055	12,962	180	135	0	0	0	0	0	0	0	2,066	482
2056	12,973	180	135	0	0	0	0	0	0	0	1,982	575
2057	12,984	180	135	0	0	0	0	0	0	0	1,924	628
2058	12,994	180	135	0	0	0	0	0	0	0	1,925	629
2059	13,004	180	135	0	0	0	0	0	0	0	1,925	630
2060	13,014	180	135	0	0	0	0	0	0	0	1,932	631

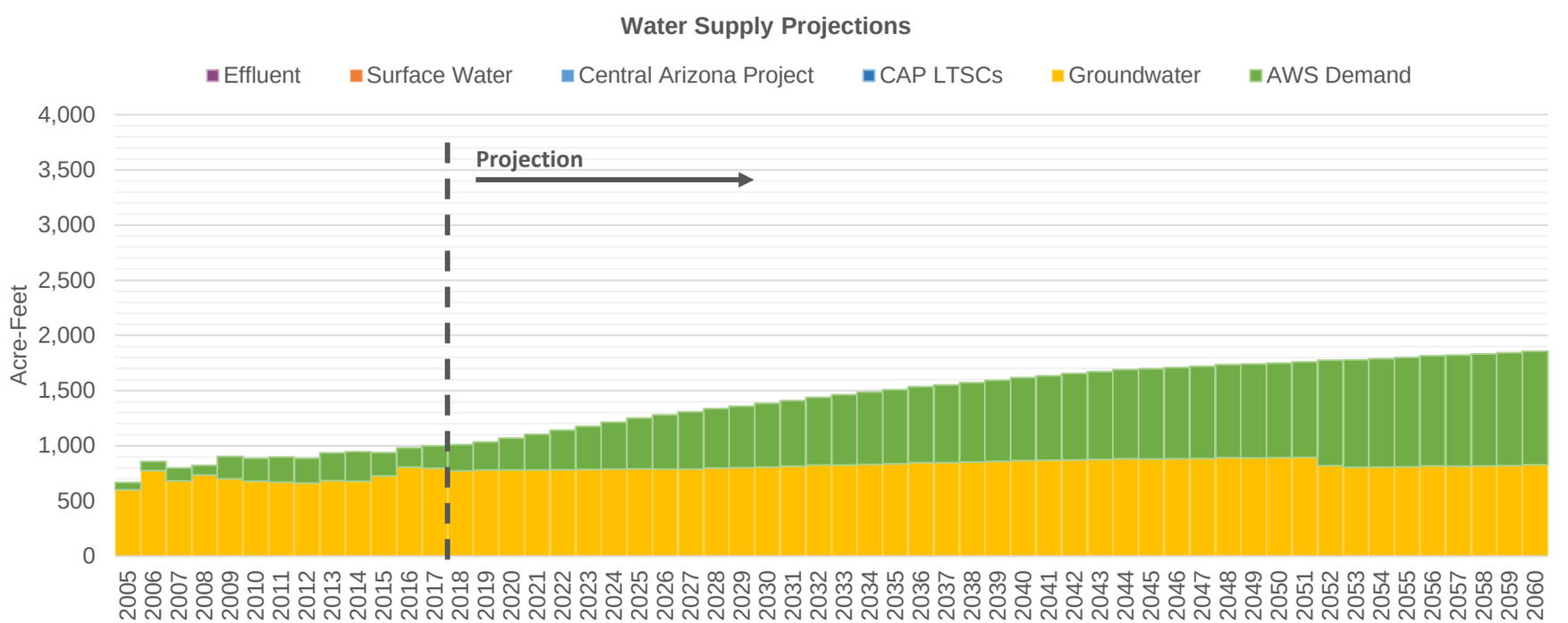
FarmersWC

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

FarmersWC

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

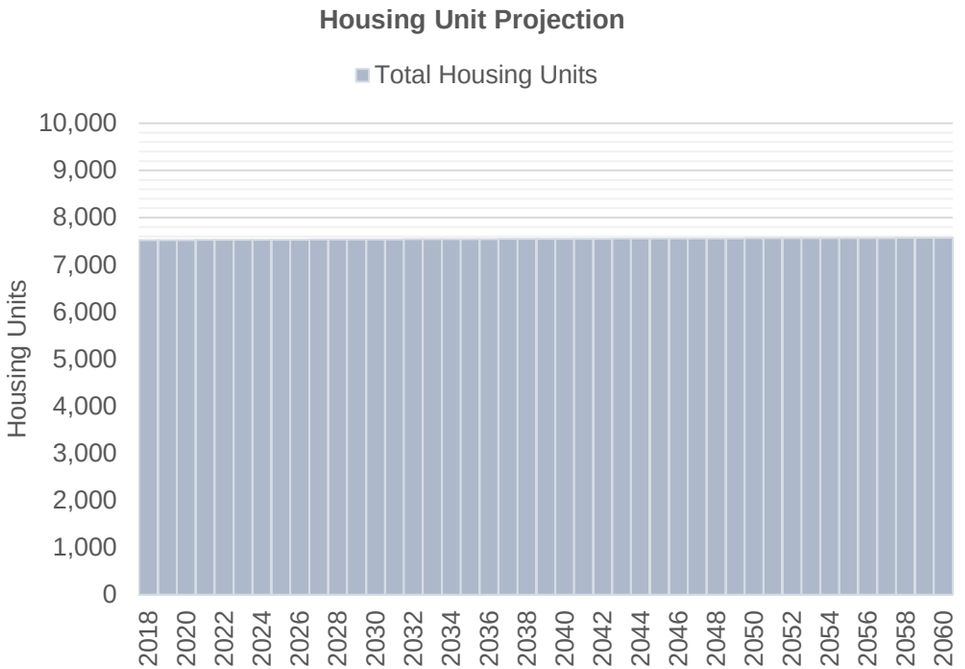
Water Supply Projections (Acre-Feet)

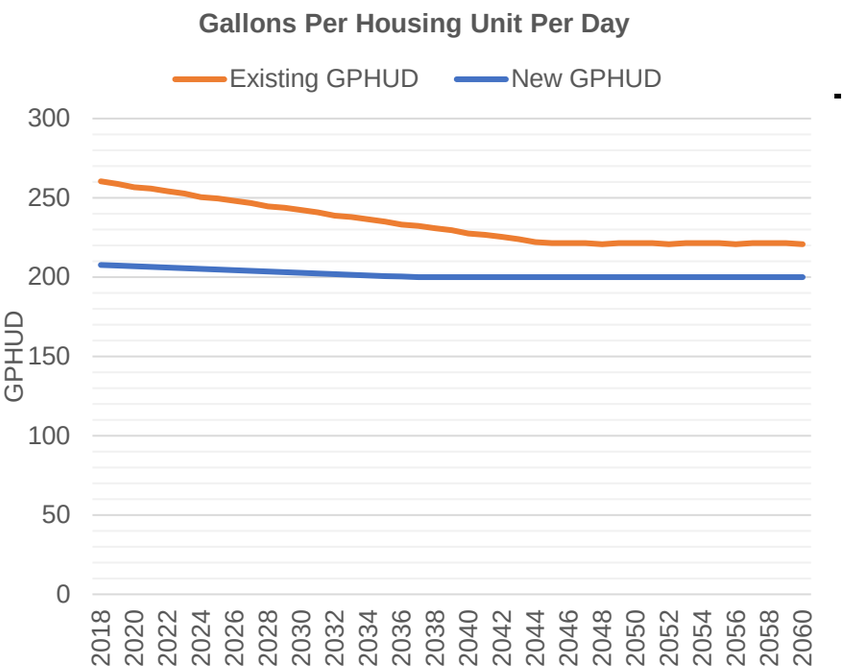
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,639	196	186	0	0	0	0	0	0	0	772	238
2019	4,836	195	186	0	0	0	0	0	0	0	780	254
2020	5,035	193	186	0	0	0	0	0	0	0	780	289
2021	5,236	193	186	0	0	0	0	0	0	0	781	324
2022	5,438	192	186	0	0	0	0	0	0	0	783	358
2023	5,641	190	186	0	0	0	0	0	0	0	785	392
2024	5,844	189	186	0	0	0	0	0	0	0	788	426
2025	6,049	188	186	0	0	0	0	0	0	0	790	460
2026	6,203	187	186	0	0	0	0	0	0	0	789	493
2027	6,329	186	186	0	0	0	0	0	0	0	789	518
2028	6,453	186	186	0	0	0	0	0	0	0	799	538
2029	6,575	186	186	0	0	0	0	0	0	0	802	557
2030	6,696	186	186	0	0	0	0	0	0	0	808	577
2031	6,822	186	186	0	0	0	0	0	0	0	815	595
2032	6.947	186	186	0	0	0	0	0	0	0	825	615
2033	7,070	186	186	0	0	0	0	0	0	0	827	635
2034	7,185	186	186	0	0	0	0	0	0	0	833	654
2035	7,289	186	186	0	0	0	0	0	0	0	838	672
2036	7,392	186	186	0	0	0	0	0	0	0	847	688
2037	7,493	186	186	0	0	0	0	0	0	0	848	705
2038	7,592	186	186	0	0	0	0	0	0	0	853	720
2039	7,691	186	186	0	0	0	0	0	0	0	858	736
2040	7,788	186	186	0	0	0	0	0	0	0	867	752
2041	7,884	186	186	0	0	0	0	0	0	0	868	767
2042	7,978	186	186	0	0	0	0	0	0	0	873	782
2043	8,058	186	186	0	0	0	0	0	0	0	876	797
2044	8,112	186	186	0	0	0	0	0	0	0	882	809
2045	8,165	186	186	0	0	0	0	0	0	0	880	818
2046	8,217	186	186	0	0	0	0	0	0	0	883	826
2047	8,268	186	186	0	0	0	0	0	0	0	885	834
2048	8,318	186	186	0	0	0	0	0	0	0	893	842
2049	8,367	186	186	0	0	0	0	0	0	0	890	850
2050	8,416	186	186	0	0	0	0	0	0	0	893	858
2051	8,463	186	186	0	0	0	0	0	0	0	895	865
2052	8,510	186	186	0	0	0	0	0	0	0	822	953
2053	8,555	186	186	0	0	0	0	0	0	0	804	976
2054	8,603	186	186	0	0	0	0	0	0	0	807	983
2055	8,656	186	186	0	0	0	0	0	0	0	810	991
2056	8,707	186	186	0	0	0	0	0	0	0	817	999
2057	8,758	186	186	0	0	0	0	0	0	0	815	1,006
2058	8,807	186	186	0	0	0	0	0	0	0	818	1,014
2059	8,855	186	186	0	0	0	0	0	0	0	821	1,021
2060	8,902	186	186	0	0	0	0	0	0	0	829	1,029

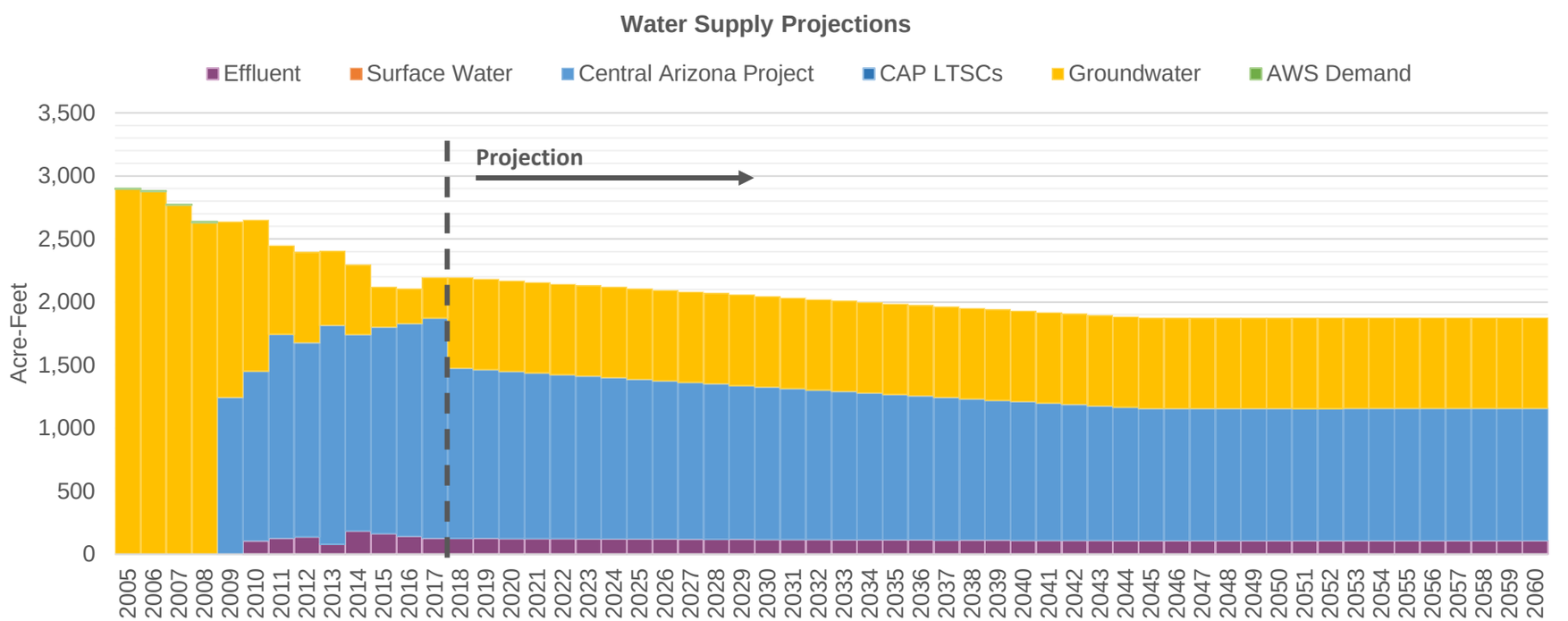
FWID

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

FWID

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

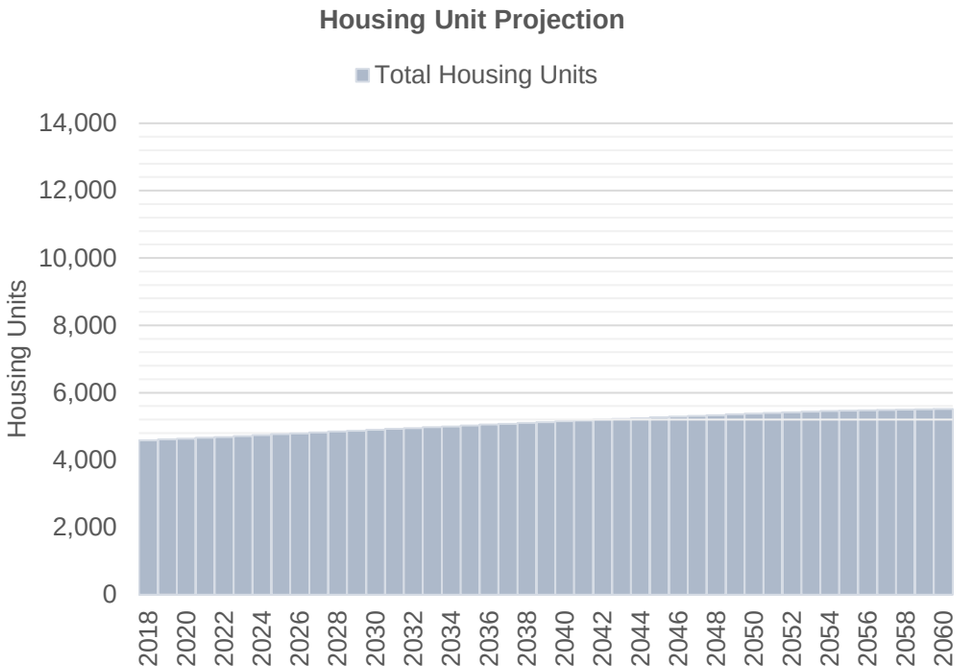
Water Supply Projections (Acre-Feet)

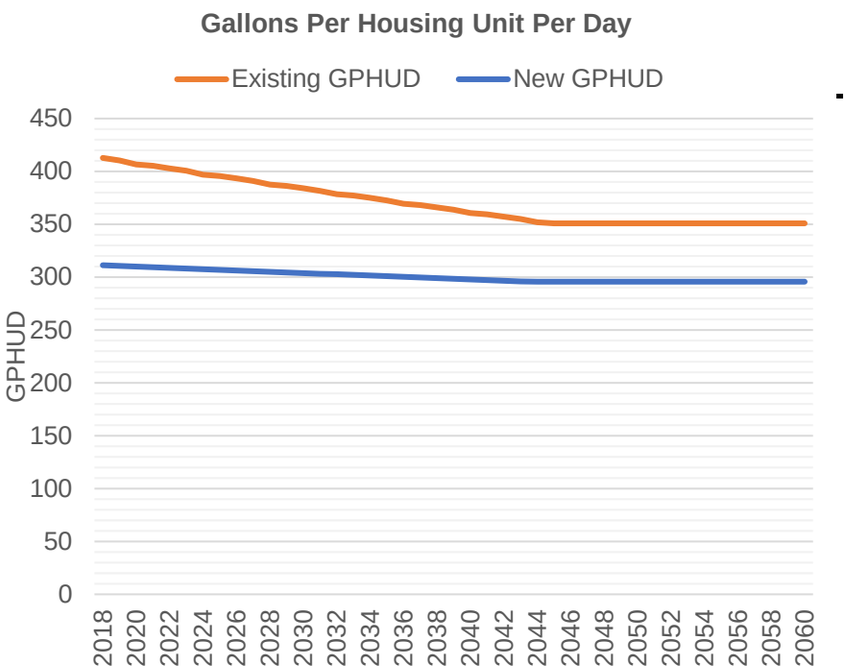
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	7,522	260	208	125	0	0	0	1,350	1,523	0	719	0
2019	7,523	259	207	125	0	0	0	1,337	1,536	0	719	0
2020	7,524	257	207	124	0	0	0	1,325	1,548	0	719	0
2021	7,526	256	206	124	0	0	0	1,313	1,560	0	719	0
2022	7,527	254	206	123	0	0	0	1,301	1,572	0	719	0
2023	7,528	253	206	122	0	0	0	1,289	1,584	0	719	0
2024	7,530	251	205	121	0	0	0	1,278	1,595	0	719	0
2025	7,531	250	205	121	0	0	0	1,266	1,607	0	719	0
2026	7,532	248	204	120	0	0	0	1,254	1,619	0	719	0
2027	7,534	247	204	119	0	0	0	1,243	1,630	0	719	0
2028	7,535	245	204	119	0	0	0	1,231	1,642	0	719	0
2029	7,536	244	203	118	0	0	0	1,220	1,653	0	719	0
2030	7,537	242	203	117	0	0	0	1,208	1,665	0	719	0
2031	7,539	241	202	116	0	0	0	1,197	1,676	0	719	0
2032	7,540	239	202	116	0	0	0	1,186	1,687	0	719	0
2033	7,542	238	202	115	0	0	0	1,175	1,698	0	719	0
2034	7,543	237	201	114	0	0	0	1,164	1,709	0	719	0
2035	7,544	235	201	114	0	0	0	1,153	1,720	0	719	0
2036	7,545	233	200	113	0	0	0	1,142	1,731	0	719	0
2037	7,547	232	200	112	0	0	0	1,131	1,742	0	719	0
2038	7,548	231	200	112	0	0	0	1,120	1,753	0	719	0
2039	7,549	230	200	111	0	0	0	1,109	1,257	0	719	0
2040	7,550	228	200	111	0	0	0	1,098	1,756	0	719	0
2041	7,551	227	200	110	0	0	0	1,088	1,785	0	719	0
2042	7,552	225	200	109	0	0	0	1,077	1,796	0	719	0
2043	7,554	224	200	109	0	0	0	1,067	1,806	0	719	0
2044	7,555	222	200	108	0	0	0	1,056	1,817	0	719	0
2045	7,556	221	200	107	0	0	0	1,046	1,827	0	719	0
2046	7,557	221	200	107	0	0	0	1,047	1,826	0	719	0
2047	7,558	221	200	107	0	0	0	1,047	1,826	0	719	0
2048	7,559	221	200	107	0	0	0	1,047	1,826	0	719	0
2049	7,560	221	200	107	0	0	0	1,047	1,826	0	719	0
2050	7,561	221	200	107	0	0	0	1,048	1,825	0	719	0
2051	7,562	221	200	107	0	0	0	1,048	1,825	0	719	0
2052	7,563	221	200	107	0	0	0	1,048	1,732	0	719	0
2053	7,564	221	200	107	0	0	0	1,048	1,732	0	719	0
2054	7,564	221	200	107	0	0	0	1,048	1,532	0	719	0
2055	7,565	221	200	107	0	0	0	1,049	1,084	0	719	0
2056	7,566	221	200	107	0	0	0	1,049	834	0	719	0
2057	7,567	221	200	107	0	0	0	1,049	1,532	0	719	0
2058	7,568	221	200	107	0	0	0	1,049	1,532	0	719	0
2059	7,569	221	200	107	0	0	0	1,049	1,531	0	719	0
2060	7,569	221	200	107	0	0	0	1,050	1,531	0	719	0

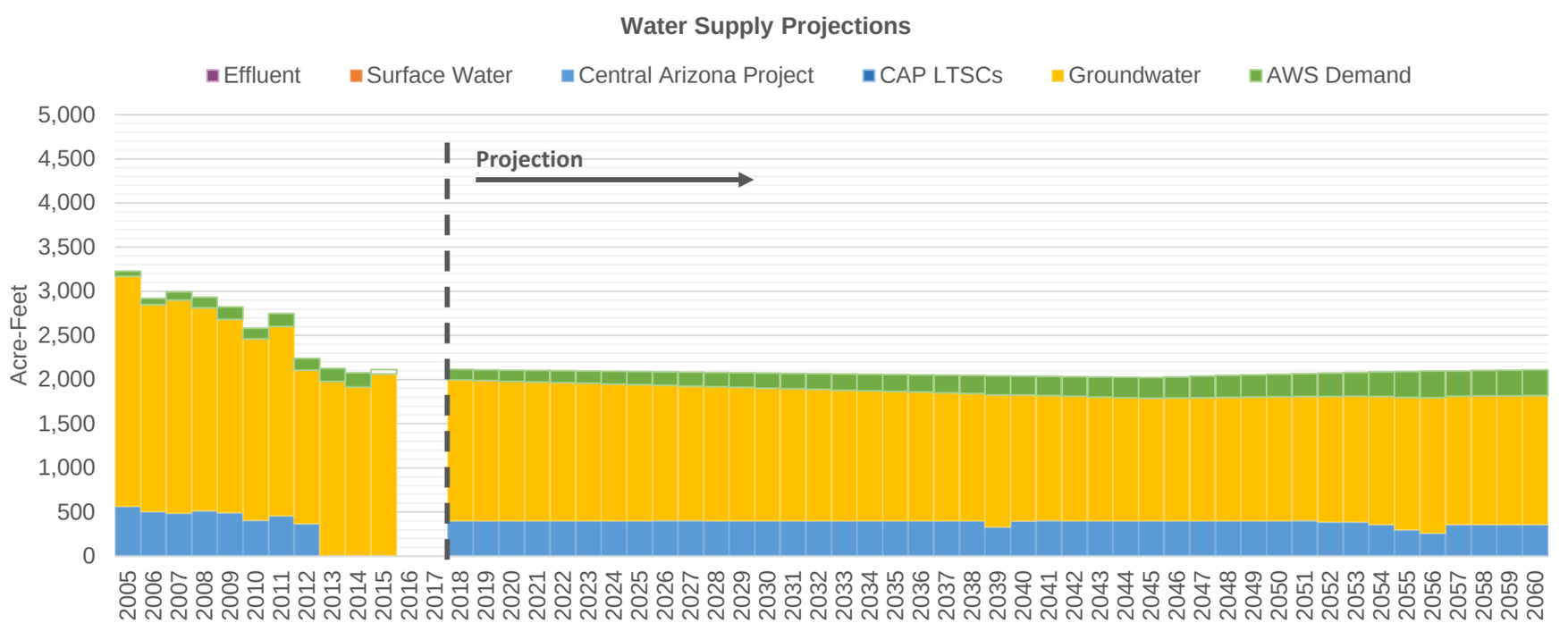
Central Arizona Project Service Area Model

GVDWID

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

GVDWID

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

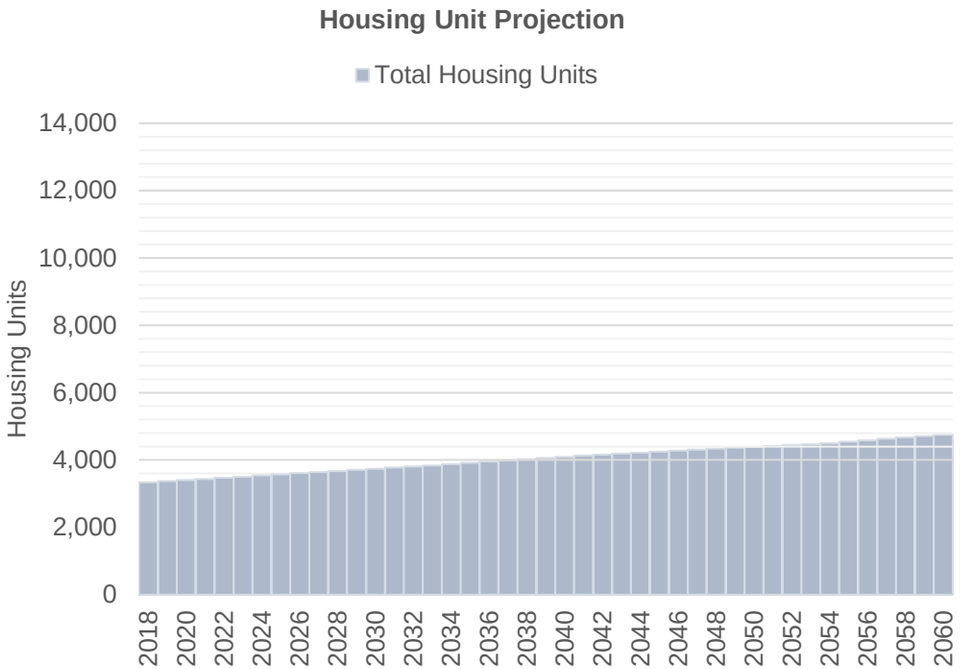
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

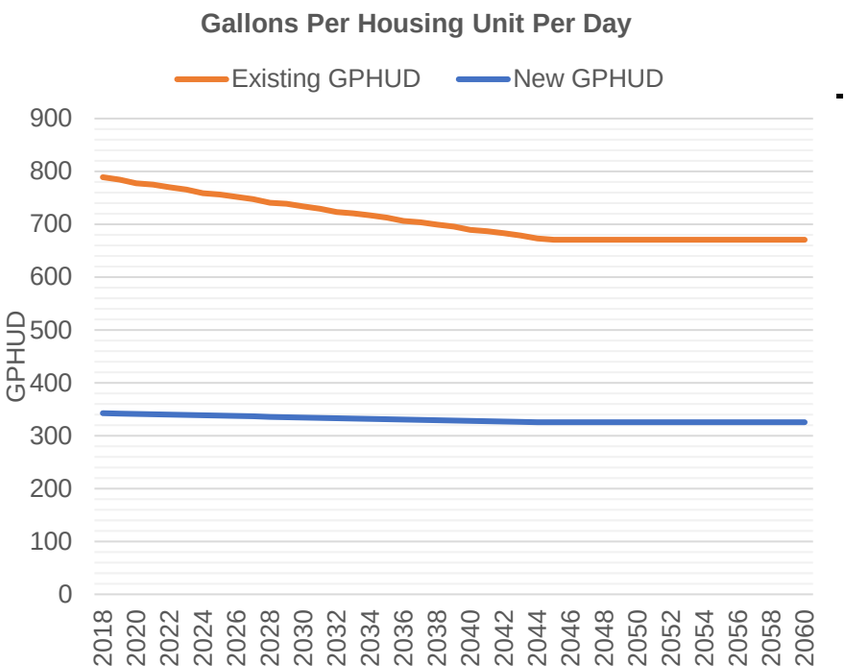
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,583	413	311	0	0	0	399	0	0	0	1,598	119
2019	4,609	410	311	0	0	0	399	0	0	0	1,590	121
2020	4,634	407	310	0	0	0	399	0	0	0	1,582	125
2021	4,660	405	309	0	0	0	399	0	0	0	1,574	129
2022	4,686	403	309	0	0	0	399	0	0	0	1,567	133
2023	4,712	401	308	0	0	0	399	0	0	0	1,559	137
2024	4,739	397	308	0	0	0	399	0	0	0	1,552	141
2025	4,765	396	307	0	0	0	399	0	0	0	1,544	146
2026	4,791	393	306	0	0	0	399	0	0	0	1,536	150
2027	4,818	391	306	0	0	0	399	0	0	0	1,528	155
2028	4,844	388	305	0	0	0	399	0	0	0	1,520	160
2029	4,870	386	304	0	0	0	399	0	0	0	1,512	164
2030	4,895	384	304	0	0	0	399	0	0	0	1,504	169
2031	4,922	382	303	0	0	0	399	0	0	0	1,497	174
2032	4,948	378	303	0	0	0	399	0	0	0	1,489	178
2033	4,974	377	302	0	0	0	399	0	0	0	1,481	183
2034	5,000	375	301	0	0	0	399	0	0	0	1,473	188
2035	5,026	373	301	0	0	0	399	0	0	0	1,466	192
2036	5,051	369	300	0	0	0	399	0	0	0	1,458	197
2037	5,076	368	300	0	0	0	399	0	0	0	1,450	201
2038	5,101	366	299	0	0	0	399	0	0	0	1,443	206
2039	5,126	364	298	0	0	0	329	0	0	0	1,497	219
2040	5,150	361	298	0	0	0	396	0	0	0	1,430	215
2041	5,173	359	297	0	0	0	399	0	0	0	1,420	218
2042	5,197	357	297	0	0	0	399	0	0	0	1,412	222
2043	5,220	355	296	0	0	0	399	0	0	0	1,404	227
2044	5,243	352	296	0	0	0	399	0	0	0	1,397	231
2045	5,266	351	296	0	0	0	399	0	0	0	1,390	234
2046	5,289	351	296	0	0	0	399	0	0	0	1,393	239
2047	5,311	351	296	0	0	0	399	0	0	0	1,396	243
2048	5,333	351	296	0	0	0	399	0	0	0	1,400	247
2049	5,354	351	296	0	0	0	399	0	0	0	1,402	251
2050	5,376	351	296	0	0	0	399	0	0	0	1,405	255
2051	5,396	351	296	0	0	0	399	0	0	0	1,408	259
2052	5,416	351	296	0	0	0	386	0	0	0	1,423	265
2053	5,436	351	296	0	0	0	386	0	0	0	1,425	269
2054	5,453	351	296	0	0	0	358	0	0	0	1,450	277
2055	5,465	351	296	0	0	0	296	0	0	0	1,504	291
2056	5,476	351	296	0	0	0	262	0	0	0	1,535	299
2057	5,487	351	296	0	0	0	358	0	0	0	1,454	285
2058	5,499	351	296	0	0	0	358	0	0	0	1,456	288
2059	5,509	351	296	0	0	0	358	0	0	0	1,457	290
2060	5,520	351	296	0	0	0	358	0	0	0	1,460	292

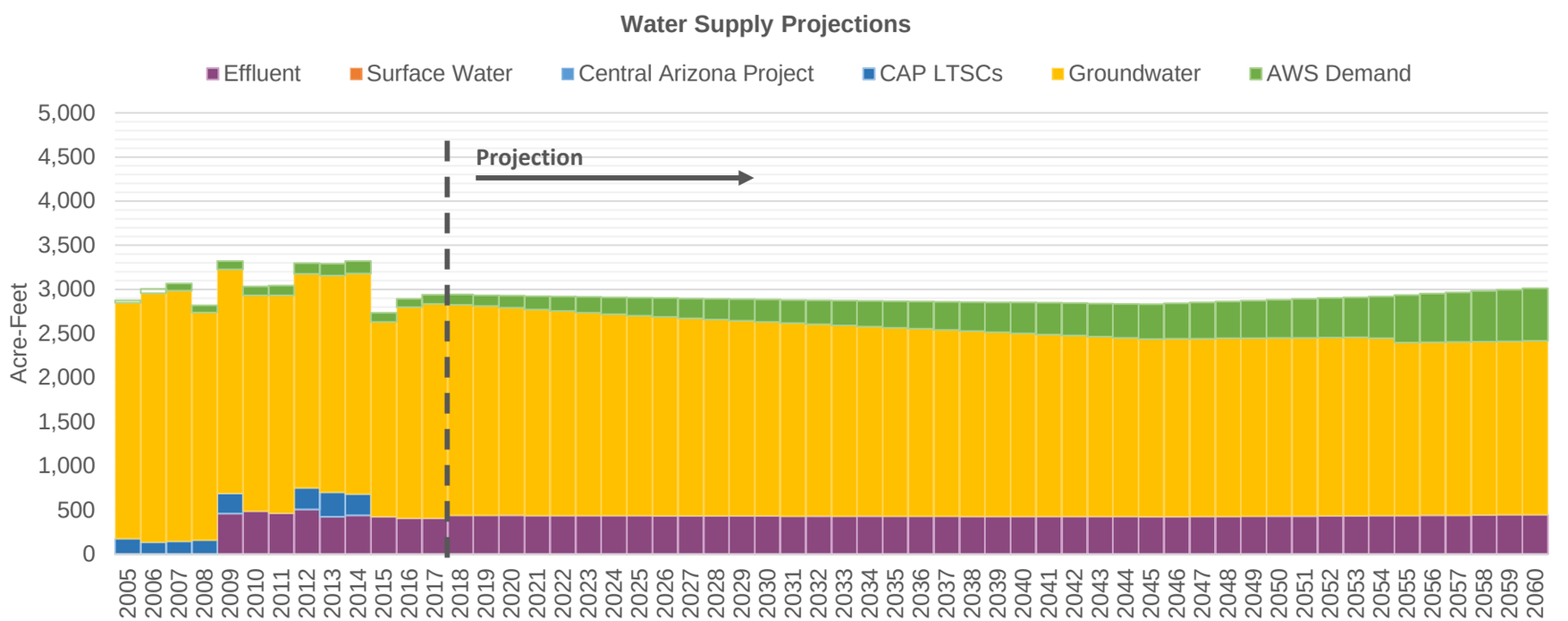
LagoDelOro

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LagoDelOro

B. Slow, Compact, Dry Climate [LSCRBS]

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Demand Assumptions

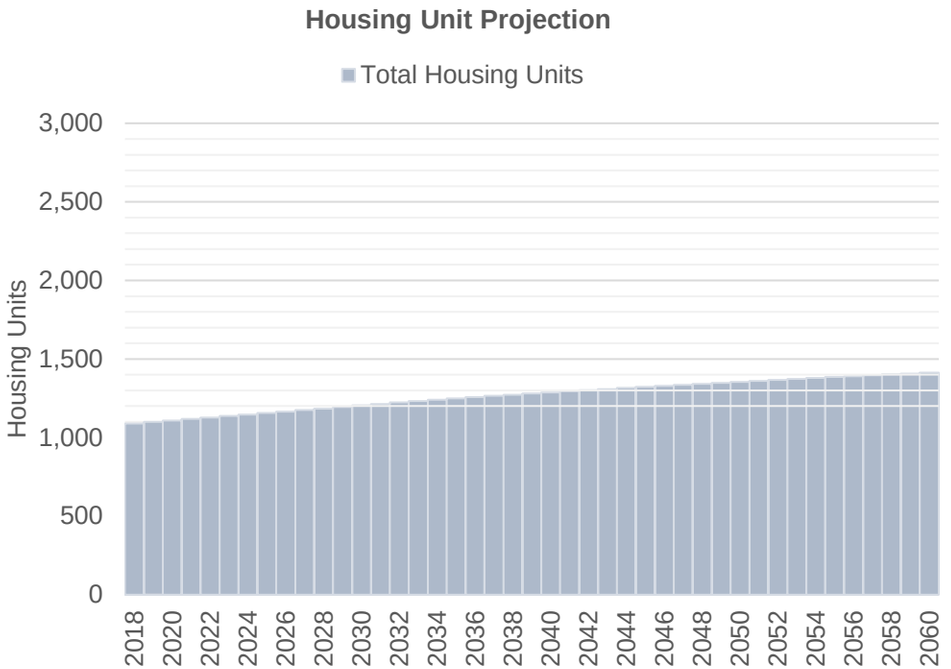
Water Supply Projections (Acre-Feet)

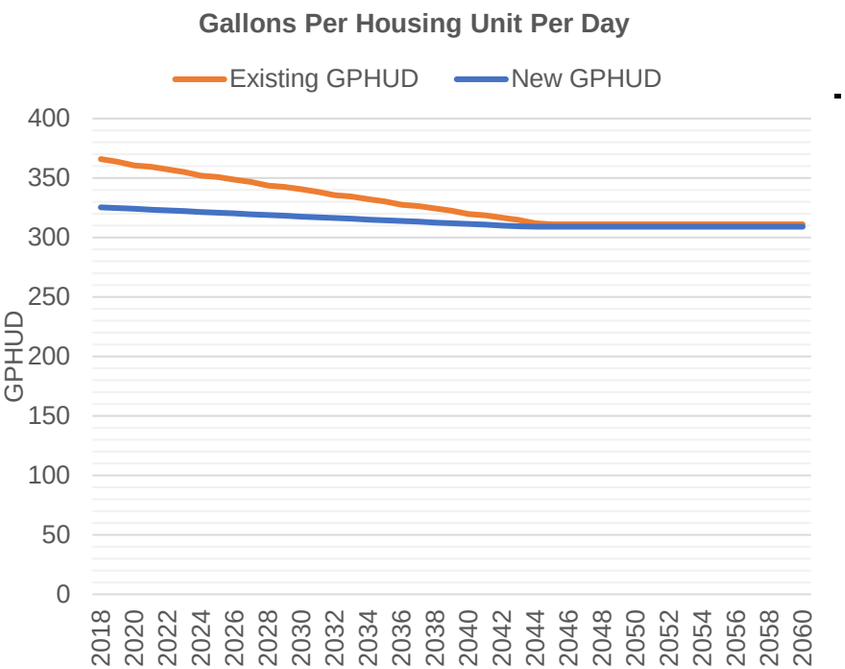
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,341	789	343	441	0	0	0	0	0	0	2,386	116
2019	3,373	784	342	441	0	0	0	0	0	0	2,370	123
2020	3,406	778	341	440	0	0	0	0	0	0	2,352	137
2021	3,439	775	341	439	0	0	0	0	0	0	2,333	152
2022	3,473	770	340	438	0	0	0	0	0	0	2,316	165
2023	3,506	766	339	437	0	0	0	0	0	0	2,300	178
2024	3,540	759	339	437	0	0	0	0	0	0	2,283	190
2025	3,574	757	338	436	0	0	0	0	0	0	2,267	203
2026	3,607	752	337	435	0	0	0	0	0	0	2,253	214
2027	3,641	747	337	435	0	0	0	0	0	0	2,239	224
2028	3,675	741	336	434	0	0	0	0	0	0	2,226	234
2029	3,708	739	335	434	0	0	0	0	0	0	2,212	243
2030	3,741	734	335	433	0	0	0	0	0	0	2,199	253
2031	3,775	730	334	432	0	0	0	0	0	0	2,187	262
2032	3,808	723	333	432	0	0	0	0	0	0	2,174	271
2033	3,842	721	333	431	0	0	0	0	0	0	2,161	280
2034	3,877	717	332	430	0	0	0	0	0	0	2,149	289
2035	3,914	712	331	430	0	0	0	0	0	0	2,136	299
2036	3,951	706	331	429	0	0	0	0	0	0	2,125	309
2037	3,988	704	330	429	0	0	0	0	0	0	2,112	319
2038	4,024	700	329	429	0	0	0	0	0	0	2,099	329
2039	4,059	695	329	428	0	0	0	0	0	0	2,087	339
2040	4,094	689	328	428	0	0	0	0	0	0	2,075	349
2041	4,129	687	327	427	0	0	0	0	0	0	2,062	358
2042	4,163	683	327	427	0	0	0	0	0	0	2,050	368
2043	4,195	679	326	426	0	0	0	0	0	0	2,038	377
2044	4,224	673	326	426	0	0	0	0	0	0	2,026	386
2045	4,253	671	326	425	0	0	0	0	0	0	2,013	394
2046	4,282	671	326	424	0	0	0	0	0	0	2,016	402
2047	4,309	671	326	426	0	0	0	0	0	0	2,017	410
2048	4,337	671	326	427	0	0	0	0	0	0	2,019	417
2049	4,364	671	326	429	0	0	0	0	0	0	2,019	425
2050	4,390	671	326	430	0	0	0	0	0	0	2,020	432
2051	4,416	671	326	432	0	0	0	0	0	0	2,021	439
2052	4,441	671	326	433	0	0	0	0	0	0	2,023	446
2053	4,466	671	326	435	0	0	0	0	0	0	2,022	453
2054	4,499	671	326	436	0	0	0	0	0	0	2,011	474
2055	4,543	671	326	438	0	0	0	0	0	0	1,960	537
2056	4,586	671	326	440	0	0	0	0	0	0	1,963	549
2057	4,629	671	326	442	0	0	0	0	0	0	1,963	561
2058	4,670	671	326	444	0	0	0	0	0	0	1,964	573
2059	4,711	671	326	447	0	0	0	0	0	0	1,965	585
2060	4,751	671	326	449	0	0	0	0	0	0	1,967	596

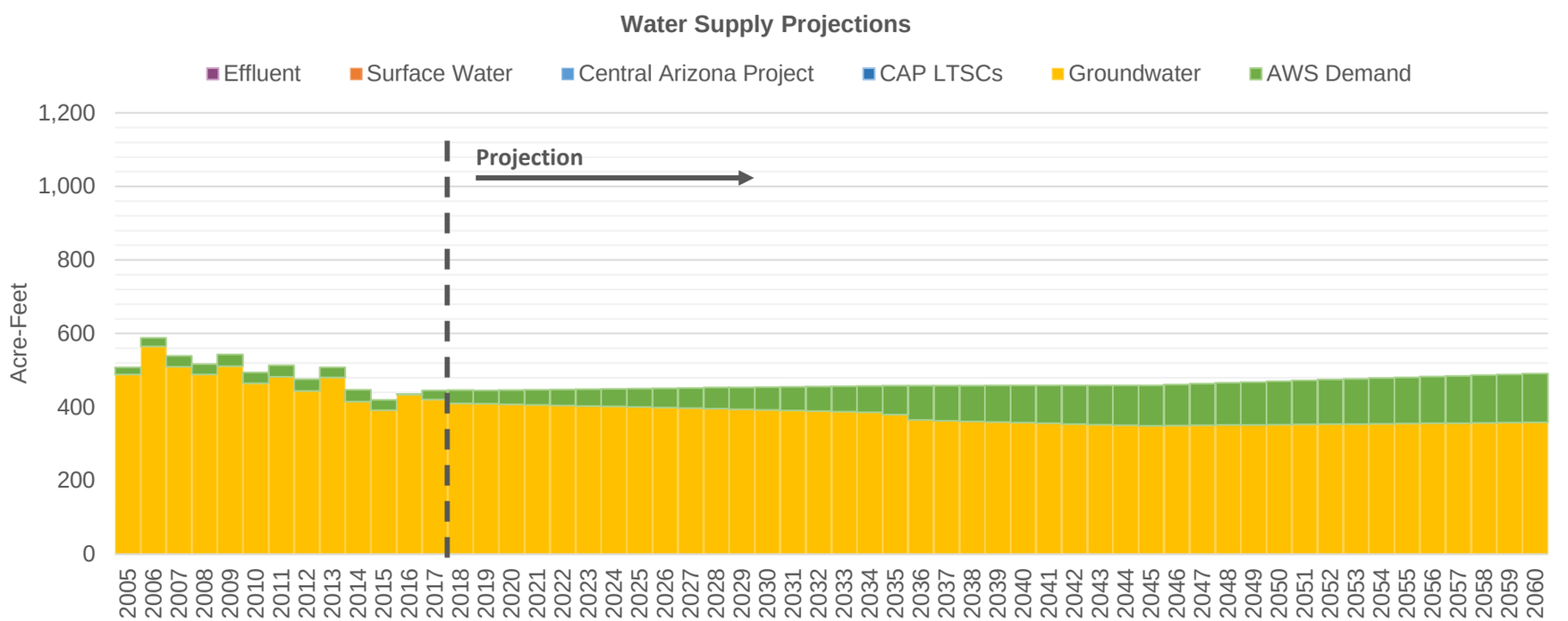
LasQuintas

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LasQuintas

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

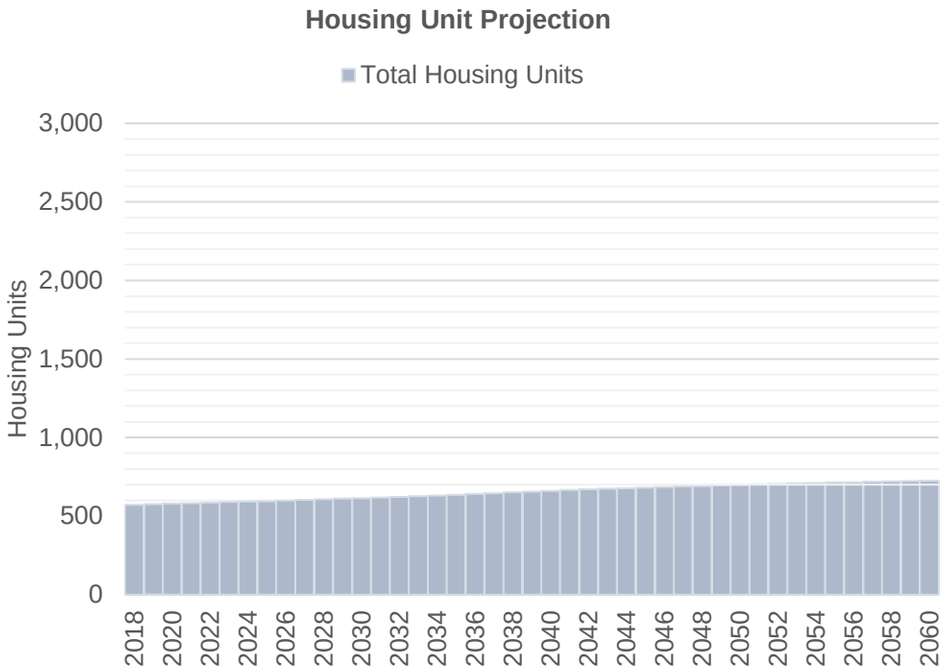
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

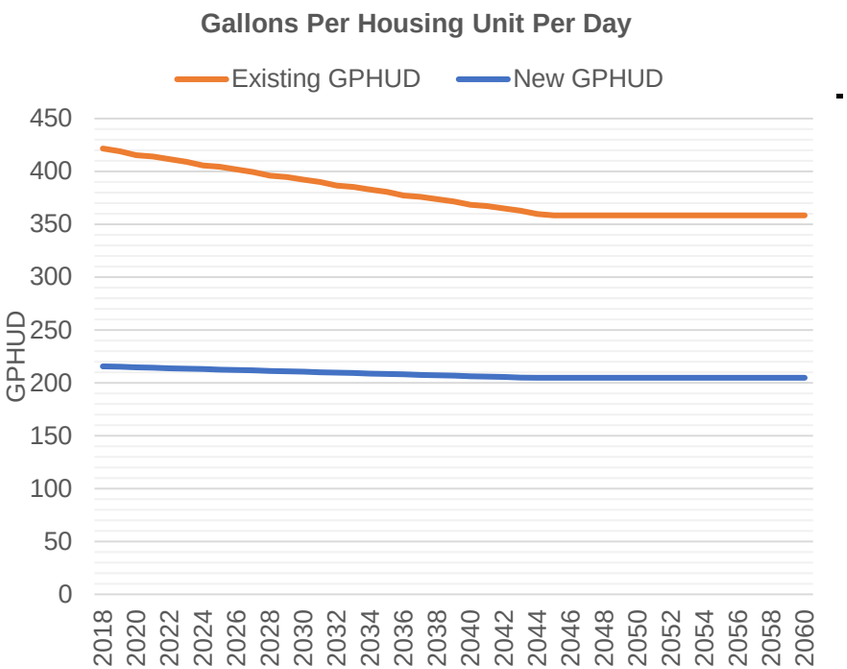
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,090	366	325	0	0	0	0	0	0	0	410	36
2019	1,099	364	325	0	0	0	0	0	0	0	409	37
2020	1,109	361	324	0	0	0	0	0	0	0	408	39
2021	1,118	359	323	0	0	0	0	0	0	0	406	41
2022	1,128	357	323	0	0	0	0	0	0	0	405	43
2023	1,137	355	322	0	0	0	0	0	0	0	403	46
2024	1,147	352	321	0	0	0	0	0	0	0	402	48
2025	1,157	351	321	0	0	0	0	0	0	0	400	50
2026	1,166	349	320	0	0	0	0	0	0	0	398	53
2027	1,176	347	320	0	0	0	0	0	0	0	397	55
2028	1,185	344	319	0	0	0	0	0	0	0	395	58
2029	1,195	343	318	0	0	0	0	0	0	0	394	60
2030	1,204	340	318	0	0	0	0	0	0	0	392	62
2031	1,213	338	317	0	0	0	0	0	0	0	391	65
2032	1,223	335	316	0	0	0	0	0	0	0	389	67
2033	1,232	334	316	0	0	0	0	0	0	0	387	69
2034	1,241	332	315	0	0	0	0	0	0	0	386	72
2035	1,249	330	314	0	0	0	0	0	0	0	380	78
2036	1,257	327	314	0	0	0	0	0	0	0	365	94
2037	1,265	326	313	0	0	0	0	0	0	0	363	96
2038	1,272	324	313	0	0	0	0	0	0	0	361	98
2039	1,280	322	312	0	0	0	0	0	0	0	359	99
2040	1,287	320	311	0	0	0	0	0	0	0	358	101
2041	1,295	319	311	0	0	0	0	0	0	0	356	103
2042	1,302	317	310	0	0	0	0	0	0	0	354	105
2043	1,309	315	309	0	0	0	0	0	0	0	352	107
2044	1,316	312	309	0	0	0	0	0	0	0	351	108
2045	1,323	311	309	0	0	0	0	0	0	0	349	110
2046	1,329	311	309	0	0	0	0	0	0	0	350	112
2047	1,336	311	309	0	0	0	0	0	0	0	350	113
2048	1,342	311	309	0	0	0	0	0	0	0	351	115
2049	1,349	311	309	0	0	0	0	0	0	0	352	116
2050	1,355	311	309	0	0	0	0	0	0	0	352	118
2051	1,361	311	309	0	0	0	0	0	0	0	353	120
2052	1,367	311	309	0	0	0	0	0	0	0	354	121
2053	1,373	311	309	0	0	0	0	0	0	0	354	123
2054	1,379	311	309	0	0	0	0	0	0	0	355	124
2055	1,385	311	309	0	0	0	0	0	0	0	355	126
2056	1,391	311	309	0	0	0	0	0	0	0	356	127
2057	1,396	311	309	0	0	0	0	0	0	0	356	128
2058	1,402	311	309	0	0	0	0	0	0	0	357	130
2059	1,407	311	309	0	0	0	0	0	0	0	357	131
2060	1,413	311	309	0	0	0	0	0	0	0	358	132

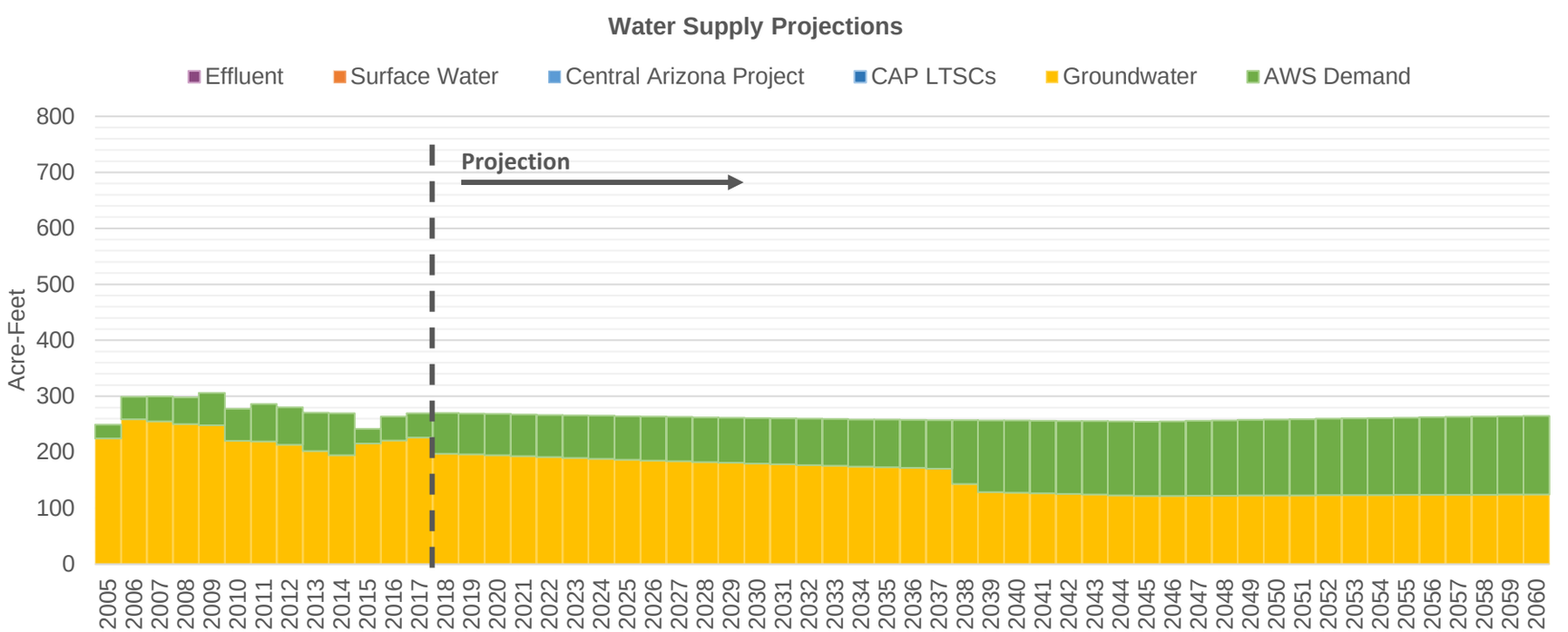
LosCerros

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LosCerros

B. Slow, Compact, Dry Climate [LSCRBS]

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Demand Assumptions

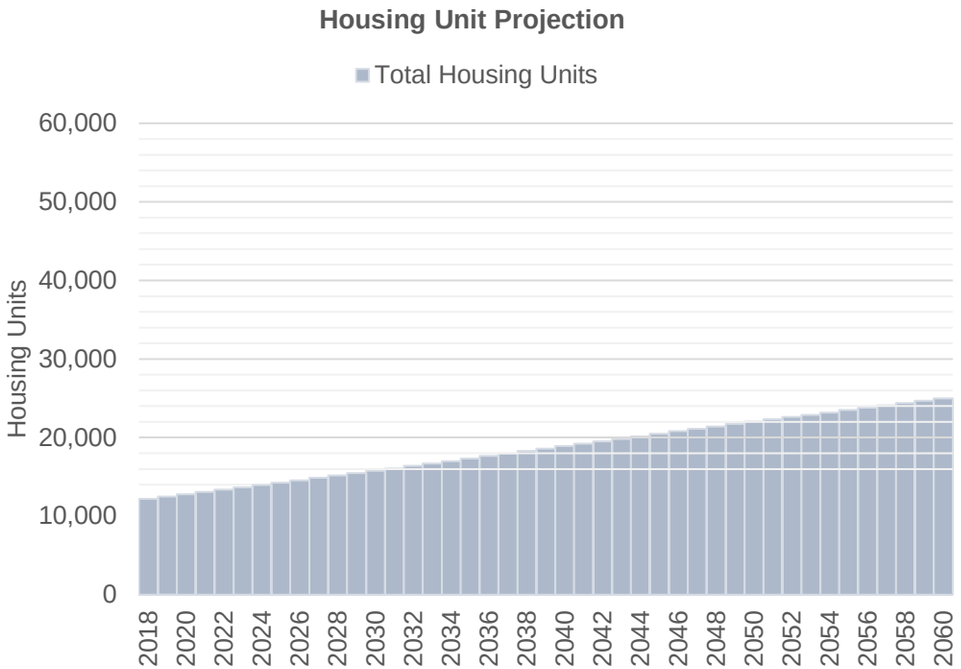
Water Supply Projections (Acre-Feet)

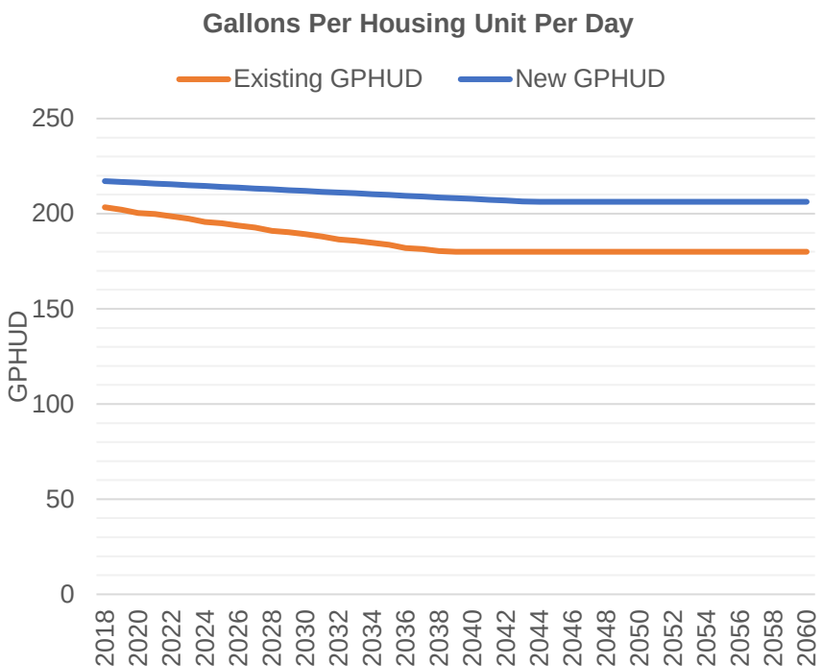
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	573	422	216	0	0	0	0	0	0	0	198	73
2019	576	419	215	0	0	0	0	0	0	0	196	73
2020	580	415	215	0	0	0	0	0	0	0	195	74
2021	583	414	214	0	0	0	0	0	0	0	193	75
2022	586	412	214	0	0	0	0	0	0	0	191	75
2023	590	409	213	0	0	0	0	0	0	0	190	76
2024	593	406	213	0	0	0	0	0	0	0	188	77
2025	596	404	213	0	0	0	0	0	0	0	187	78
2026	600	402	212	0	0	0	0	0	0	0	185	78
2027	604	399	212	0	0	0	0	0	0	0	184	79
2028	608	396	211	0	0	0	0	0	0	0	182	80
2029	612	395	211	0	0	0	0	0	0	0	181	81
2030	615	392	210	0	0	0	0	0	0	0	180	81
2031	619	390	210	0	0	0	0	0	0	0	178	82
2032	623	387	210	0	0	0	0	0	0	0	177	83
2033	627	385	209	0	0	0	0	0	0	0	176	83
2034	631	383	209	0	0	0	0	0	0	0	174	84
2035	636	381	208	0	0	0	0	0	0	0	173	85
2036	641	377	208	0	0	0	0	0	0	0	172	86
2037	646	376	208	0	0	0	0	0	0	0	171	87
2038	651	374	207	0	0	0	0	0	0	0	143	114
2039	656	372	207	0	0	0	0	0	0	0	129	128
2040	661	368	206	0	0	0	0	0	0	0	128	129
2041	666	367	206	0	0	0	0	0	0	0	127	130
2042	670	365	205	0	0	0	0	0	0	0	125	130
2043	675	363	205	0	0	0	0	0	0	0	124	131
2044	678	360	205	0	0	0	0	0	0	0	123	132
2045	682	358	205	0	0	0	0	0	0	0	122	132
2046	685	358	205	0	0	0	0	0	0	0	122	133
2047	689	358	205	0	0	0	0	0	0	0	122	134
2048	692	358	205	0	0	0	0	0	0	0	123	134
2049	696	358	205	0	0	0	0	0	0	0	123	135
2050	699	358	205	0	0	0	0	0	0	0	123	135
2051	702	358	205	0	0	0	0	0	0	0	123	136
2052	705	358	205	0	0	0	0	0	0	0	123	136
2053	708	358	205	0	0	0	0	0	0	0	124	137
2054	711	358	205	0	0	0	0	0	0	0	124	137
2055	714	358	205	0	0	0	0	0	0	0	124	138
2056	716	358	205	0	0	0	0	0	0	0	124	138
2057	719	358	205	0	0	0	0	0	0	0	124	139
2058	721	358	205	0	0	0	0	0	0	0	124	139
2059	723	358	205	0	0	0	0	0	0	0	124	140
2060	726	358	205	0	0	0	0	0	0	0	125	140

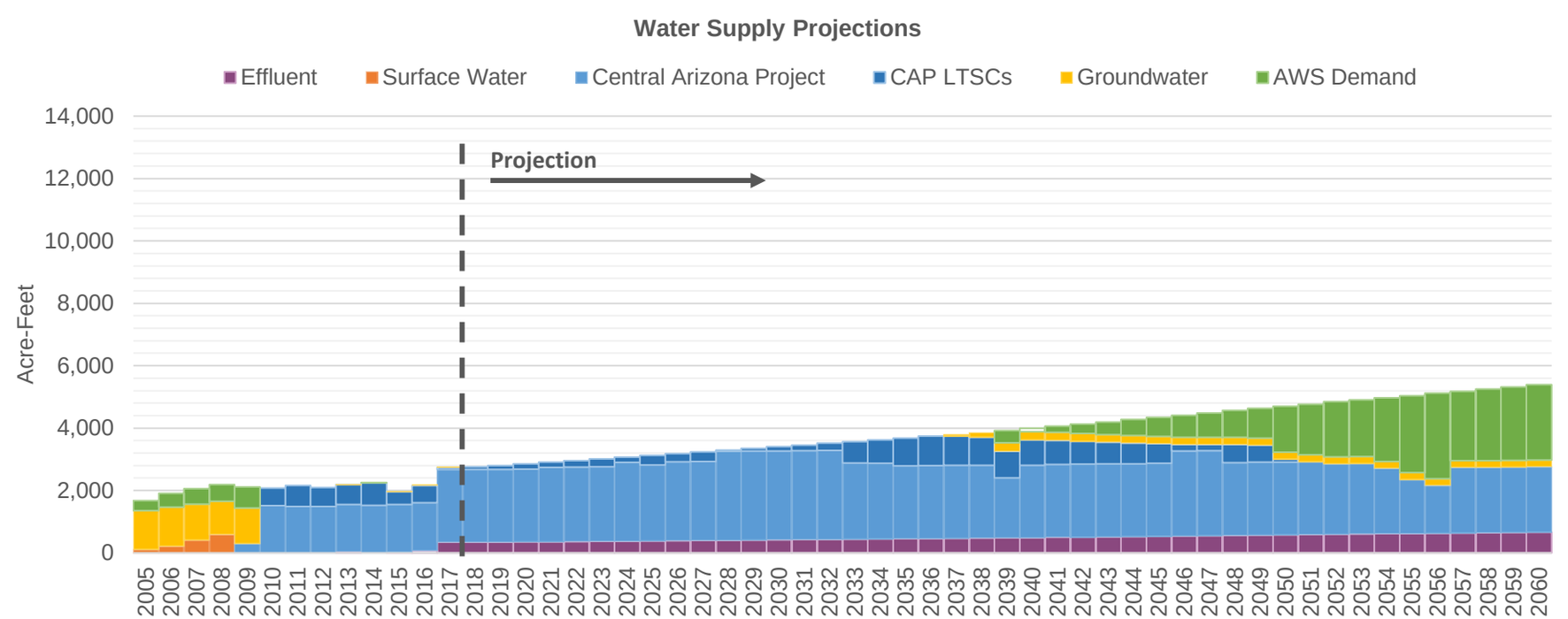
Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]

Marana







Central Arizona Project Service Area Model

Marana

B. Slow, Compact, Dry Climate [LSCRBS]

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Demand Assumptions

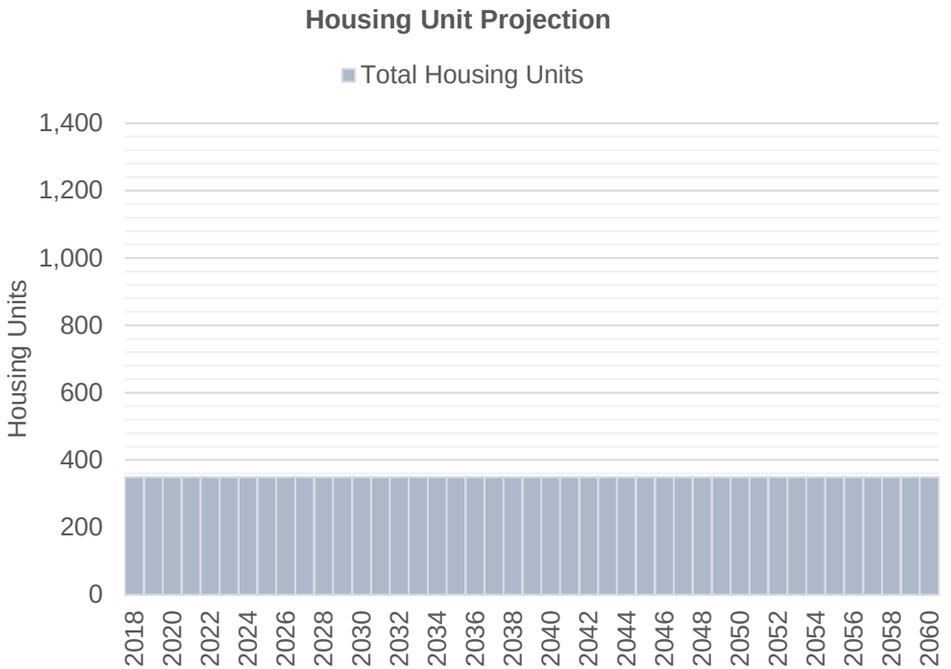
Water Supply Projections (Acre-Feet)

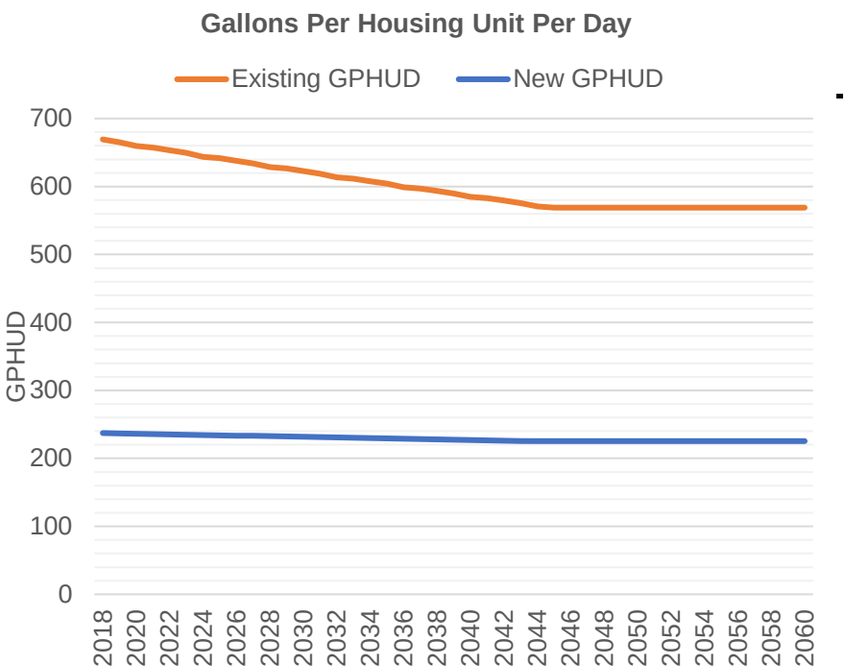
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	12,194	203	217	345	0	0	0	2,336	0	84	0	0
2019	12,483	202	217	345	0	0	0	2,336	0	118	0	0
2020	12,774	200	216	349	0	0	0	2,336	0	168	0	0
2021	13,068	200	216	356	0	0	0	2,389	0	162	0	0
2022	13,364	199	215	362	0	0	0	2,392	0	207	0	0
2023	13,662	197	215	369	0	0	0	2,391	0	256	0	0
2024	13,960	196	215	376	0	0	0	2,526	0	170	0	0
2025	14,259	195	214	383	0	0	0	2,431	0	312	0	0
2026	14,560	194	214	390	0	0	0	2,533	0	258	0	0
2027	14,870	193	213	397	0	0	0	2,532	0	308	0	0
2028	15,175	191	213	404	0	0	0	2,851	0	40	0	0
2029	15,476	190	212	411	0	0	0	2,851	0	86	0	0
2030	15,773	189	212	418	0	0	0	2,851	0	134	0	0
2031	16,083	188	212	424	0	0	0	2,851	0	182	0	0
2032	16,390	186	211	431	0	0	0	2,851	0	234	0	0
2033	16,694	186	211	438	0	0	0	2,445	0	685	0	0
2034	17,007	185	210	445	0	0	0	2,431	0	748	0	0
2035	17,335	184	210	452	0	0	0	2,336	0	894	0	0
2036	17,659	182	209	459	0	0	0	2,336	0	949	0	0
2037	17,979	181	209	467	0	0	0	2,336	0	945	51	0
2038	18,295	180	209	474	0	0	0	2,336	0	898	148	0
2039	18,606	180	208	481	0	0	0	1,924	0	853	271	393
2040	18,913	180	208	489	0	0	0	2,321	0	811	265	116
2041	19,216	180	207	499	0	0	0	2,336	0	770	259	194
2042	19,514	180	207	506	0	0	0	2,336	0	732	254	297
2043	19,822	180	207	514	0	0	0	2,336	0	695	250	397
2044	20,153	180	206	523	0	0	0	2,336	0	660	246	510
2045	20,479	180	206	533	0	0	0	2,336	0	627	242	601
2046	20,800	180	206	541	0	0	0	2,726	0	206	238	703
2047	21,115	180	206	550	0	0	0	2,726	0	196	235	781
2048	21,425	180	206	560	0	0	0	2,336	0	576	232	868
2049	21,729	180	206	570	0	0	0	2,336	0	547	229	948
2050	22,028	180	206	577	0	0	0	2,336	0	93	227	1,467
2051	22,320	180	206	586	0	0	0	2,336	0	0	225	1,621
2052	22,608	180	206	595	0	0	0	2,261	0	0	223	1,770
2053	22,889	180	206	605	0	0	0	2,261	0	0	222	1,814
2054	23,183	180	206	611	0	0	0	2,098	0	0	220	2,038
2055	23,497	180	206	619	0	0	0	1,734	0	0	219	2,466
2056	23,805	180	206	628	0	0	0	1,531	0	0	218	2,746
2057	24,107	180	206	639	0	0	0	2,098	0	0	217	2,225
2058	24,401	180	206	646	0	0	0	2,098	0	0	216	2,288
2059	24,690	180	206	655	0	0	0	2,098	0	0	216	2,347
2060	24,971	180	206	663	0	0	0	2,098	0	0	216	2,420

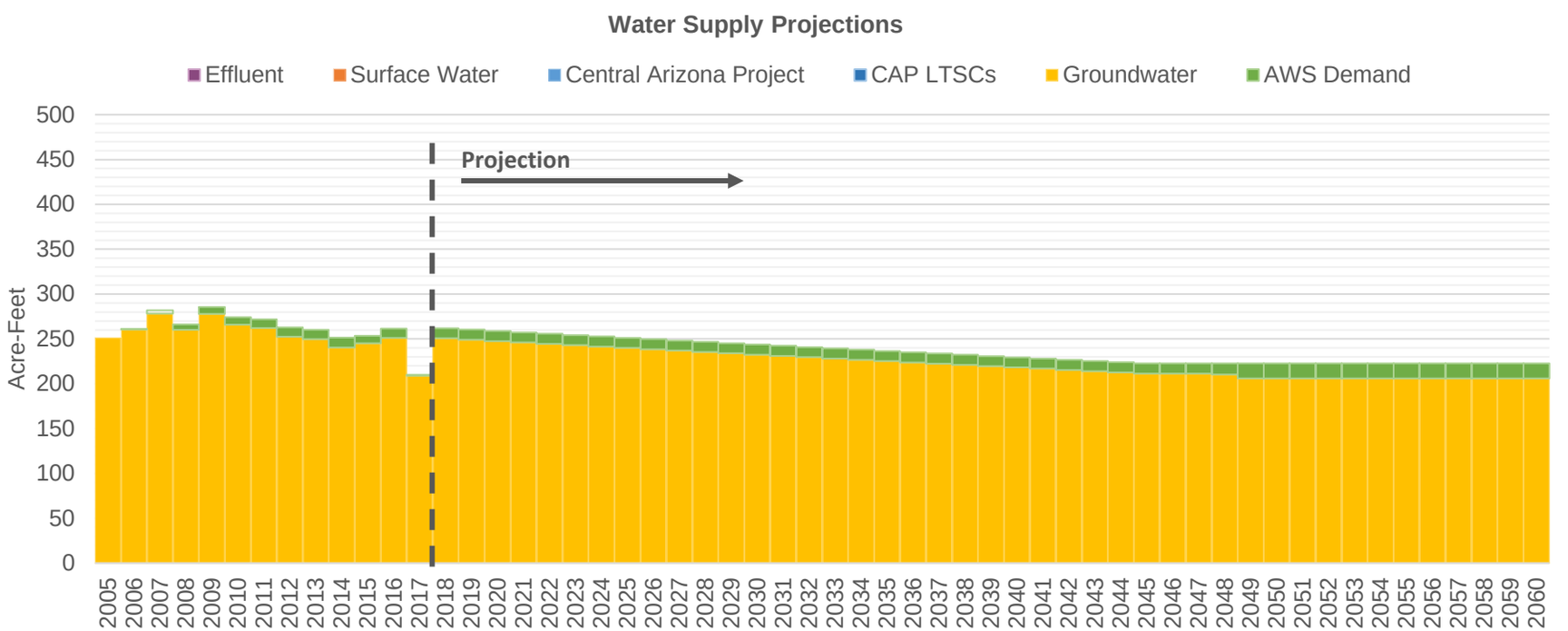
Central Arizona Project Service Area Model

MaranaDomestic

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MaranaDomesti

B. Slow, Compact, Dry Climate [LSCRBS]

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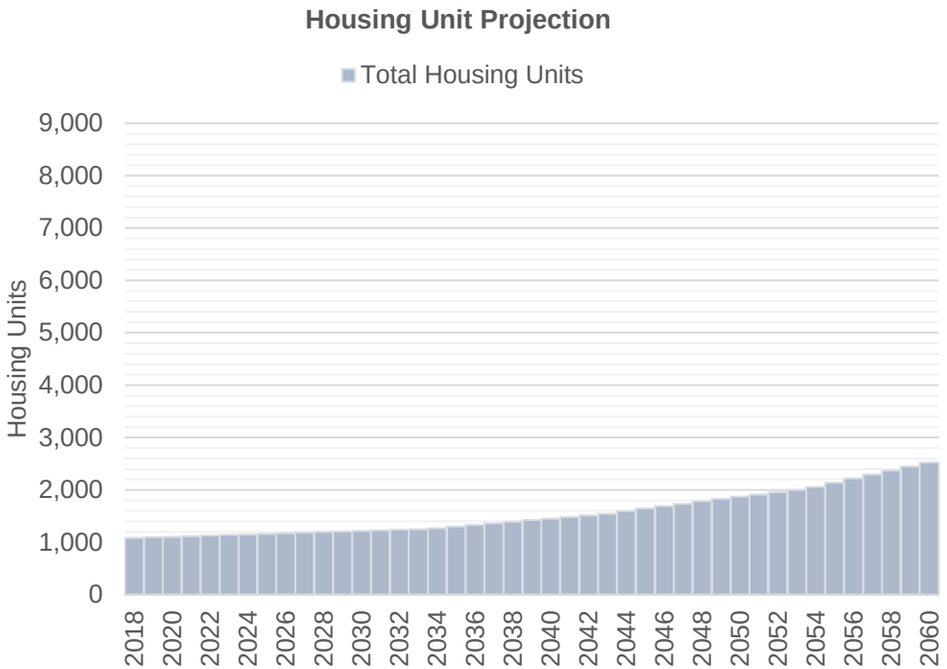
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

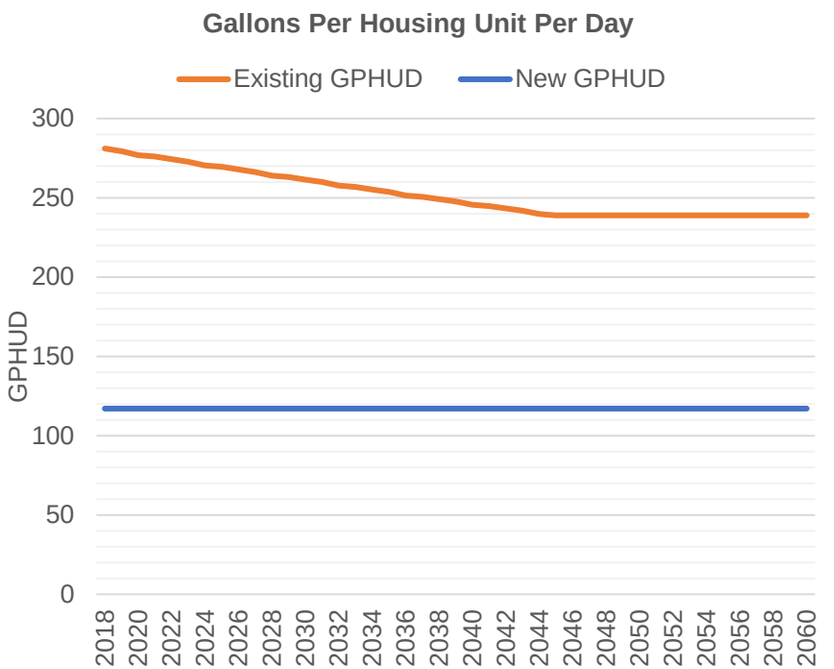
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	349	669	237	0	0	0	0	0	0	0	251	11
2019	349	665	237	0	0	0	0	0	0	0	249	11
2020	349	659	236	0	0	0	0	0	0	0	248	11
2021	349	657	236	0	0	0	0	0	0	0	246	11
2022	349	653	235	0	0	0	0	0	0	0	245	11
2023	349	649	235	0	0	0	0	0	0	0	243	11
2024	349	644	234	0	0	0	0	0	0	0	241	11
2025	349	642	234	0	0	0	0	0	0	0	240	11
2026	349	638	234	0	0	0	0	0	0	0	238	11
2027	349	634	233	0	0	0	0	0	0	0	237	11
2028	349	628	233	0	0	0	0	0	0	0	235	11
2029	349	626	232	0	0	0	0	0	0	0	234	11
2030	349	623	232	0	0	0	0	0	0	0	232	11
2031	349	619	231	0	0	0	0	0	0	0	231	11
2032	349	614	231	0	0	0	0	0	0	0	230	11
2033	349	612	230	0	0	0	0	0	0	0	228	11
2034	349	608	230	0	0	0	0	0	0	0	227	11
2035	349	604	229	0	0	0	0	0	0	0	225	11
2036	349	599	229	0	0	0	0	0	0	0	224	11
2037	349	597	228	0	0	0	0	0	0	0	222	11
2038	349	593	228	0	0	0	0	0	0	0	221	11
2039	349	590	228	0	0	0	0	0	0	0	220	11
2040	349	585	227	0	0	0	0	0	0	0	218	11
2041	349	583	227	0	0	0	0	0	0	0	217	11
2042	349	579	226	0	0	0	0	0	0	0	216	11
2043	349	576	226	0	0	0	0	0	0	0	214	11
2044	349	571	225	0	0	0	0	0	0	0	213	11
2045	349	569	225	0	0	0	0	0	0	0	211	11
2046	349	569	225	0	0	0	0	0	0	0	211	11
2047	349	569	225	0	0	0	0	0	0	0	211	11
2048	349	569	225	0	0	0	0	0	0	0	210	12
2049	349	569	225	0	0	0	0	0	0	0	206	17
2050	349	569	225	0	0	0	0	0	0	0	206	17
2051	349	569	225	0	0	0	0	0	0	0	206	17
2052	349	569	225	0	0	0	0	0	0	0	206	17
2053	349	569	225	0	0	0	0	0	0	0	206	17
2054	349	569	225	0	0	0	0	0	0	0	206	17
2055	349	569	225	0	0	0	0	0	0	0	206	17
2056	349	569	225	0	0	0	0	0	0	0	206	17
2057	349	569	225	0	0	0	0	0	0	0	206	17
2058	349	569	225	0	0	0	0	0	0	0	206	17
2059	349	569	225	0	0	0	0	0	0	0	206	17
2060	349	569	225	0	0	0	0	0	0	0	206	17

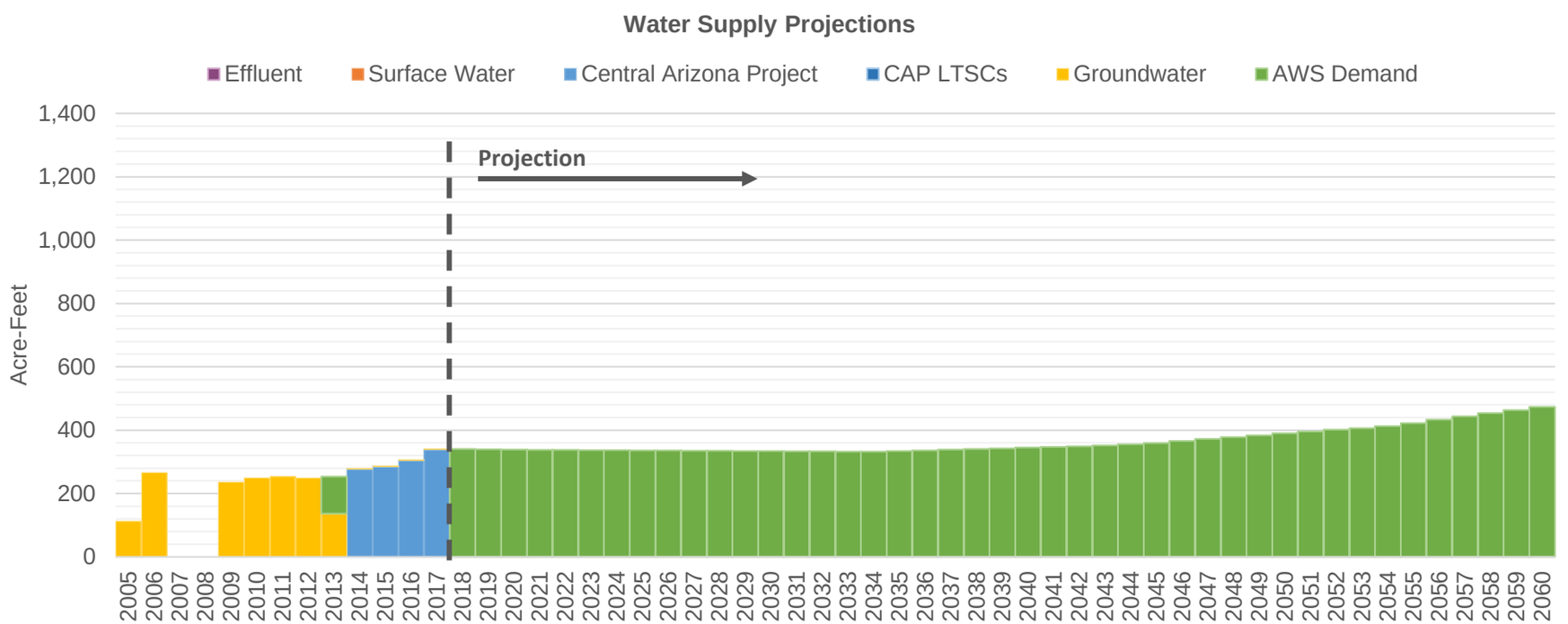
Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]

MetroDiablo







Central Arizona Project Service Area Model

MetroDiablo

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

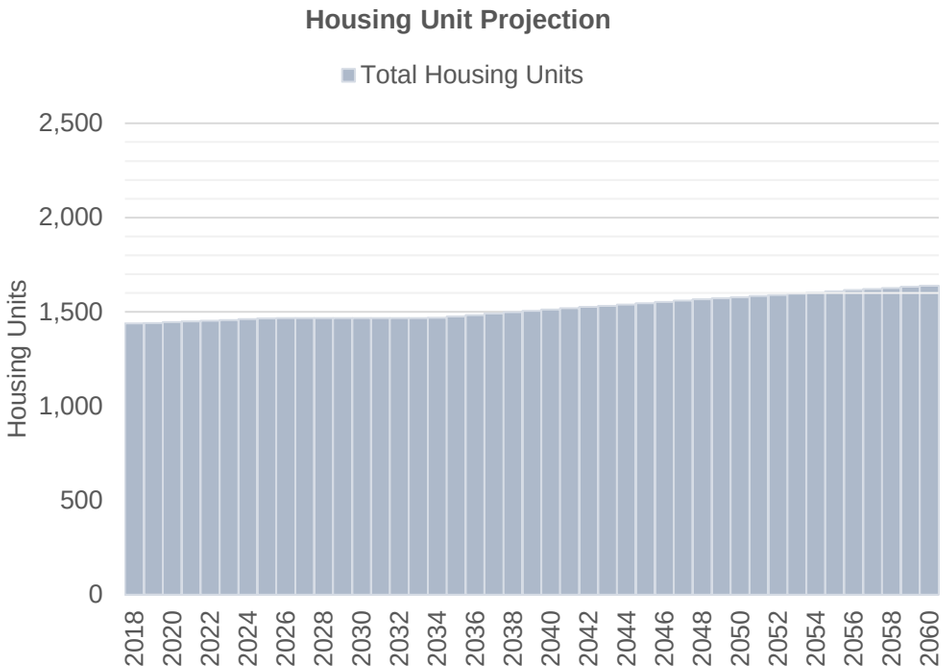
Water Supply Projections (Acre-Feet)

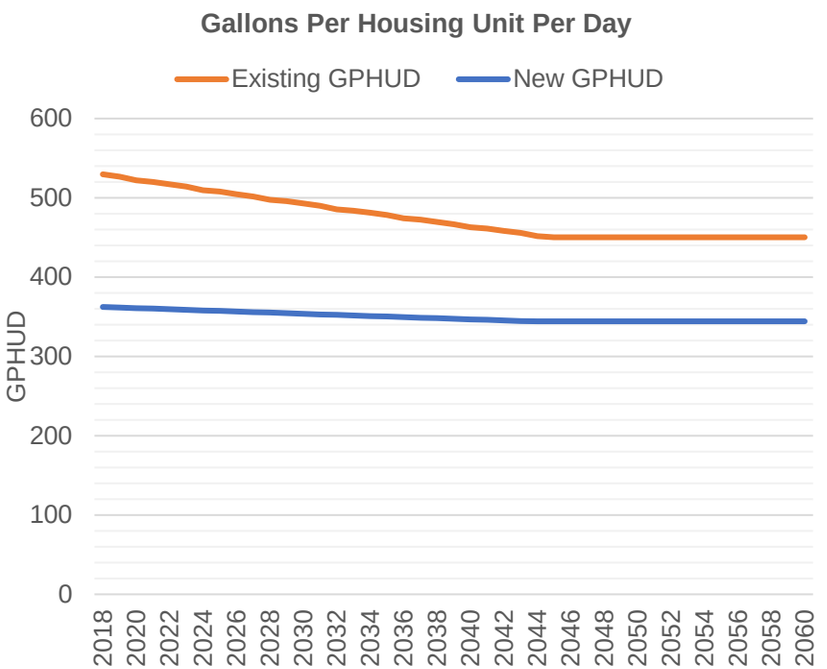
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,085	281	117	0	0	0	0	0	0	0	0	340
2019	1,096	279	117	0	0	0	0	0	0	0	0	339
2020	1,107	277	117	0	0	0	0	0	0	0	0	339
2021	1,118	276	117	0	0	0	0	0	0	0	0	338
2022	1,129	274	117	0	0	0	0	0	0	0	0	338
2023	1,140	273	117	0	0	0	0	0	0	0	0	337
2024	1,151	270	117	0	0	0	0	0	0	0	0	337
2025	1,163	270	117	0	0	0	0	0	0	0	0	336
2026	1,174	268	117	0	0	0	0	0	0	0	0	336
2027	1,185	266	117	0	0	0	0	0	0	0	0	335
2028	1,196	264	117	0	0	0	0	0	0	0	0	335
2029	1,207	263	117	0	0	0	0	0	0	0	0	334
2030	1,218	262	117	0	0	0	0	0	0	0	0	334
2031	1,229	260	117	0	0	0	0	0	0	0	0	333
2032	1,240	258	117	0	0	0	0	0	0	0	0	333
2033	1,251	257	117	0	0	0	0	0	0	0	0	332
2034	1,270	255	117	0	0	0	0	0	0	0	0	333
2035	1,302	254	117	0	0	0	0	0	0	0	0	334
2036	1,333	252	117	0	0	0	0	0	0	0	0	336
2037	1,364	251	117	0	0	0	0	0	0	0	0	339
2038	1,395	249	117	0	0	0	0	0	0	0	0	341
2039	1,425	248	117	0	0	0	0	0	0	0	0	343
2040	1,454	246	117	0	0	0	0	0	0	0	0	345
2041	1,483	245	117	0	0	0	0	0	0	0	0	347
2042	1,512	243	117	0	0	0	0	0	0	0	0	349
2043	1,547	242	117	0	0	0	0	0	0	0	0	352
2044	1,596	240	117	0	0	0	0	0	0	0	0	355
2045	1,644	239	117	0	0	0	0	0	0	0	0	360
2046	1,691	239	117	0	0	0	0	0	0	0	0	366
2047	1,737	239	117	0	0	0	0	0	0	0	0	372
2048	1,783	239	117	0	0	0	0	0	0	0	0	378
2049	1,827	239	117	0	0	0	0	0	0	0	0	384
2050	1,871	239	117	0	0	0	0	0	0	0	0	390
2051	1,914	239	117	0	0	0	0	0	0	0	0	396
2052	1,956	239	117	0	0	0	0	0	0	0	0	402
2053	1,998	239	117	0	0	0	0	0	0	0	0	407
2054	2,055	239	117	0	0	0	0	0	0	0	0	413
2055	2,138	239	117	0	0	0	0	0	0	0	0	422
2056	2,218	239	117	0	0	0	0	0	0	0	0	433
2057	2,297	239	117	0	0	0	0	0	0	0	0	444
2058	2,375	239	117	0	0	0	0	0	0	0	0	454
2059	2,450	239	117	0	0	0	0	0	0	0	0	464
2060	2,524	239	117	0	0	0	0	0	0	0	0	474

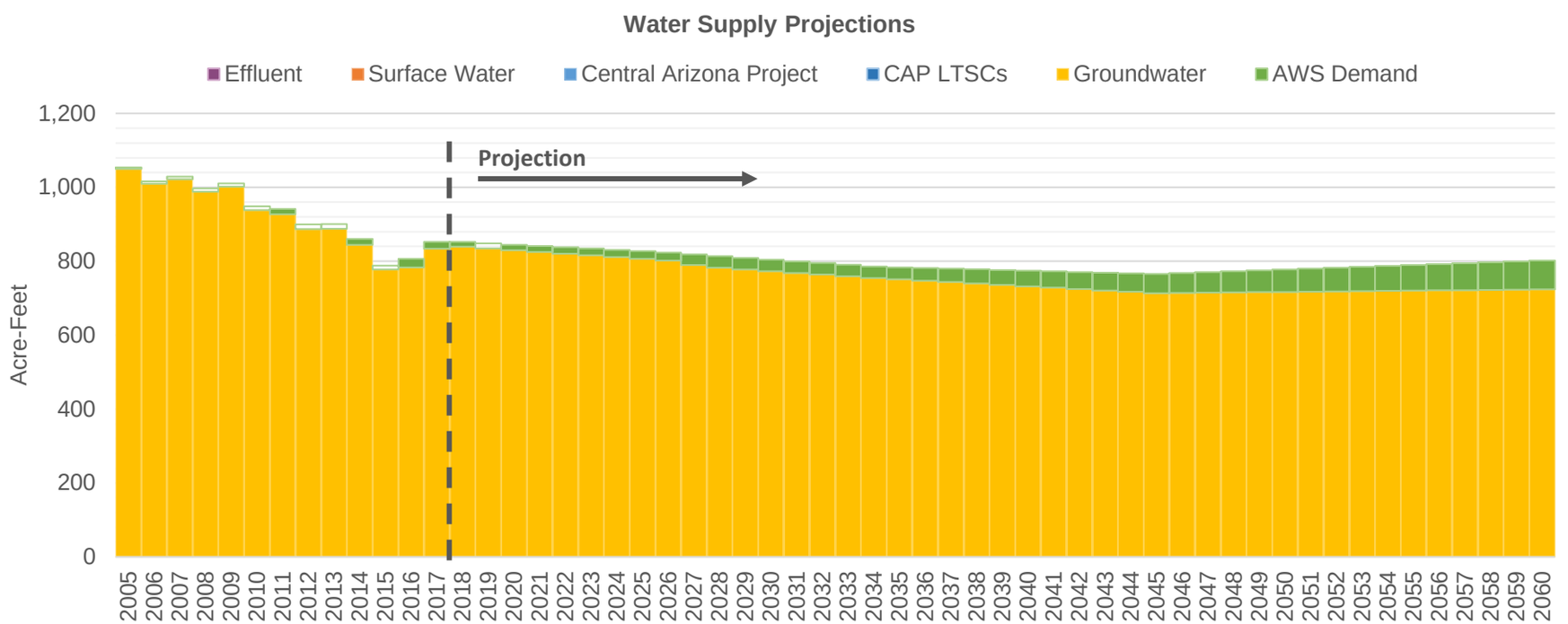
MetroHub

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroHub

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

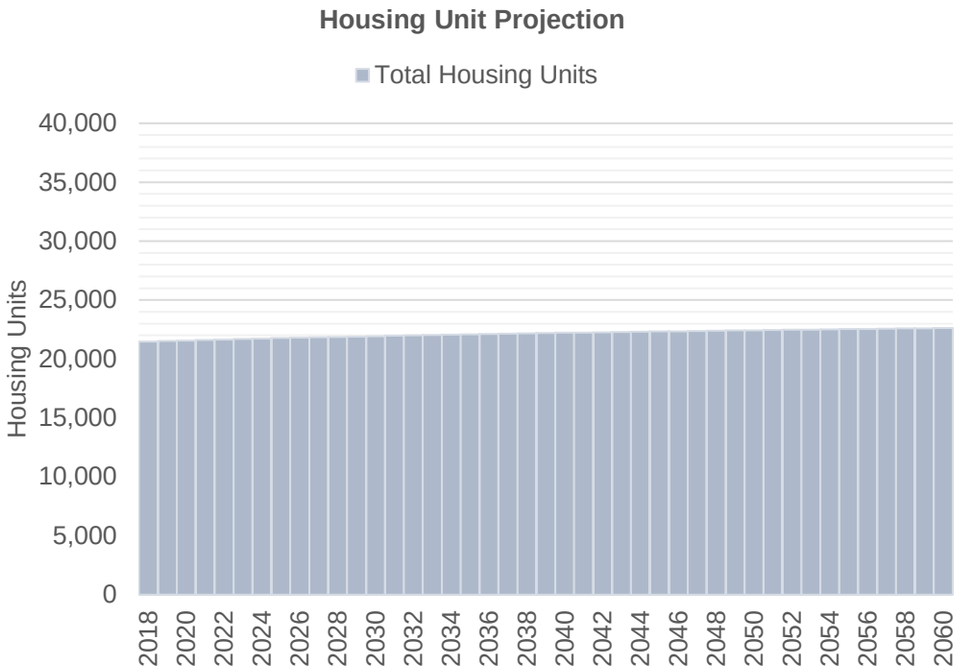
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

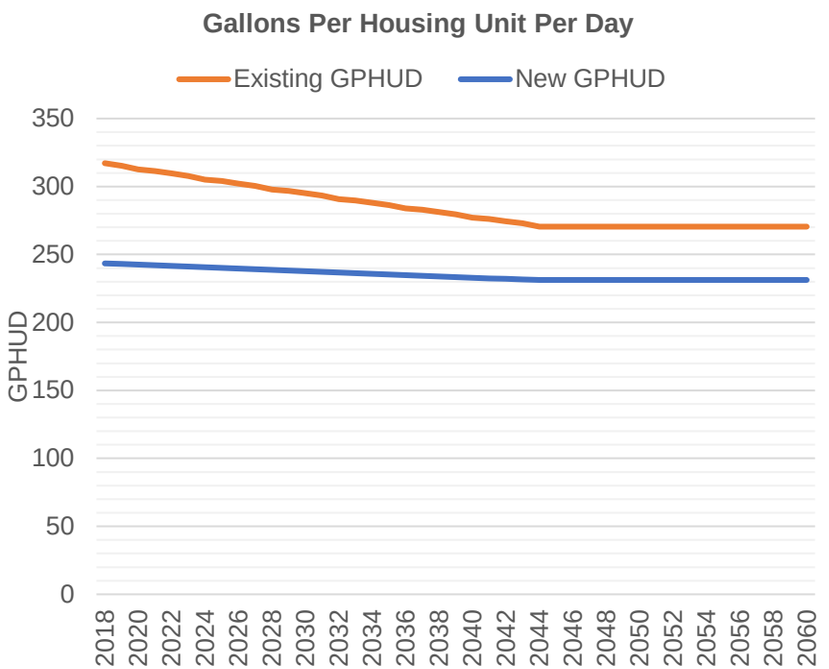
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,438	530	362	0	0	0	0	0	0	0	839	13
2019	1,441	527	362	0	0	0	0	0	0	0	834	14
2020	1,445	522	361	0	0	0	0	0	0	0	830	15
2021	1,449	520	360	0	0	0	0	0	0	0	825	16
2022	1,453	517	360	0	0	0	0	0	0	0	821	17
2023	1,457	514	359	0	0	0	0	0	0	0	816	18
2024	1,461	510	358	0	0	0	0	0	0	0	811	20
2025	1,465	508	357	0	0	0	0	0	0	0	807	21
2026	1,466	505	357	0	0	0	0	0	0	0	802	22
2027	1,466	502	356	0	0	0	0	0	0	0	790	29
2028	1,466	497	355	0	0	0	0	0	0	0	783	31
2029	1,466	496	355	0	0	0	0	0	0	0	778	31
2030	1,466	493	354	0	0	0	0	0	0	0	773	31
2031	1,466	490	353	0	0	0	0	0	0	0	768	31
2032	1,466	486	352	0	0	0	0	0	0	0	764	31
2033	1,466	484	352	0	0	0	0	0	0	0	759	31
2034	1,468	481	351	0	0	0	0	0	0	0	755	31
2035	1,476	478	350	0	0	0	0	0	0	0	751	32
2036	1,483	474	350	0	0	0	0	0	0	0	748	34
2037	1,491	472	349	0	0	0	0	0	0	0	744	36
2038	1,498	470	348	0	0	0	0	0	0	0	740	38
2039	1,505	467	347	0	0	0	0	0	0	0	736	40
2040	1,512	463	347	0	0	0	0	0	0	0	732	42
2041	1,519	461	346	0	0	0	0	0	0	0	728	44
2042	1,526	458	345	0	0	0	0	0	0	0	725	46
2043	1,532	456	345	0	0	0	0	0	0	0	721	48
2044	1,539	452	344	0	0	0	0	0	0	0	717	50
2045	1,546	450	344	0	0	0	0	0	0	0	714	52
2046	1,553	450	344	0	0	0	0	0	0	0	714	54
2047	1,559	450	344	0	0	0	0	0	0	0	715	56
2048	1,566	450	344	0	0	0	0	0	0	0	716	57
2049	1,572	450	344	0	0	0	0	0	0	0	716	59
2050	1,578	450	344	0	0	0	0	0	0	0	717	61
2051	1,584	450	344	0	0	0	0	0	0	0	718	62
2052	1,590	450	344	0	0	0	0	0	0	0	718	64
2053	1,596	450	344	0	0	0	0	0	0	0	719	66
2054	1,602	450	344	0	0	0	0	0	0	0	720	67
2055	1,609	450	344	0	0	0	0	0	0	0	720	69
2056	1,615	450	344	0	0	0	0	0	0	0	721	71
2057	1,621	450	344	0	0	0	0	0	0	0	722	73
2058	1,627	450	344	0	0	0	0	0	0	0	722	74
2059	1,633	450	344	0	0	0	0	0	0	0	723	76
2060	1,639	450	344	0	0	0	0	0	0	0	724	78

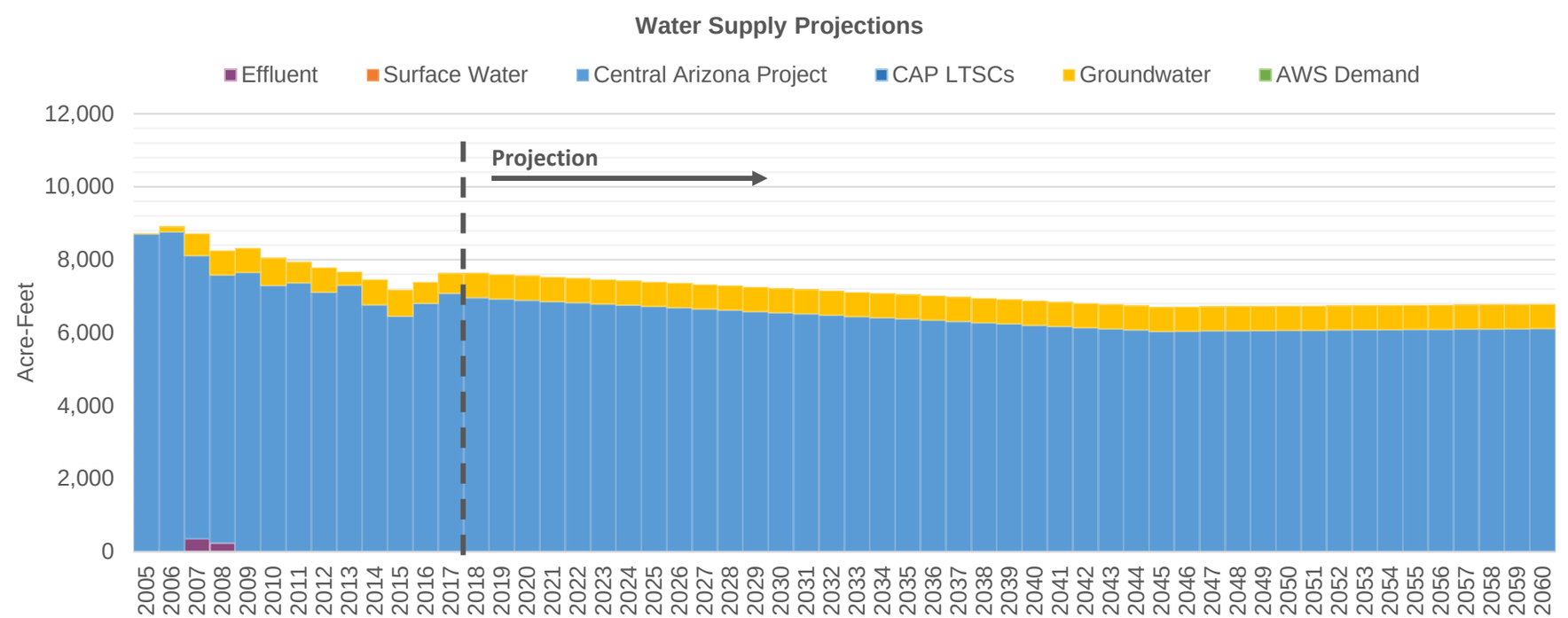
MetroMain

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroMain

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

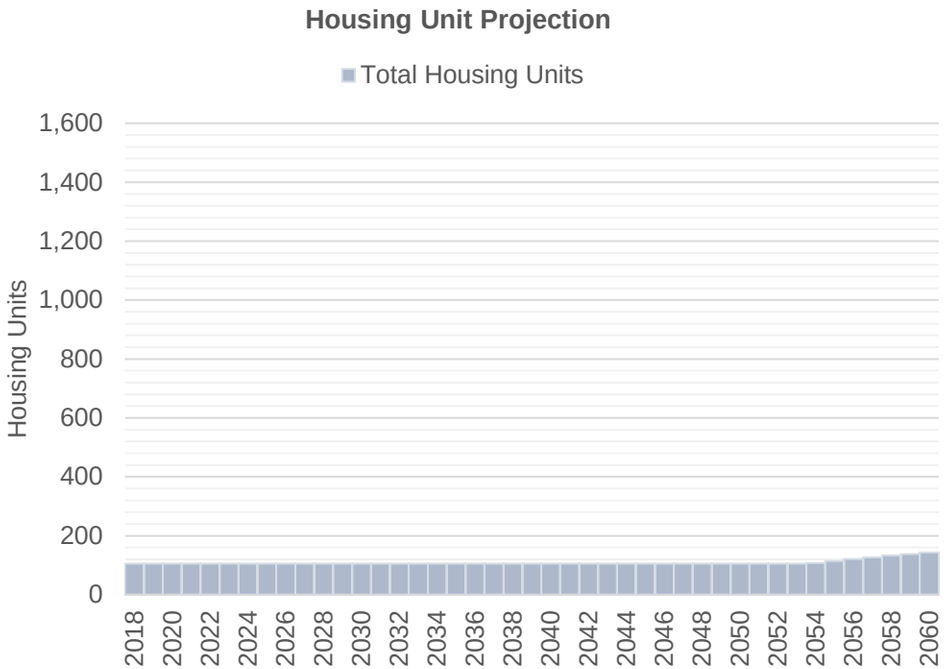
Water Supply Projections (Acre-Feet)

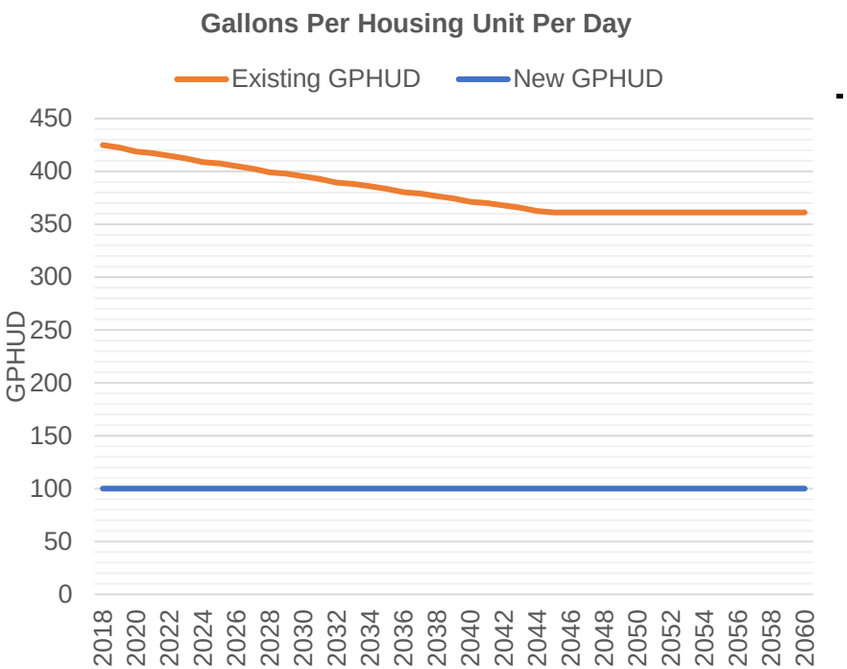
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	21,487	317	243	0	0	0	0	6,962	6,498	0	668	0
2019	21,527	315	243	0	0	0	0	6,924	6,536	0	668	0
2020	21,568	313	242	0	0	0	0	6,889	6,571	0	668	0
2021	21,610	311	242	0	0	0	0	6,855	6,605	0	668	0
2022	21,651	310	241	0	0	0	0	6,822	6,638	0	668	0
2023	21,693	308	241	0	0	0	0	6,788	6,672	0	668	0
2024	21,735	305	241	0	0	0	0	6,755	6,705	0	668	0
2025	21,777	304	240	0	0	0	0	6,722	6,738	0	668	0
2026	21,813	302	240	0	0	0	0	6,688	6,772	0	668	0
2027	21,845	300	239	0	0	0	0	6,654	6,806	0	668	0
2028	21,878	298	239	0	0	0	0	6,619	6,841	0	668	0
2029	21,909	297	238	0	0	0	0	6,584	6,876	0	668	0
2030	21,940	295	238	0	0	0	0	6,549	6,911	0	668	0
2031	21,973	293	237	0	0	0	0	6,515	6,945	0	668	0
2032	22,005	291	237	0	0	0	0	6,481	6,979	0	668	0
2033	22,037	290	236	0	0	0	0	6,447	7,013	0	668	0
2034	22,067	288	236	0	0	0	0	6,413	7,047	0	668	0
2035	22,094	286	235	0	0	0	0	6,379	7,081	0	668	0
2036	22,120	284	235	0	0	0	0	6,345	7,115	0	668	0
2037	22,146	283	234	0	0	0	0	6,310	7,150	0	668	0
2038	22,171	281	234	0	0	0	0	6,275	7,185	0	668	0
2039	22,197	280	233	0	0	0	0	6,241	4,845	0	668	0
2040	22,222	277	233	0	0	0	0	6,207	7,165	0	668	0
2041	22,246	276	232	0	0	0	0	6,173	7,287	0	668	0
2042	22,270	275	232	0	0	0	0	6,139	7,321	0	668	0
2043	22,294	273	232	0	0	0	0	6,105	7,355	0	668	0
2044	22,316	270	231	0	0	0	0	6,072	7,388	0	668	0
2045	22,338	270	231	0	0	0	0	6,038	7,422	0	668	0
2046	22,359	270	231	0	0	0	0	6,043	7,417	0	668	0
2047	22,381	270	231	0	0	0	0	6,049	7,411	0	668	0
2048	22,401	270	231	0	0	0	0	6,055	7,405	0	668	0
2049	22,422	270	231	0	0	0	0	6,059	7,401	0	668	0
2050	22,442	270	231	0	0	0	0	6,065	7,395	0	668	0
2051	22,461	270	231	0	0	0	0	6,070	7,390	0	668	0
2052	22,481	270	231	0	0	0	0	6,076	6,949	0	668	0
2053	22,499	270	231	0	0	0	0	6,080	6,945	0	668	0
2054	22,518	270	231	0	0	0	0	6,085	6,007	0	668	0
2055	22,535	270	231	0	0	0	0	6,089	3,901	0	668	0
2056	22,553	270	231	0	0	0	0	6,095	2,728	0	668	0
2057	22,570	270	231	0	0	0	0	6,098	5,993	0	668	0
2058	22,586	270	231	0	0	0	0	6,103	5,989	0	668	0
2059	22,602	270	231	0	0	0	0	6,107	5,985	0	668	0
2060	22,618	270	231	0	0	0	0	6,112	5,980	0	668	0

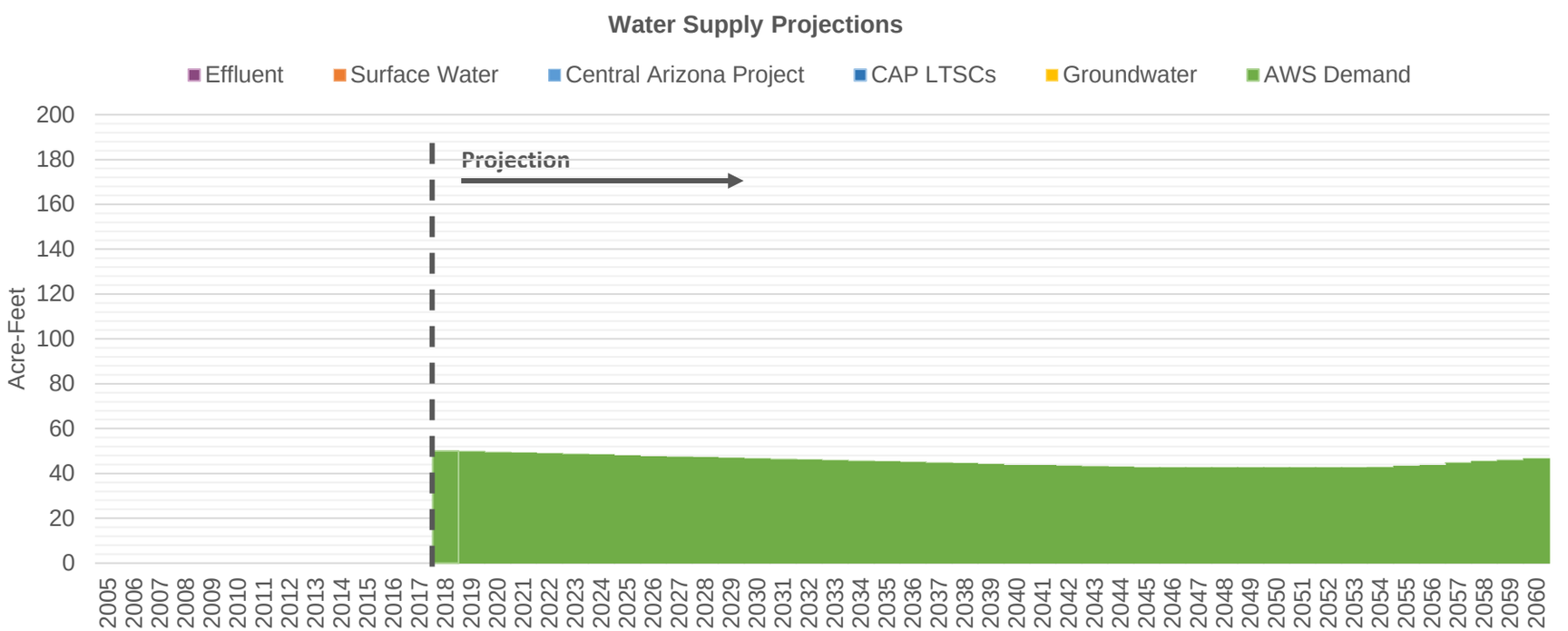
MetroWest

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroWest

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

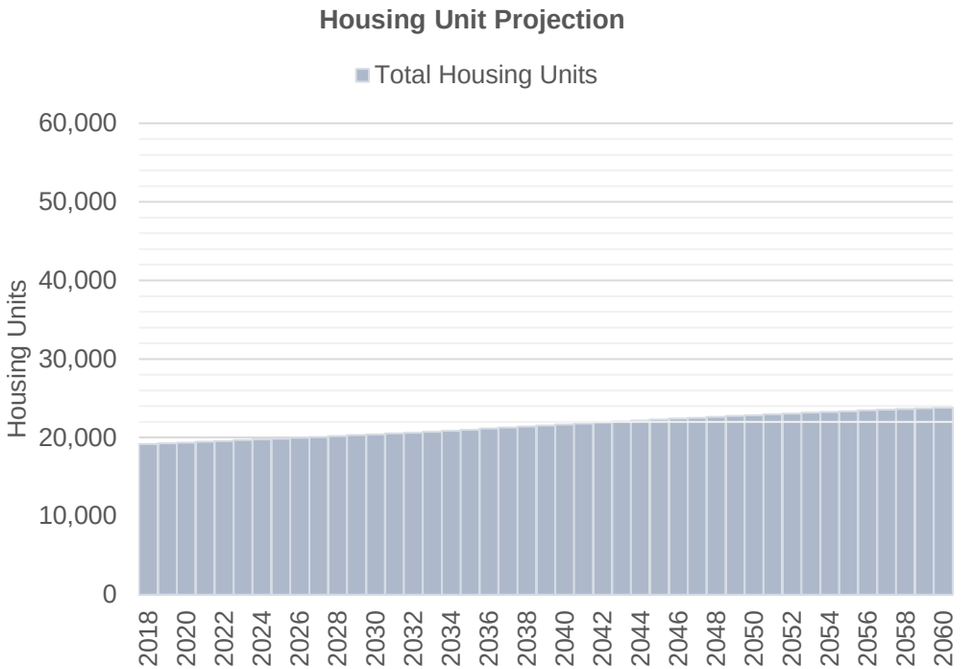
Water Supply Projections (Acre-Feet)

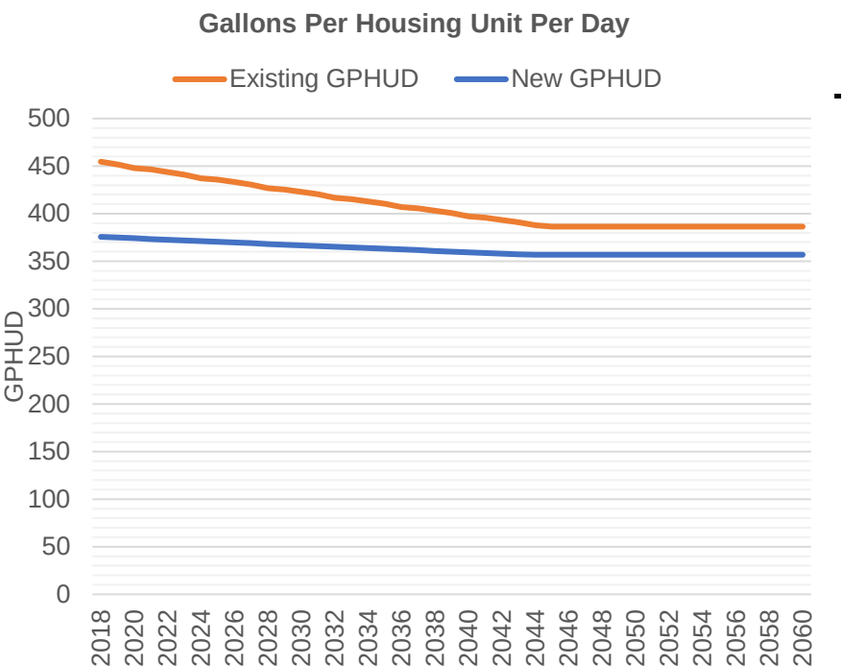
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	105	425	100	0	0	0	0	0	0	0	0	50
2019	105	422	100	0	0	0	0	0	0	0	0	50
2020	105	419	100	0	0	0	0	0	0	0	0	49
2021	105	417	100	0	0	0	0	0	0	0	0	49
2022	105	415	100	0	0	0	0	0	0	0	0	49
2023	105	412	100	0	0	0	0	0	0	0	0	49
2024	105	409	100	0	0	0	0	0	0	0	0	48
2025	105	407	100	0	0	0	0	0	0	0	0	48
2026	105	405	100	0	0	0	0	0	0	0	0	48
2027	105	403	100	0	0	0	0	0	0	0	0	47
2028	105	399	100	0	0	0	0	0	0	0	0	47
2029	105	398	100	0	0	0	0	0	0	0	0	47
2030	105	395	100	0	0	0	0	0	0	0	0	47
2031	105	393	100	0	0	0	0	0	0	0	0	46
2032	105	390	100	0	0	0	0	0	0	0	0	46
2033	105	388	100	0	0	0	0	0	0	0	0	46
2034	105	386	100	0	0	0	0	0	0	0	0	45
2035	105	384	100	0	0	0	0	0	0	0	0	45
2036	105	380	100	0	0	0	0	0	0	0	0	45
2037	105	379	100	0	0	0	0	0	0	0	0	45
2038	105	377	100	0	0	0	0	0	0	0	0	44
2039	105	374	100	0	0	0	0	0	0	0	0	44
2040	105	371	100	0	0	0	0	0	0	0	0	44
2041	105	370	100	0	0	0	0	0	0	0	0	44
2042	105	368	100	0	0	0	0	0	0	0	0	43
2043	105	366	100	0	0	0	0	0	0	0	0	43
2044	105	362	100	0	0	0	0	0	0	0	0	43
2045	105	361	100	0	0	0	0	0	0	0	0	43
2046	105	361	100	0	0	0	0	0	0	0	0	43
2047	105	361	100	0	0	0	0	0	0	0	0	43
2048	105	361	100	0	0	0	0	0	0	0	0	43
2049	105	361	100	0	0	0	0	0	0	0	0	43
2050	105	361	100	0	0	0	0	0	0	0	0	43
2051	105	361	100	0	0	0	0	0	0	0	0	43
2052	105	361	100	0	0	0	0	0	0	0	0	43
2053	105	361	100	0	0	0	0	0	0	0	0	43
2054	108	361	100	0	0	0	0	0	0	0	0	43
2055	114	361	100	0	0	0	0	0	0	0	0	43
2056	121	361	100	0	0	0	0	0	0	0	0	44
2057	127	361	100	0	0	0	0	0	0	0	0	45
2058	133	361	100	0	0	0	0	0	0	0	0	45
2059	138	361	100	0	0	0	0	0	0	0	0	46
2060	144	361	100	0	0	0	0	0	0	0	0	47

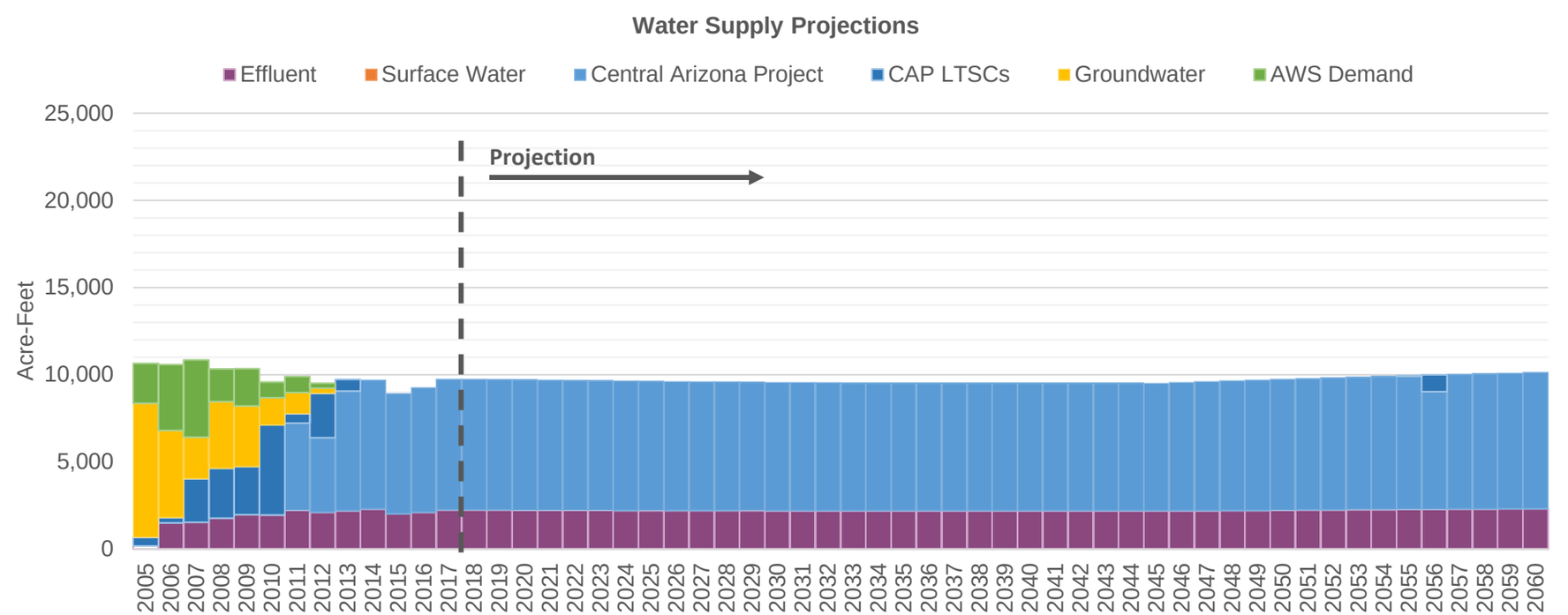
OroValley

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

OroValley

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

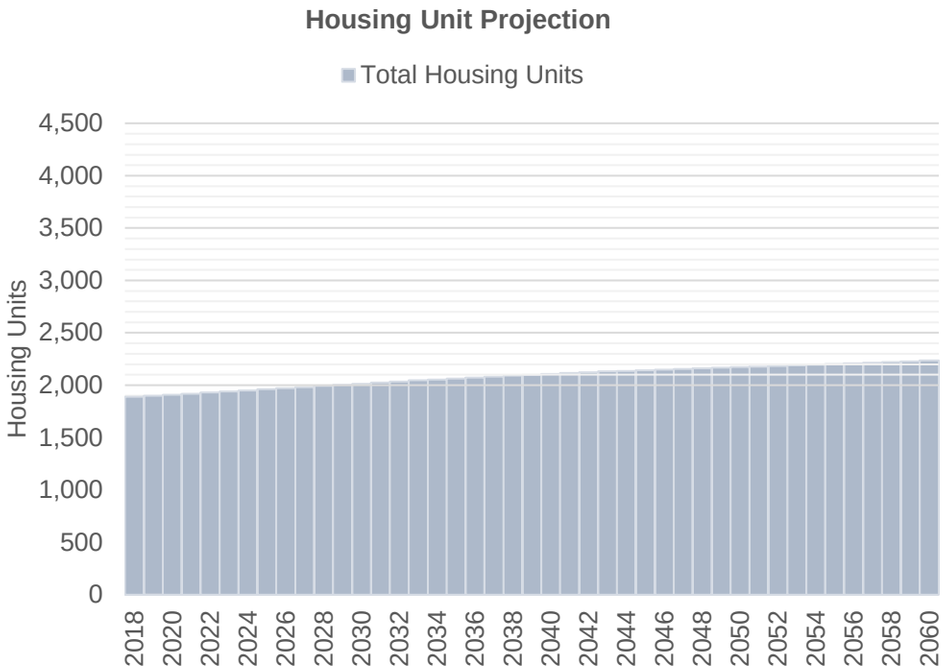
Water Supply Projections (Acre-Feet)

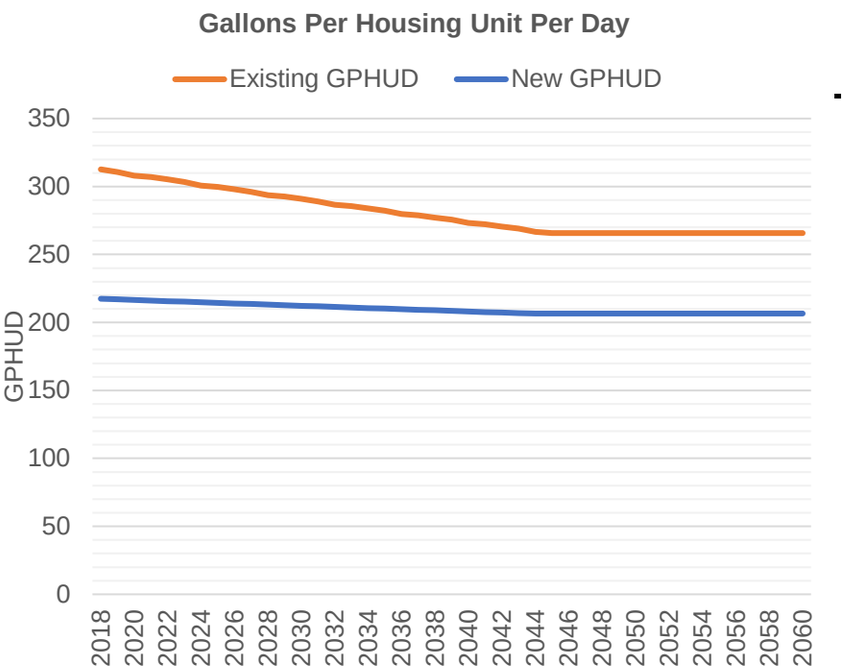
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	19,174	455	376	2,232	0	0	0	7,520	2,785	0	0	0
2019	19,271	452	375	2,232	0	0	0	7,491	2,814	0	0	0
2020	19,368	448	374	2,225	0	0	0	7,481	2,824	0	0	0
2021	19,467	447	373	2,221	0	0	0	7,467	2,838	0	0	0
2022	19,566	444	373	2,217	0	0	0	7,455	2,850	0	0	0
2023	19,666	441	372	2,214	0	0	0	7,442	2,863	0	0	0
2024	19,766	437	371	2,210	0	0	0	7,431	2,874	0	0	0
2025	19,866	436	370	2,207	0	0	0	7,419	2,886	0	0	0
2026	19,971	433	370	2,203	0	0	0	7,408	2,897	0	0	0
2027	20,082	431	369	2,200	0	0	0	7,400	2,905	0	0	0
2028	20,192	427	368	2,197	0	0	0	7,393	2,912	0	0	0
2029	20,300	426	367	2,195	0	0	0	7,383	2,922	0	0	0
2030	20,407	423	367	2,192	0	0	0	7,374	2,931	0	0	0
2031	20,519	420	366	2,190	0	0	0	7,366	2,939	0	0	0
2032	20,629	417	365	2,187	0	0	0	7,361	2,944	0	0	0
2033	20,738	415	365	2,185	0	0	0	7,351	2,954	0	0	0
2034	20,859	413	364	2,183	0	0	0	7,346	2,959	0	0	0
2035	20,999	410	363	2,181	0	0	0	7,346	2,959	0	0	0
2036	21,137	407	362	2,180	0	0	0	7,351	2,954	0	0	0
2037	21,273	406	362	2,181	0	0	0	7,349	2,956	0	0	0
2038	21,408	403	361	2,181	0	0	0	7,350	2,955	0	0	0
2039	21,540	401	360	2,181	0	0	0	7,351	1,137	0	0	0
2040	21,671	397	359	2,182	0	0	0	7,352	2,885	0	0	0
2041	21,800	396	359	2,182	0	0	0	7,348	2,957	0	0	0
2042	21,927	394	358	2,181	0	0	0	7,348	2,957	0	0	0
2043	22,050	391	357	2,181	0	0	0	7,345	2,960	0	0	0
2044	22,170	388	357	2,180	0	0	0	7,346	2,959	0	0	0
2045	22,287	386	357	2,180	0	0	0	7,340	2,965	0	0	0
2046	22,403	386	357	2,179	0	0	0	7,387	2,918	0	0	0
2047	22,516	386	357	2,190	0	0	0	7,423	2,882	0	0	0
2048	22,628	386	357	2,200	0	0	0	7,461	2,844	0	0	0
2049	22,737	386	357	2,211	0	0	0	7,490	2,815	0	0	0
2050	22,845	386	357	2,220	0	0	0	7,525	2,780	0	0	0
2051	22,950	386	357	2,230	0	0	0	7,557	2,748	0	0	0
2052	23,054	386	357	2,240	0	0	0	7,593	2,379	0	0	0
2053	23,155	386	357	2,251	0	0	0	7,619	2,353	0	0	0
2054	23,255	386	357	2,259	0	0	0	7,651	1,606	0	0	0
2055	23,354	386	357	2,268	0	0	0	7,649	0	33	0	0
2056	23,451	386	357	2,277	0	0	0	6,755	0	962	0	0
2057	23,545	386	357	2,287	0	0	0	7,740	1,517	0	0	0
2058	23,638	386	357	2,295	0	0	0	7,770	1,487	0	0	0
2059	23,728	386	357	2,304	0	0	0	7,798	1,459	0	0	0
2060	23,817	386	357	2,312	0	0	0	7,830	1,427	0	0	0

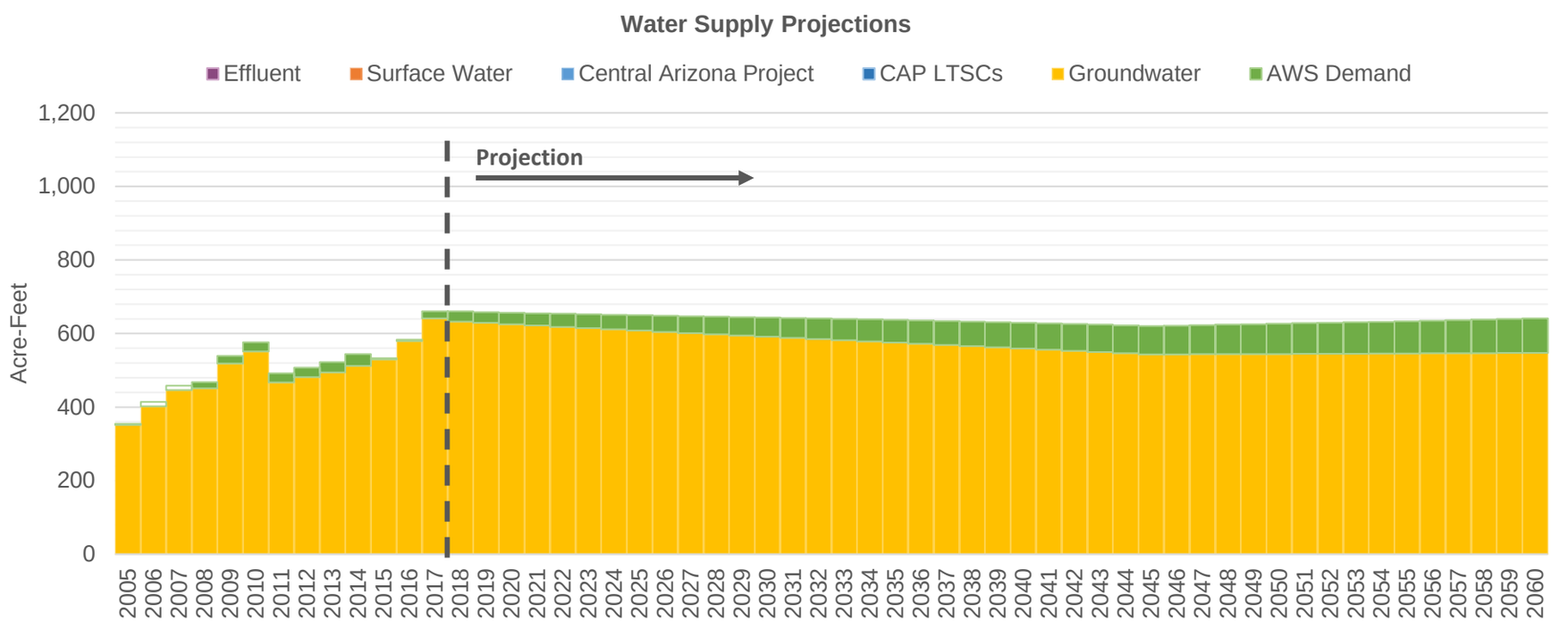
QuailCreek

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

QuailCreek

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

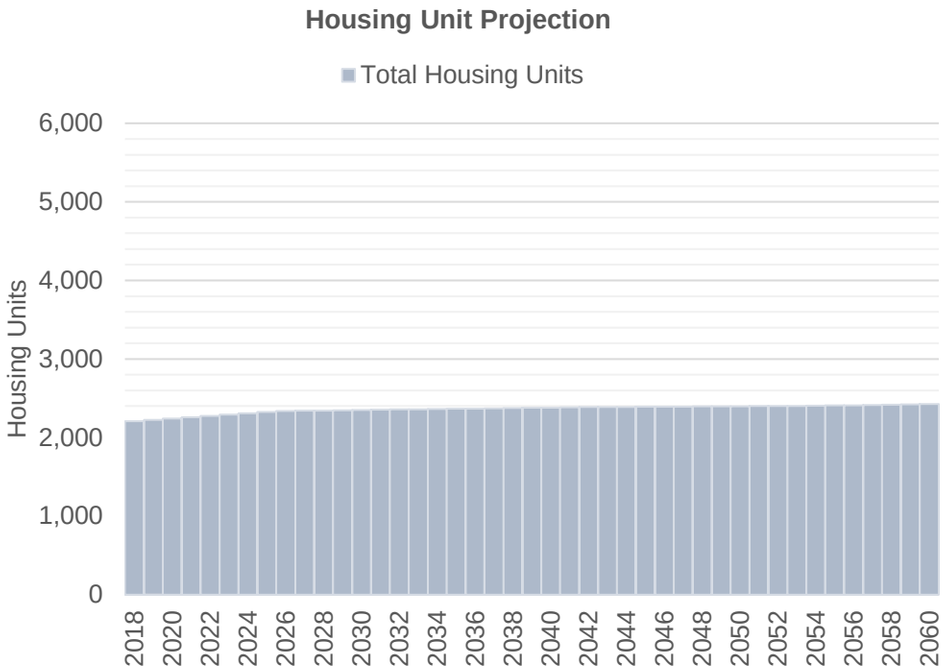
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

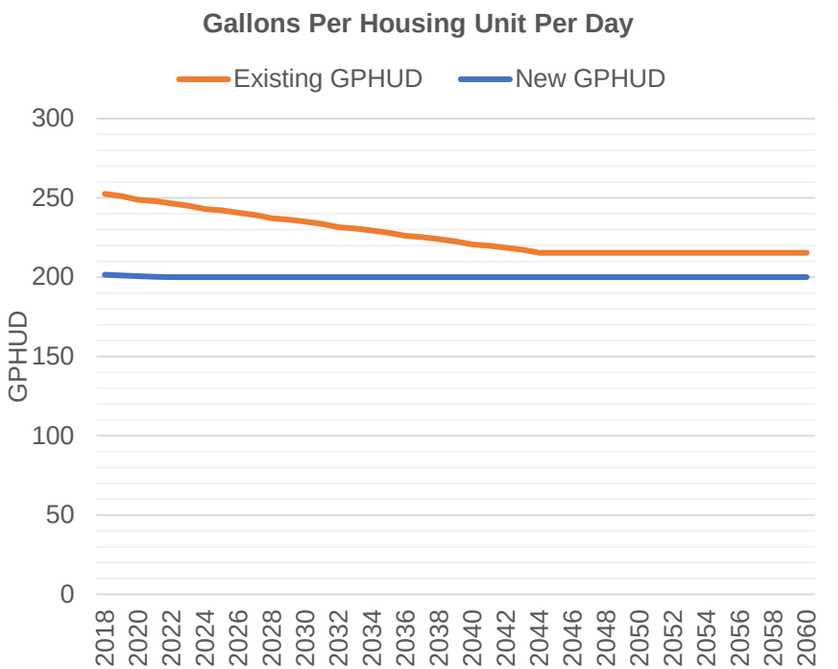
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,889	313	217	0	0	0	0	0	0	0	632	28
2019	1,899	311	217	0	0	0	0	0	0	0	629	29
2020	1,909	308	217	0	0	0	0	0	0	0	626	31
2021	1,919	307	216	0	0	0	0	0	0	0	622	33
2022	1,930	305	216	0	0	0	0	0	0	0	618	36
2023	1,940	303	215	0	0	0	0	0	0	0	615	38
2024	1,950	301	215	0	0	0	0	0	0	0	611	40
2025	1,961	300	214	0	0	0	0	0	0	0	608	42
2026	1,971	298	214	0	0	0	0	0	0	0	605	44
2027	1,982	296	214	0	0	0	0	0	0	0	601	46
2028	1,993	294	213	0	0	0	0	0	0	0	598	48
2029	2,003	293	213	0	0	0	0	0	0	0	595	50
2030	2,013	291	212	0	0	0	0	0	0	0	591	52
2031	2,024	289	212	0	0	0	0	0	0	0	588	54
2032	2.035	287	211	0	0	0	0	0	0	0	585	56
2033	2,046	286	211	0	0	0	0	0	0	0	582	58
2034	2,055	284	211	0	0	0	0	0	0	0	579	60
2035	2,064	282	210	0	0	0	0	0	0	0	575	62
2036	2,073	280	210	0	0	0	0	0	0	0	572	63
2037	2,082	279	209	0	0	0	0	0	0	0	569	65
2038	2,091	277	209	0	0	0	0	0	0	0	566	67
2039	2,099	276	208	0	0	0	0	0	0	0	562	68
2040	2,107	273	208	0	0	0	0	0	0	0	559	70
2041	2,116	272	208	0	0	0	0	0	0	0	556	71
2042	2,124	271	207	0	0	0	0	0	0	0	553	73
2043	2,131	269	207	0	0	0	0	0	0	0	550	75
2044	2,137	267	207	0	0	0	0	0	0	0	546	76
2045	2,143	266	207	0	0	0	0	0	0	0	543	77
2046	2,149	266	207	0	0	0	0	0	0	0	543	78
2047	2,155	266	207	0	0	0	0	0	0	0	544	79
2048	2,161	266	207	0	0	0	0	0	0	0	544	80
2049	2,166	266	207	0	0	0	0	0	0	0	544	81
2050	2,172	266	207	0	0	0	0	0	0	0	544	82
2051	2,177	266	207	0	0	0	0	0	0	0	545	83
2052	2,183	266	207	0	0	0	0	0	0	0	545	84
2053	2,188	266	207	0	0	0	0	0	0	0	545	85
2054	2,194	266	207	0	0	0	0	0	0	0	545	86
2055	2,201	266	207	0	0	0	0	0	0	0	546	88
2056	2,208	266	207	0	0	0	0	0	0	0	546	89
2057	2,215	266	207	0	0	0	0	0	0	0	546	90
2058	2,222	266	207	0	0	0	0	0	0	0	547	91
2059	2,228	266	207	0	0	0	0	0	0	0	547	93
2060	2,235	266	207	0	0	0	0	0	0	0	548	94

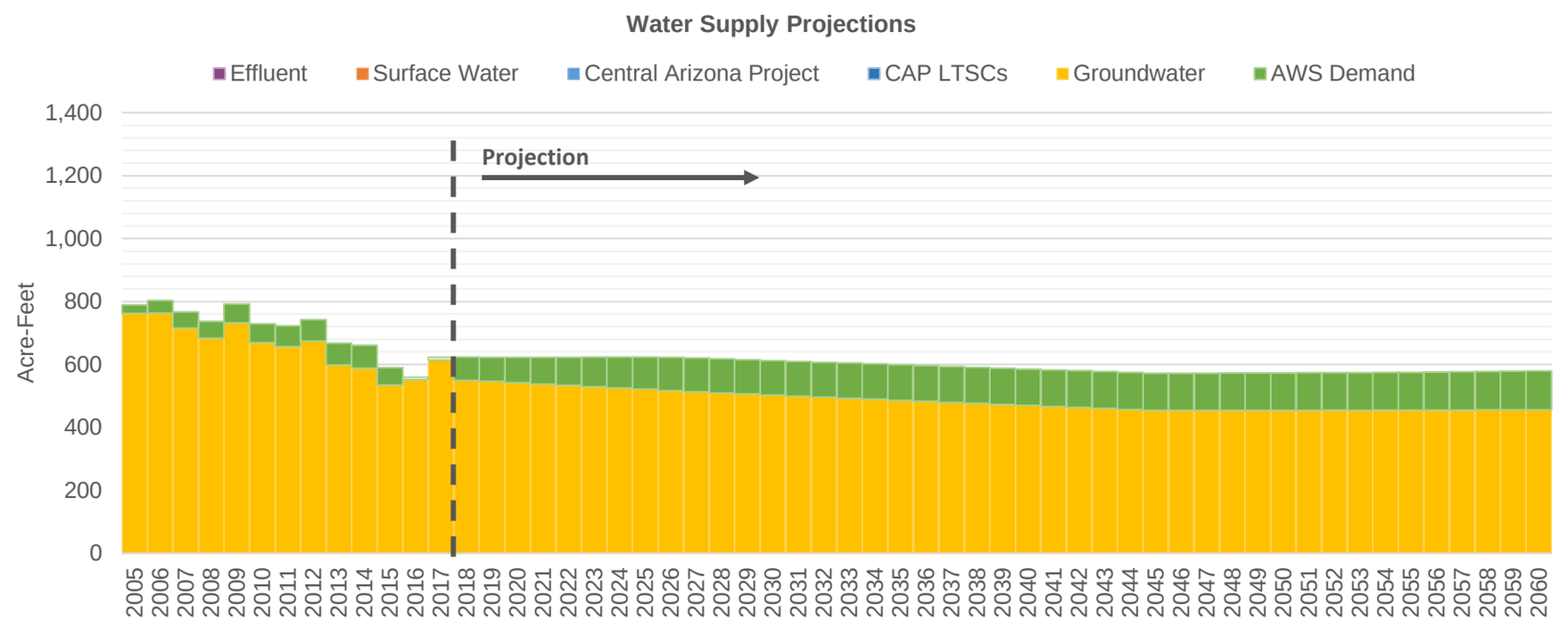
RayWC

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

RayWC

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

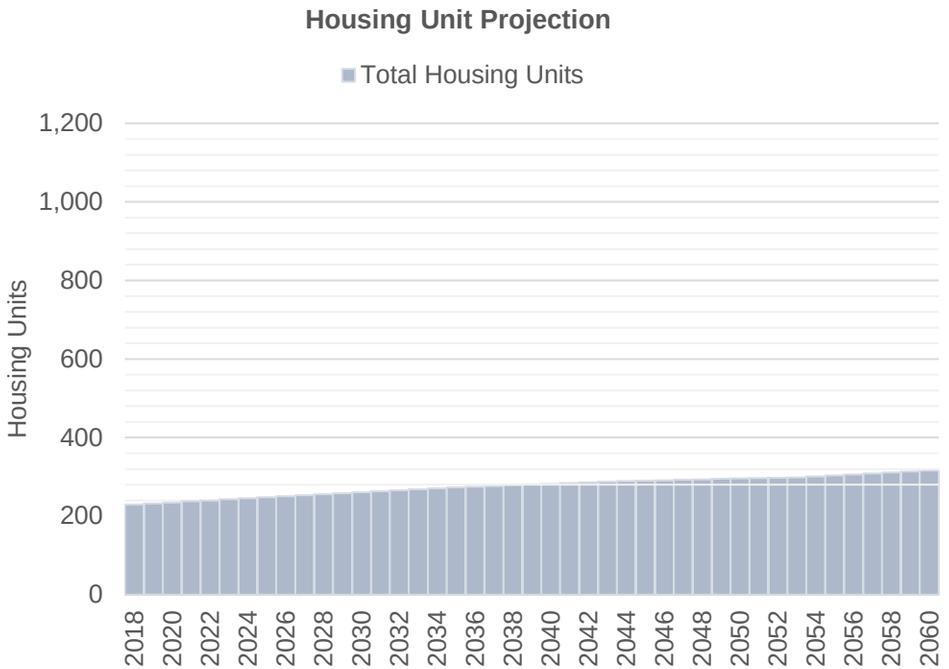
Water Supply Projections (Acre-Feet)

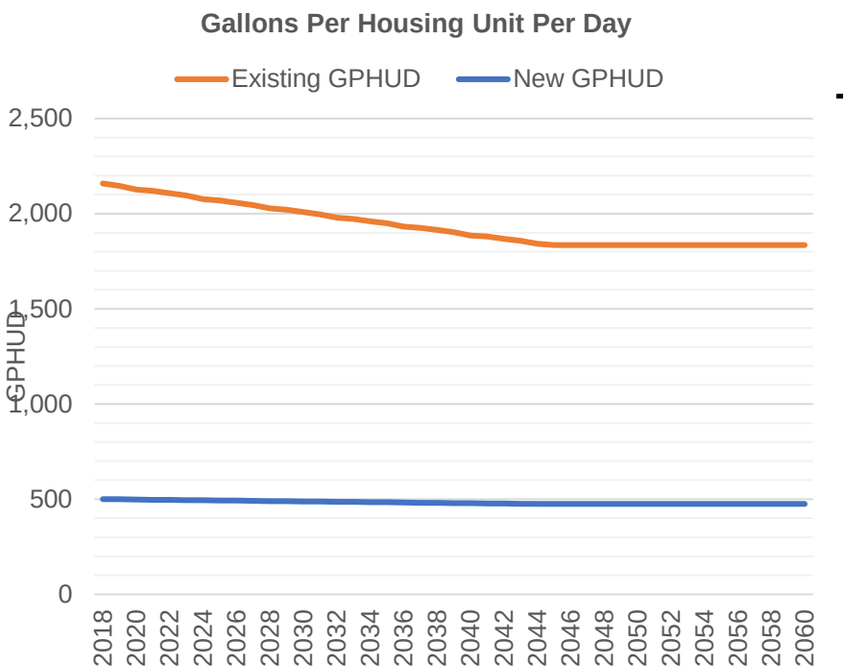
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,210	253	202	0	0	0	0	0	0	0	550	74
2019	2,226	251	201	0	0	0	0	0	0	0	547	76
2020	2,243	249	201	0	0	0	0	0	0	0	542	81
2021	2,260	248	200	0	0	0	0	0	0	0	537	86
2022	2,277	247	200	0	0	0	0	0	0	0	533	90
2023	2,294	245	200	0	0	0	0	0	0	0	529	94
2024	2,311	243	200	0	0	0	0	0	0	0	525	98
2025	2,328	242	200	0	0	0	0	0	0	0	521	102
2026	2,337	241	200	0	0	0	0	0	0	0	517	106
2027	2,341	239	200	0	0	0	0	0	0	0	513	108
2028	2,344	237	200	0	0	0	0	0	0	0	510	108
2029	2,347	236	200	0	0	0	0	0	0	0	506	109
2030	2,351	235	200	0	0	0	0	0	0	0	503	110
2031	2,354	234	200	0	0	0	0	0	0	0	499	110
2032	2.358	231	200	0	0	0	0	0	0	0	496	111
2033	2,361	231	200	0	0	0	0	0	0	0	493	112
2034	2,364	229	200	0	0	0	0	0	0	0	489	112
2035	2,367	228	200	0	0	0	0	0	0	0	486	113
2036	2,370	226	200	0	0	0	0	0	0	0	483	114
2037	2,373	225	200	0	0	0	0	0	0	0	479	114
2038	2,376	224	200	0	0	0	0	0	0	0	476	115
2039	2,379	223	200	0	0	0	0	0	0	0	473	115
2040	2,381	221	200	0	0	0	0	0	0	0	470	116
2041	2,384	220	200	0	0	0	0	0	0	0	467	116
2042	2,387	219	200	0	0	0	0	0	0	0	463	117
2043	2,389	217	200	0	0	0	0	0	0	0	460	117
2044	2,390	215	200	0	0	0	0	0	0	0	457	118
2045	2,392	215	200	0	0	0	0	0	0	0	454	118
2046	2,393	215	200	0	0	0	0	0	0	0	454	118
2047	2,395	215	200	0	0	0	0	0	0	0	454	118
2048	2,396	215	200	0	0	0	0	0	0	0	454	119
2049	2,397	215	200	0	0	0	0	0	0	0	454	119
2050	2,399	215	200	0	0	0	0	0	0	0	454	119
2051	2,400	215	200	0	0	0	0	0	0	0	454	119
2052	2,401	215	200	0	0	0	0	0	0	0	455	119
2053	2,402	215	200	0	0	0	0	0	0	0	454	120
2054	2,405	215	200	0	0	0	0	0	0	0	455	120
2055	2,408	215	200	0	0	0	0	0	0	0	455	120
2056	2,412	215	200	0	0	0	0	0	0	0	455	121
2057	2,415	215	200	0	0	0	0	0	0	0	455	121
2058	2,418	215	200	0	0	0	0	0	0	0	456	122
2059	2,422	215	200	0	0	0	0	0	0	0	456	122
2060	2,425	215	200	0	0	0	0	0	0	0	456	123

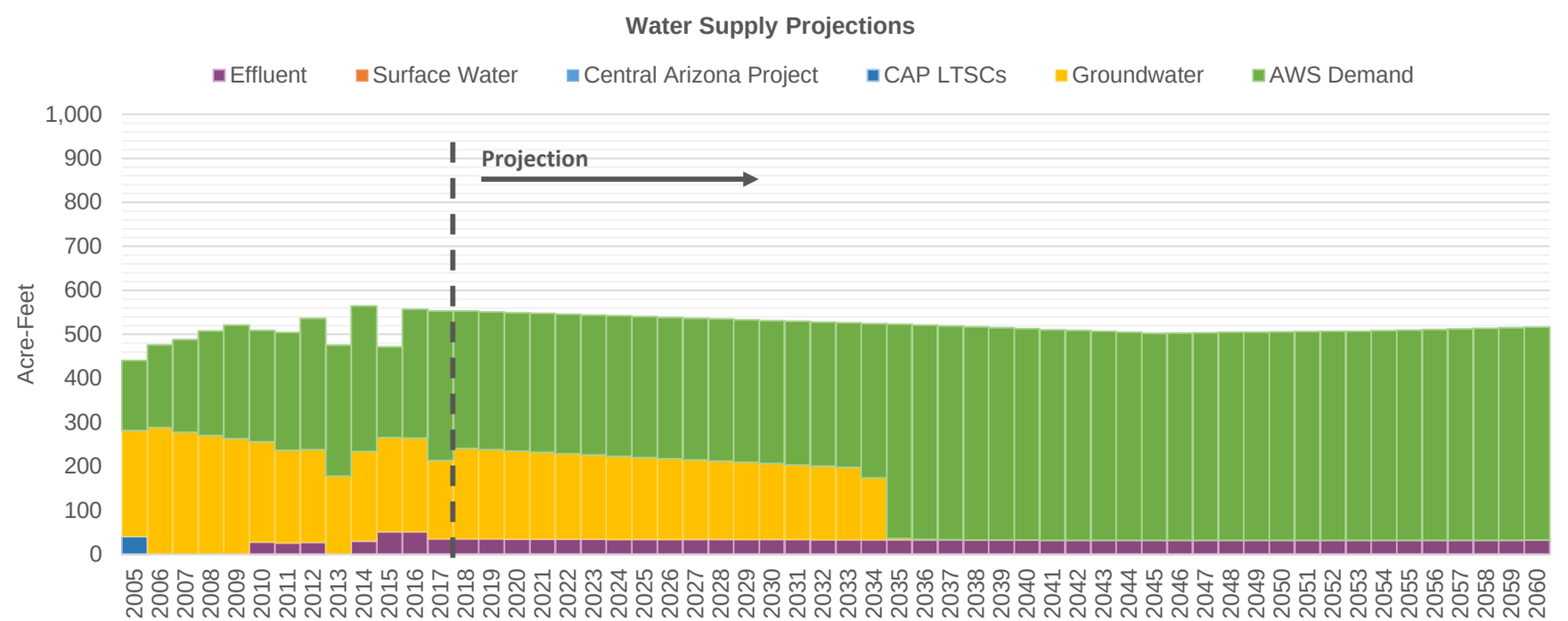
RidgeView

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

RidgeView

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

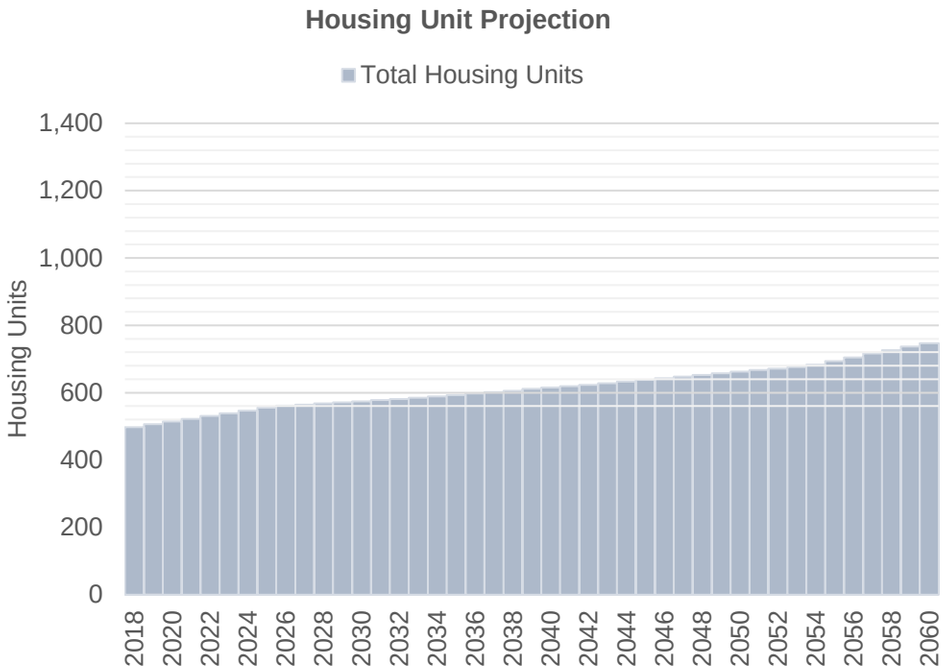
Water Supply Projections (Acre-Feet)

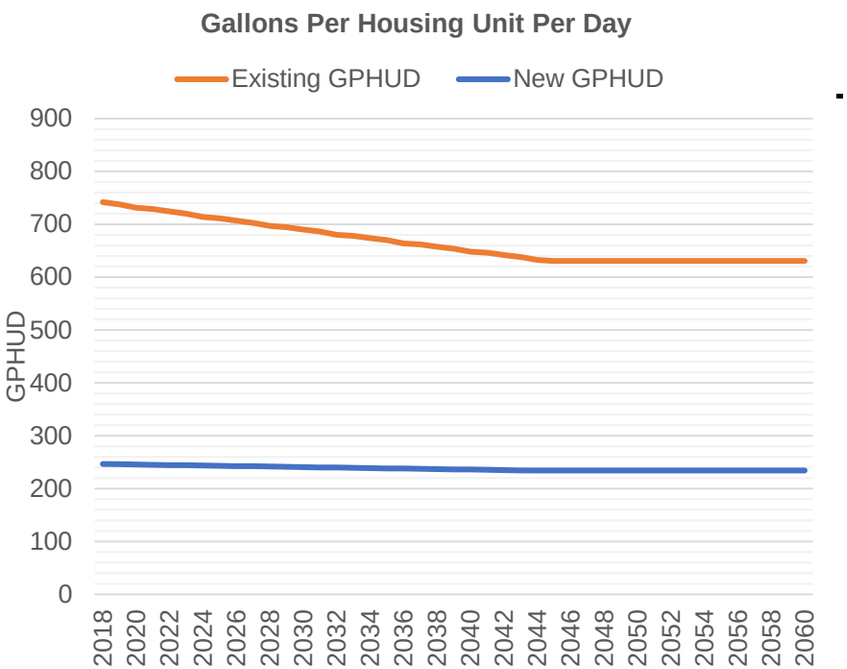
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	230	2,159	500	35	0	0	0	0	0	0	206	313
2019	232	2,146	499	35	0	0	0	0	0	0	203	313
2020	235	2,127	498	35	0	0	0	0	0	0	200	314
2021	238	2,120	497	35	0	0	0	0	0	0	197	316
2022	240	2,108	496	35	0	0	0	0	0	0	194	317
2023	243	2,095	495	35	0	0	0	0	0	0	191	318
2024	246	2,077	494	34	0	0	0	0	0	0	189	319
2025	248	2,070	493	34	0	0	0	0	0	0	186	320
2026	251	2,058	492	34	0	0	0	0	0	0	183	321
2027	253	2,045	491	34	0	0	0	0	0	0	180	322
2028	256	2,027	490	34	0	0	0	0	0	0	178	323
2029	258	2,021	489	34	0	0	0	0	0	0	175	324
2030	261	2,009	488	34	0	0	0	0	0	0	173	325
2031	263	1,997	487	34	0	0	0	0	0	0	170	326
2032	266	1,979	486	33	0	0	0	0	0	0	168	327
2033	268	1,973	485	33	0	0	0	0	0	0	165	328
2034	271	1,961	484	33	0	0	0	0	0	0	141	351
2035	273	1,949	483	33	0	0	0	0	0	0	3	486
2036	275	1,932	482	33	0	0	0	0	0	0	1	487
2037	277	1,926	481	33	0	0	0	0	0	0	0	486
2038	279	1,914	480	33	0	0	0	0	0	0	0	484
2039	281	1,903	479	33	0	0	0	0	0	0	0	482
2040	282	1,886	478	33	0	0	0	0	0	0	0	480
2041	284	1,880	477	32	0	0	0	0	0	0	0	479
2042	286	1,869	477	32	0	0	0	0	0	0	0	477
2043	288	1,858	476	32	0	0	0	0	0	0	0	475
2044	289	1,841	475	32	0	0	0	0	0	0	0	473
2045	290	1,835	475	32	0	0	0	0	0	0	0	471
2046	291	1,835	475	32	0	0	0	0	0	0	0	471
2047	293	1,835	475	32	0	0	0	0	0	0	0	472
2048	294	1,835	475	32	0	0	0	0	0	0	0	473
2049	295	1,835	475	32	0	0	0	0	0	0	0	473
2050	296	1,835	475	32	0	0	0	0	0	0	0	474
2051	297	1,835	475	32	0	0	0	0	0	0	0	474
2052	298	1,835	475	32	0	0	0	0	0	0	0	475
2053	299	1,835	475	32	0	0	0	0	0	0	0	475
2054	301	1,835	475	32	0	0	0	0	0	0	0	476
2055	304	1,835	475	32	0	0	0	0	0	0	0	477
2056	306	1,835	475	32	0	0	0	0	0	0	0	479
2057	309	1,835	475	32	0	0	0	0	0	0	0	480
2058	311	1,835	475	32	0	0	0	0	0	0	0	481
2059	314	1,835	475	32	0	0	0	0	0	0	0	483
2060	316	1,835	475	33	0	0	0	0	0	0	0	484

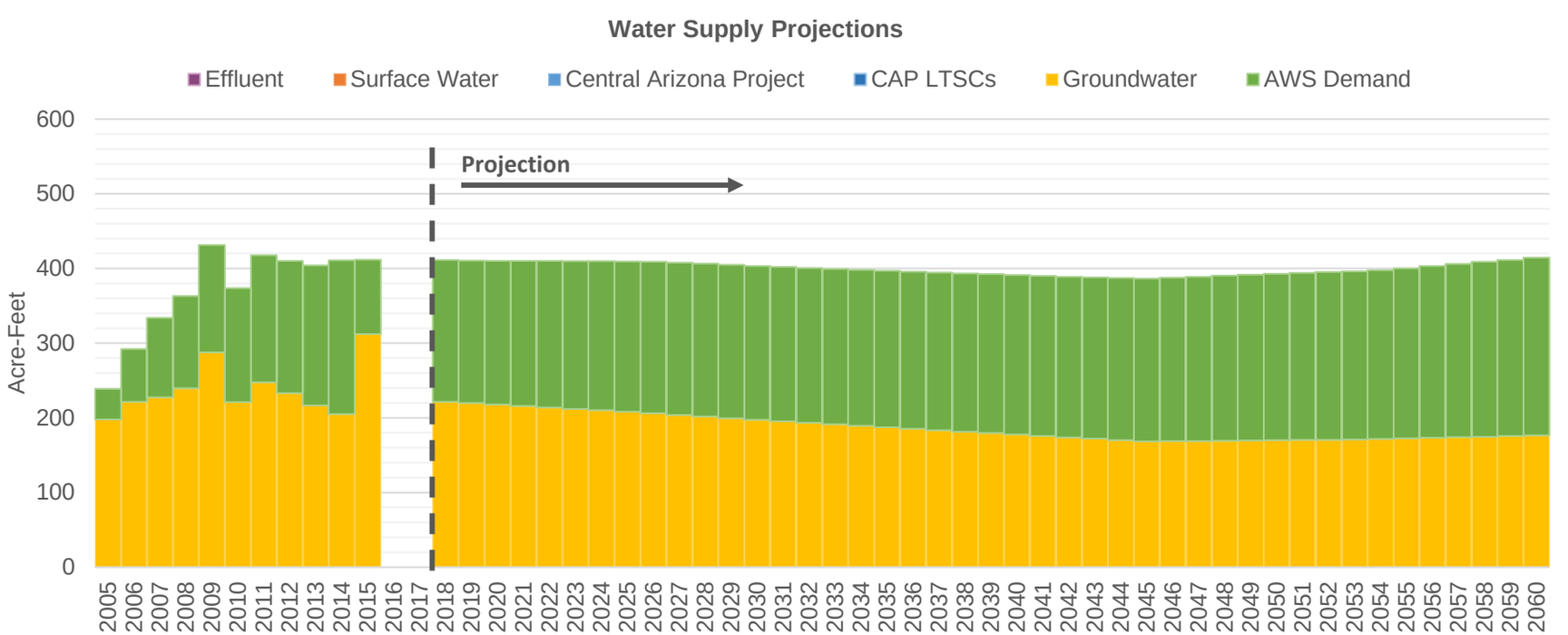
Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]

Saguaro







Central Arizona Project Service Area Model

Saguaro

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

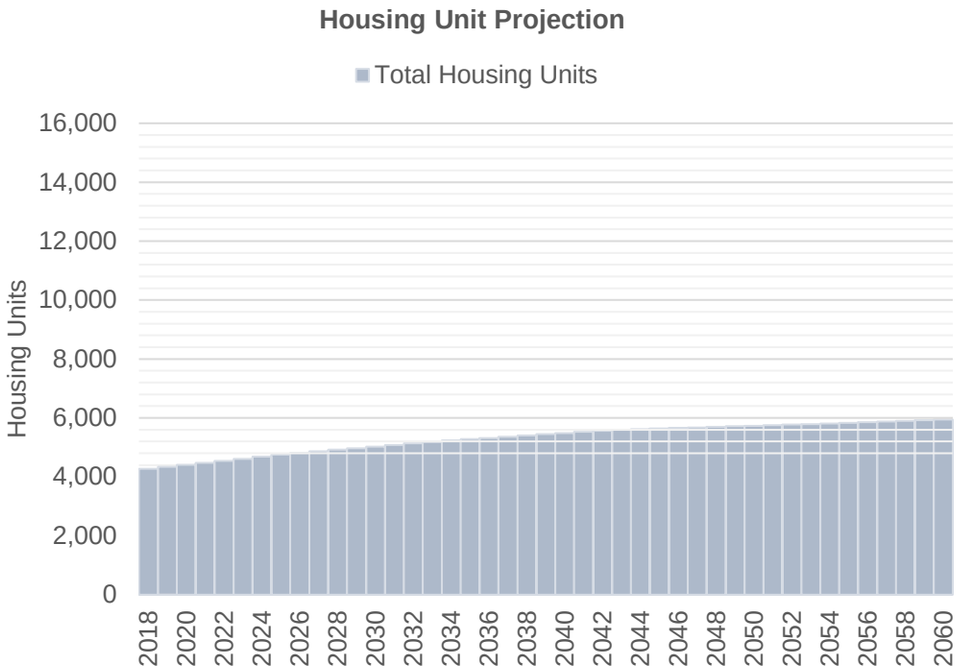
Water Supply Projections (Acre-Feet)

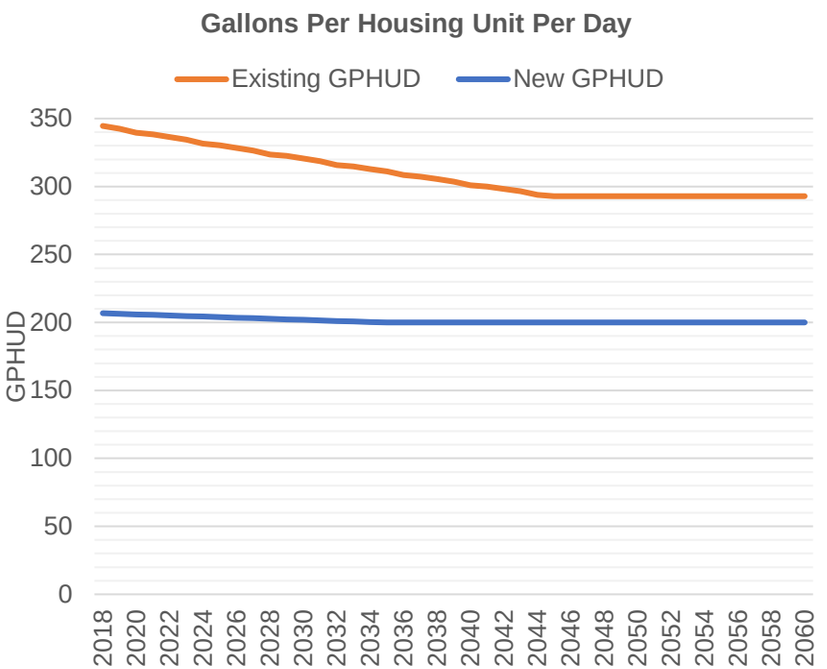
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	498	742	247	0	0	0	0	0	0	0	221	190
2019	506	737	246	0	0	0	0	0	0	0	220	191
2020	514	731	246	0	0	0	0	0	0	0	218	193
2021	522	729	245	0	0	0	0	0	0	0	216	194
2022	531	724	245	0	0	0	0	0	0	0	214	196
2023	539	720	244	0	0	0	0	0	0	0	212	198
2024	547	714	244	0	0	0	0	0	0	0	210	200
2025	555	711	243	0	0	0	0	0	0	0	208	201
2026	561	707	243	0	0	0	0	0	0	0	206	203
2027	564	703	242	0	0	0	0	0	0	0	204	204
2028	568	697	242	0	0	0	0	0	0	0	202	205
2029	571	694	241	0	0	0	0	0	0	0	200	205
2030	574	690	241	0	0	0	0	0	0	0	197	206
2031	578	686	240	0	0	0	0	0	0	0	195	207
2032	581	680	240	0	0	0	0	0	0	0	193	207
2033	585	678	239	0	0	0	0	0	0	0	191	208
2034	589	674	239	0	0	0	0	0	0	0	189	209
2035	593	670	238	0	0	0	0	0	0	0	187	209
2036	598	664	238	0	0	0	0	0	0	0	186	210
2037	602	662	237	0	0	0	0	0	0	0	183	211
2038	606	658	237	0	0	0	0	0	0	0	181	212
2039	611	654	236	0	0	0	0	0	0	0	180	213
2040	615	648	236	0	0	0	0	0	0	0	178	214
2041	619	646	235	0	0	0	0	0	0	0	176	215
2042	623	642	235	0	0	0	0	0	0	0	174	215
2043	628	638	235	0	0	0	0	0	0	0	172	216
2044	633	633	234	0	0	0	0	0	0	0	170	217
2045	638	631	234	0	0	0	0	0	0	0	168	218
2046	643	631	234	0	0	0	0	0	0	0	169	219
2047	648	631	234	0	0	0	0	0	0	0	169	220
2048	653	631	234	0	0	0	0	0	0	0	169	221
2049	658	631	234	0	0	0	0	0	0	0	170	222
2050	662	631	234	0	0	0	0	0	0	0	170	223
2051	667	631	234	0	0	0	0	0	0	0	170	224
2052	671	631	234	0	0	0	0	0	0	0	171	225
2053	676	631	234	0	0	0	0	0	0	0	171	225
2054	683	631	234	0	0	0	0	0	0	0	172	226
2055	694	631	234	0	0	0	0	0	0	0	173	228
2056	705	631	234	0	0	0	0	0	0	0	173	230
2057	716	631	234	0	0	0	0	0	0	0	174	232
2058	726	631	234	0	0	0	0	0	0	0	175	234
2059	737	631	234	0	0	0	0	0	0	0	176	236
2060	747	631	234	0	0	0	0	0	0	0	176	238

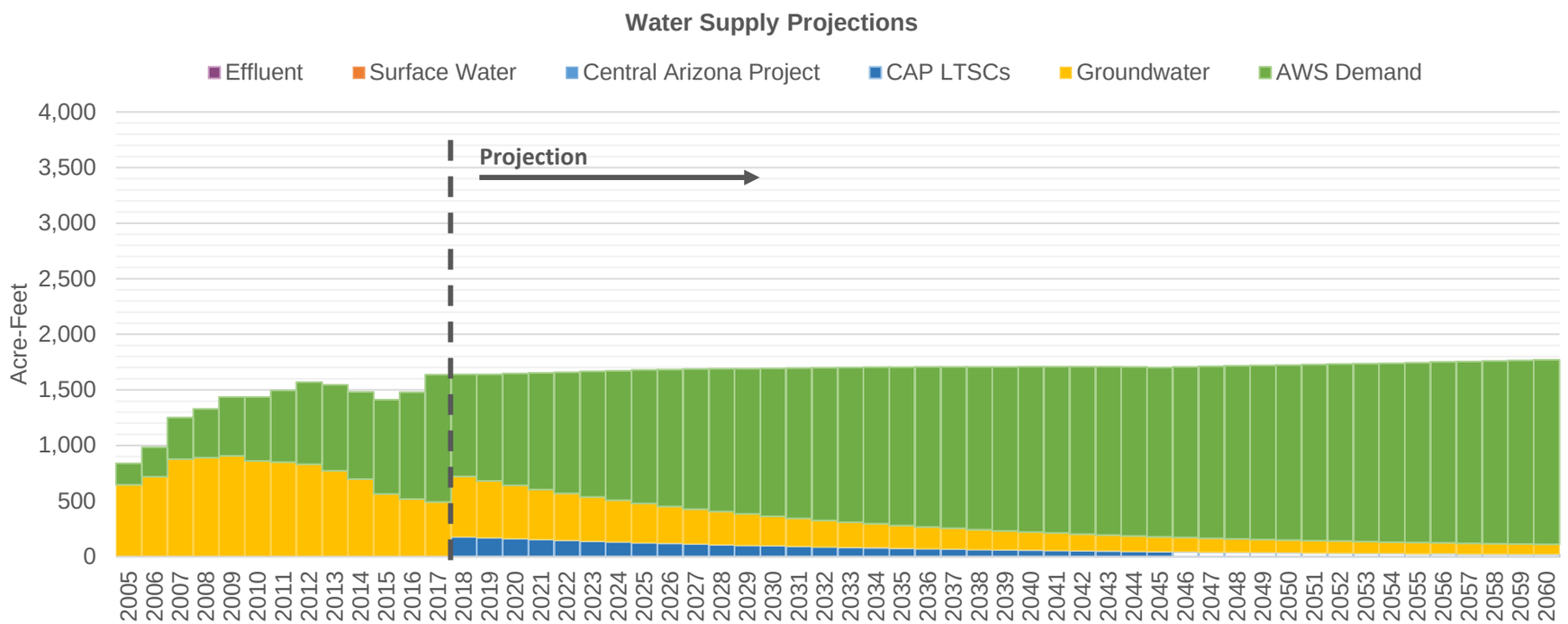
Central Arizona Project Service Area Model

Sahuarita

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Sahuarita

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

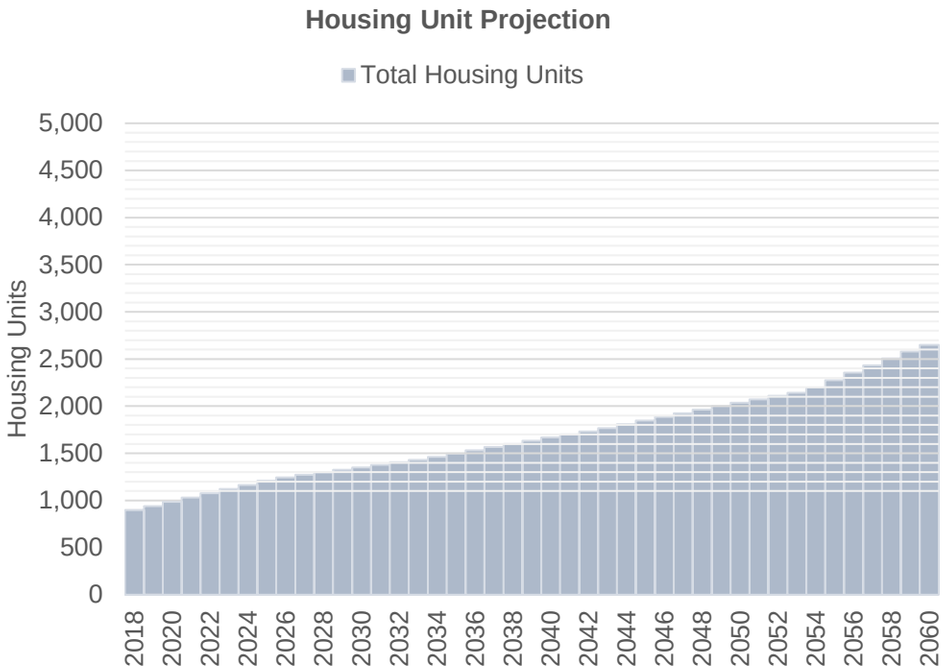
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

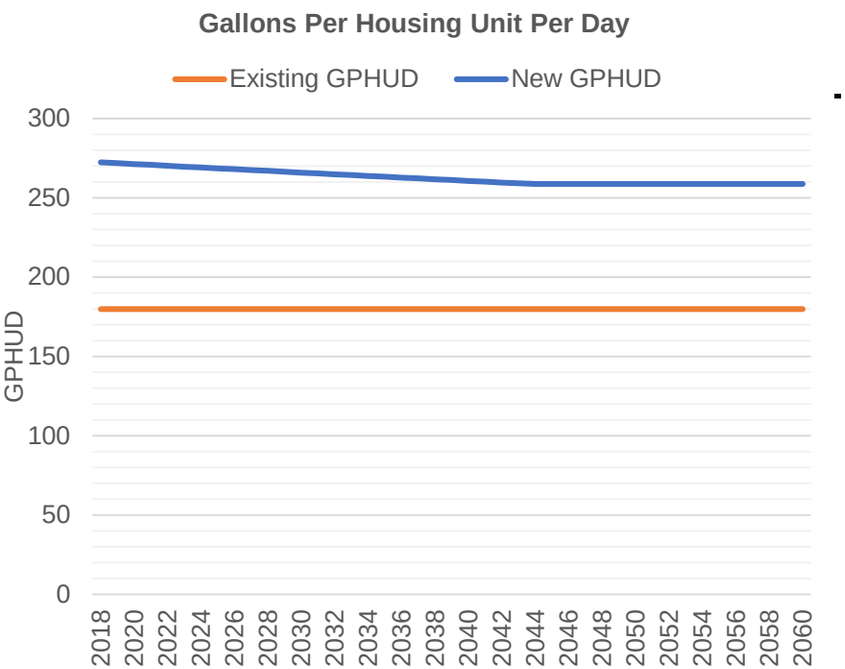
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,269	345	207	0	0	0	0	0	0	179	544	916
2019	4,337	343	206	0	0	0	0	0	0	171	510	960
2020	4,406	340	206	0	0	0	0	0	0	162	479	1,006
2021	4,475	338	206	0	0	0	0	0	0	154	450	1,049
2022	4,545	336	205	0	0	0	0	0	0	146	423	1,090
2023	4,615	334	205	0	0	0	0	0	0	139	398	1,129
2024	4,685	331	204	0	0	0	0	0	0	132	375	1,165
2025	4,756	330	204	0	0	0	0	0	0	125	353	1,200
2026	4,816	328	204	0	0	0	0	0	0	119	333	1,231
2027	4,869	326	203	0	0	0	0	0	0	113	315	1,259
2028	4,922	324	203	0	0	0	0	0	0	107	297	1,285
2029	4,974	323	202	0	0	0	0	0	0	102	281	1,309
2030	5,026	321	202	0	0	0	0	0	0	97	266	1,331
2031	5,080	319	201	0	0	0	0	0	0	92	252	1,352
2032	5.133	316	201	0	0	0	0	0	0	88	240	1.373
2033	5,186	315	201	0	0	0	0	0	0	83	228	1,391
2034	5,235	313	200	0	0	0	0	0	0	79	216	1,409
2035	5,278	311	200	0	0	0	0	0	0	75	206	1,424
2036	5,321	308	200	0	0	0	0	0	0	71	196	1,439
2037	5,364	307	200	0	0	0	0	0	0	68	187	1,451
2038	5,406	306	200	0	0	0	0	0	0	64	179	1,464
2039	5,447	304	200	0	0	0	0	0	0	61	171	1,476
2040	5,488	301	200	0	0	0	0	0	0	58	164	1,487
2041	5,528	300	200	0	0	0	0	0	0	55	157	1,496
2042	5,568	298	200	0	0	0	0	0	0	52	151	1,506
2043	5,601	296	200	0	0	0	0	0	0	50	145	1,514
2044	5,621	294	200	0	0	0	0	0	0	47	140	1,520
2045	5,641	293	200	0	0	0	0	0	0	45	135	1,523
2046	5,661	293	200	0	0	0	0	0	0	43	130	1,534
2047	5,680	293	200	0	0	0	0	0	0	41	126	1,545
2048	5,699	293	200	0	0	0	0	0	0	39	122	1,556
2049	5,717	293	200	0	0	0	0	0	0	37	118	1,565
2050	5,735	293	200	0	0	0	0	0	0	35	115	1,574
2051	5,753	293	200	0	0	0	0	0	0	33	111	1,583
2052	5,771	293	200	0	0	0	0	0	0	31	108	1,593
2053	5,788	293	200	0	0	0	0	0	0	30	106	1,600
2054	5,808	293	200	0	0	0	0	0	0	28	103	1,608
2055	5,831	293	200	0	0	0	0	0	0	27	101	1,617
2056	5,855	293	200	0	0	0	0	0	0	26	99	1,627
2057	5,877	293	200	0	0	0	0	0	0	24	97	1,634
2058	5,899	293	200	0	0	0	0	0	0	23	95	1,642
2059	5,921	293	200	0	0	0	0	0	0	22	93	1,650
2060	5,942	293	200	0	0	0	0	0	0	21	91	1,659

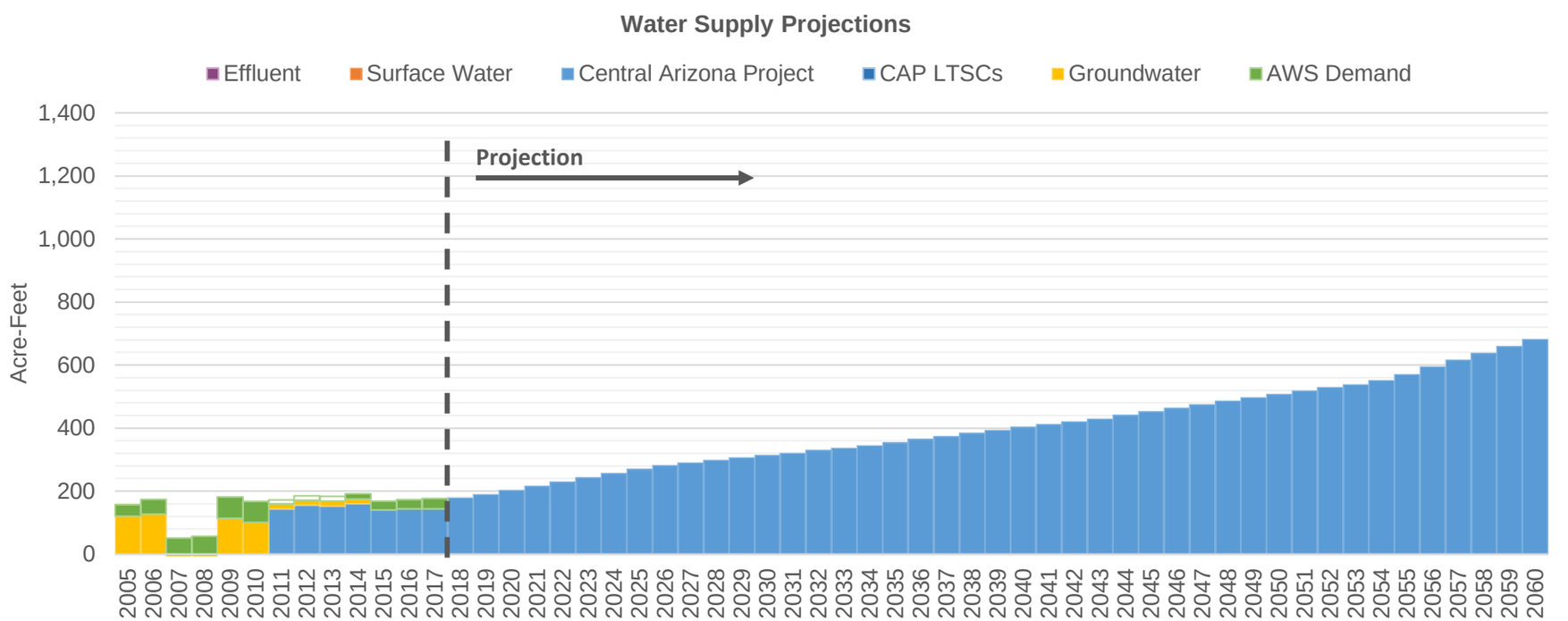
Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]

SpanishTrailWC







Central Arizona Project Service Area Model

SpanishTrailWC

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

Water Supply Projections (Acre-Feet)

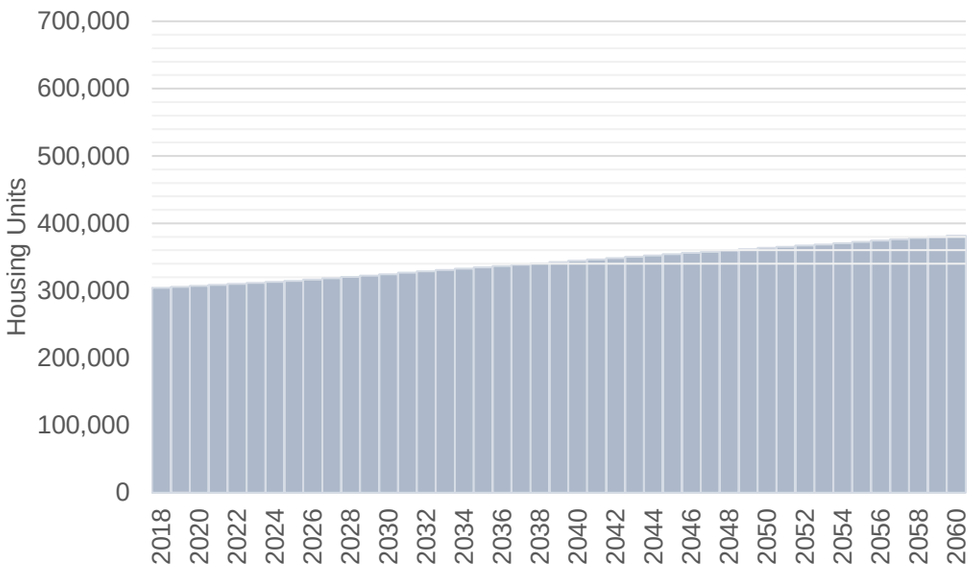
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	898	180	272	0	0	0	0	180	2,857	0	0	0
2019	941	180	272	0	0	0	0	189	2,848	0	0	0
2020	985	180	271	0	0	0	0	203	2,834	0	0	0
2021	1,030	180	271	0	0	0	0	216	2,821	0	0	0
2022	1,075	180	270	0	0	0	0	230	2,807	0	0	0
2023	1,120	180	270	0	0	0	0	243	2,794	0	0	0
2024	1,165	180	269	0	0	0	0	257	2,780	0	0	0
2025	1,210	180	269	0	0	0	0	270	2,767	0	0	0
2026	1,244	180	268	0	0	0	0	282	2,755	0	0	0
2027	1,271	180	268	0	0	0	0	291	2,746	0	0	0
2028	1,298	180	267	0	0	0	0	299	2,738	0	0	0
2029	1,324	180	266	0	0	0	0	306	2,731	0	0	0
2030	1,350	180	266	0	0	0	0	314	2,723	0	0	0
2031	1,378	180	265	0	0	0	0	321	2,716	0	0	0
2032	1,405	180	265	0	0	0	0	330	2,707	0	0	0
2033	1,431	180	264	0	0	0	0	337	2,700	0	0	0
2034	1,462	180	264	0	0	0	0	345	2,692	0	0	0
2035	1,497	180	263	0	0	0	0	354	2,683	0	0	0
2036	1,532	180	263	0	0	0	0	365	2,672	0	0	0
2037	1,566	180	262	0	0	0	0	374	2,663	0	0	0
2038	1,600	180	262	0	0	0	0	384	2,653	0	0	0
2039	1,634	180	261	0	0	0	0	393	2,108	0	0	0
2040	1,667	180	261	0	0	0	0	403	2,614	0	0	0
2041	1,700	180	260	0	0	0	0	412	2,625	0	0	0
2042	1,732	180	260	0	0	0	0	421	2,616	0	0	0
2043	1,767	180	259	0	0	0	0	430	2,607	0	0	0
2044	1,807	180	259	0	0	0	0	441	2,596	0	0	0
2045	1,847	180	259	0	0	0	0	452	2,585	0	0	0
2046	1,887	180	259	0	0	0	0	464	2,573	0	0	0
2047	1,925	180	259	0	0	0	0	475	2,562	0	0	0
2048	1,963	180	259	0	0	0	0	487	2,550	0	0	0
2049	2,001	180	259	0	0	0	0	497	2,540	0	0	0
2050	2,037	180	259	0	0	0	0	508	2,529	0	0	0
2051	2,073	180	259	0	0	0	0	518	2,519	0	0	0
2052	2,109	180	259	0	0	0	0	529	2,409	0	0	0
2053	2,143	180	259	0	0	0	0	539	2,400	0	0	0
2054	2,196	180	259	0	0	0	0	551	2,177	0	0	0
2055	2,276	180	259	0	0	0	0	570	1,684	0	0	0
2056	2,354	180	259	0	0	0	0	595	1,396	0	0	0
2057	2,431	180	259	0	0	0	0	616	2,112	0	0	0
2058	2,506	180	259	0	0	0	0	638	2,090	0	0	0
2059	2,579	180	259	0	0	0	0	659	2,069	0	0	0
2060	2,650	180	259	0	0	0	0	682	2,047	0	0	0

Central Arizona Project Service Area Model

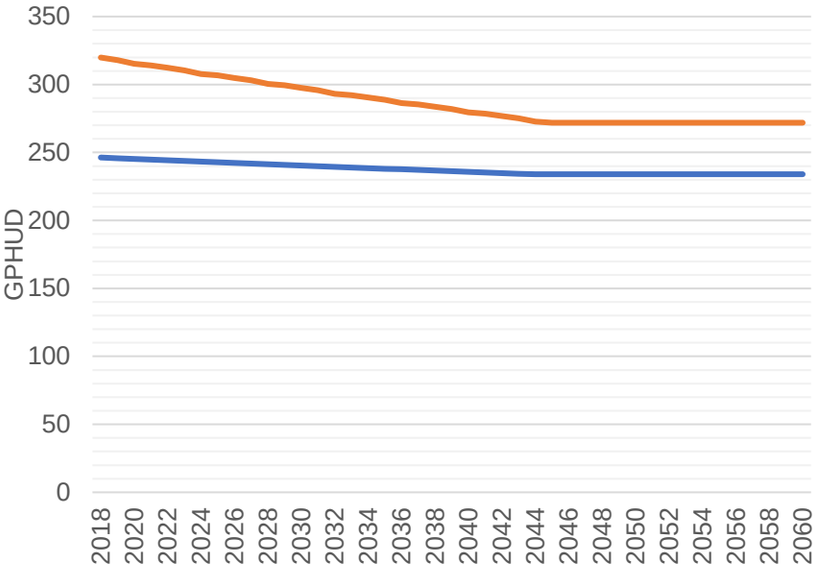
B. Slow, Compact, Dry Climate [LSCRBS]

Tucson

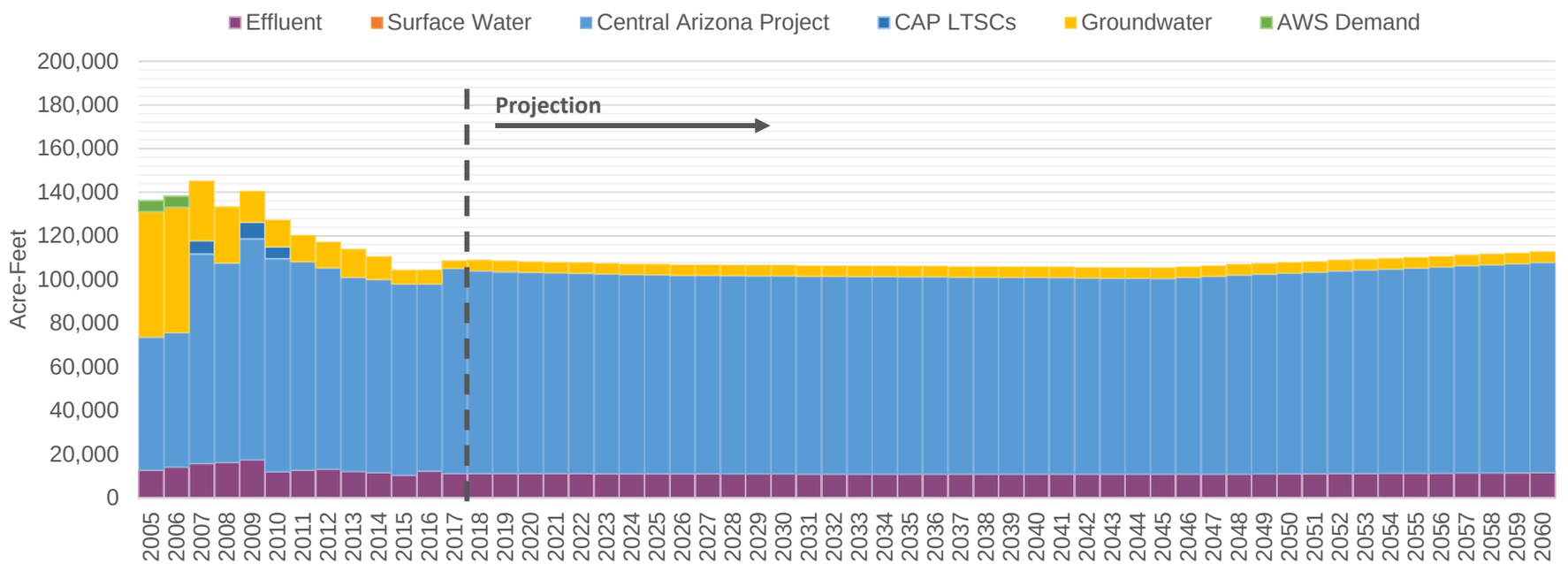
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

Tucson

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

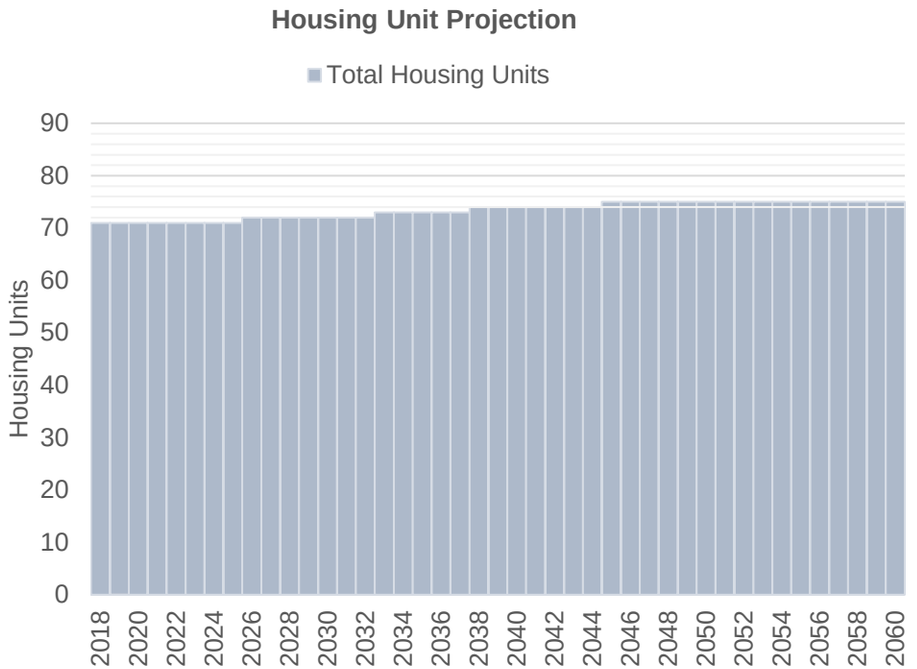
Water Supply Projections (Acre-Feet)

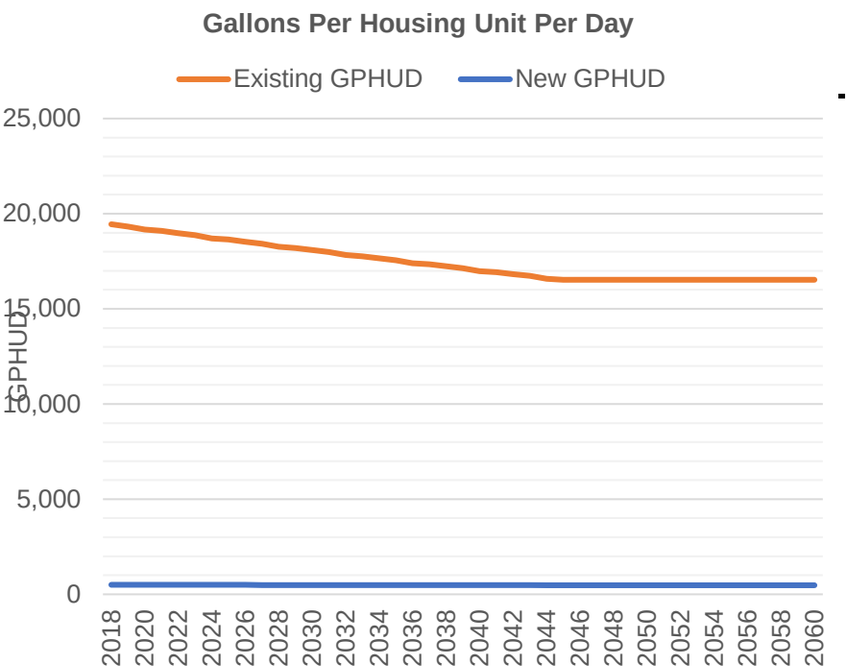
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	304,290	320	246	11,236	0	0	0	92,696	51,476	0	4,951	0
2019	305,746	318	246	11,236	0	0	0	92,332	51,840	0	4,951	0
2020	307,215	315	245	11,198	0	0	0	92,125	52,047	0	4,951	0
2021	308,698	314	245	11,173	0	0	0	91,906	52,266	0	4,951	0
2022	310,190	312	244	11,148	0	0	0	91,695	52,477	0	4,951	0
2023	311,691	310	244	11,124	0	0	0	91,487	52,685	0	4,951	0
2024	313,196	308	243	11,100	0	0	0	91,290	52,882	0	4,951	0
2025	314,705	307	243	11,077	0	0	0	91,082	53,090	0	4,951	0
2026	316,514	305	242	11,053	0	0	0	90,925	53,247	0	4,951	0
2027	318,564	303	242	11,034	0	0	0	90,838	53,334	0	4,951	0
2028	320,587	300	241	11,023	0	0	0	90,786	53,386	0	4,951	0
2029	322,582	299	241	11,017	0	0	0	90,699	53,473	0	4,951	0
2030	324,548	298	240	11,007	0	0	0	90,622	53,550	0	4,951	0
2031	326,605	296	240	10,998	0	0	0	90,554	53,618	0	4,951	0
2032	328,640	293	240	10,990	0	0	0	90,513	53,659	0	4,951	0
2033	330,653	292	239	10,985	0	0	0	90,429	53,743	0	4,951	0
2034	332,674	291	239	10,976	0	0	0	90,367	53,805	0	4,951	0
2035	334,718	289	238	10,969	0	0	0	90,308	53,864	0	4,951	0
2036	336,737	286	238	10,962	0	0	0	90,274	53,898	0	4,951	0
2037	338,730	285	237	10,958	0	0	0	90,185	53,987	0	4,951	0
2038	340,697	284	237	10,948	0	0	0	90,119	54,053	0	4,951	0
2039	342,637	282	236	10,940	0	0	0	90,046	28,698	0	4,951	0
2040	344,551	279	236	10,932	0	0	0	89,996	53,234	0	4,951	0
2041	346,436	279	235	10,926	0	0	0	89,881	54,291	0	4,951	0
2042	348,294	277	235	10,914	0	0	0	89,795	54,377	0	4,951	0
2043	350,185	275	234	10,903	0	0	0	89,710	54,462	0	4,951	0
2044	352,172	273	234	10,893	0	0	0	89,686	54,486	0	4,951	0
2045	354,127	272	234	10,890	0	0	0	89,613	54,559	0	4,951	0
2046	356,050	272	234	10,882	0	0	0	90,126	54,046	0	4,951	0
2047	357,939	272	234	10,934	0	0	0	90,574	53,598	0	4,951	0
2048	359,796	272	234	10,986	0	0	0	91,053	53,119	0	4,951	0
2049	361,619	272	234	11,041	0	0	0	91,440	52,732	0	4,951	0
2050	363,408	272	234	11,086	0	0	0	91,868	52,304	0	4,951	0
2051	365,163	272	234	11,135	0	0	0	92,284	51,888	0	4,951	0
2052	366,885	272	234	11,183	0	0	0	92,736	46,777	0	4,951	0
2053	368,573	272	234	11,235	0	0	0	93,087	46,427	0	4,951	0
2054	370,381	272	234	11,276	0	0	0	93,504	36,008	0	4,951	0
2055	372,385	272	234	11,323	0	0	0	93,956	13,051	0	4,951	0
2056	374,348	272	234	11,375	0	0	0	94,474	31	0	4,951	0
2057	376,268	272	234	11,434	0	0	0	94,874	34,637	0	4,951	0
2058	378,146	272	234	11,481	0	0	0	95,325	34,187	0	4,951	0
2059	379,981	272	234	11,533	0	0	0	95,760	33,752	0	4,951	0
2060	381,775	272	234	11,583	0	0	0	96,241	33,271	0	4,951	0

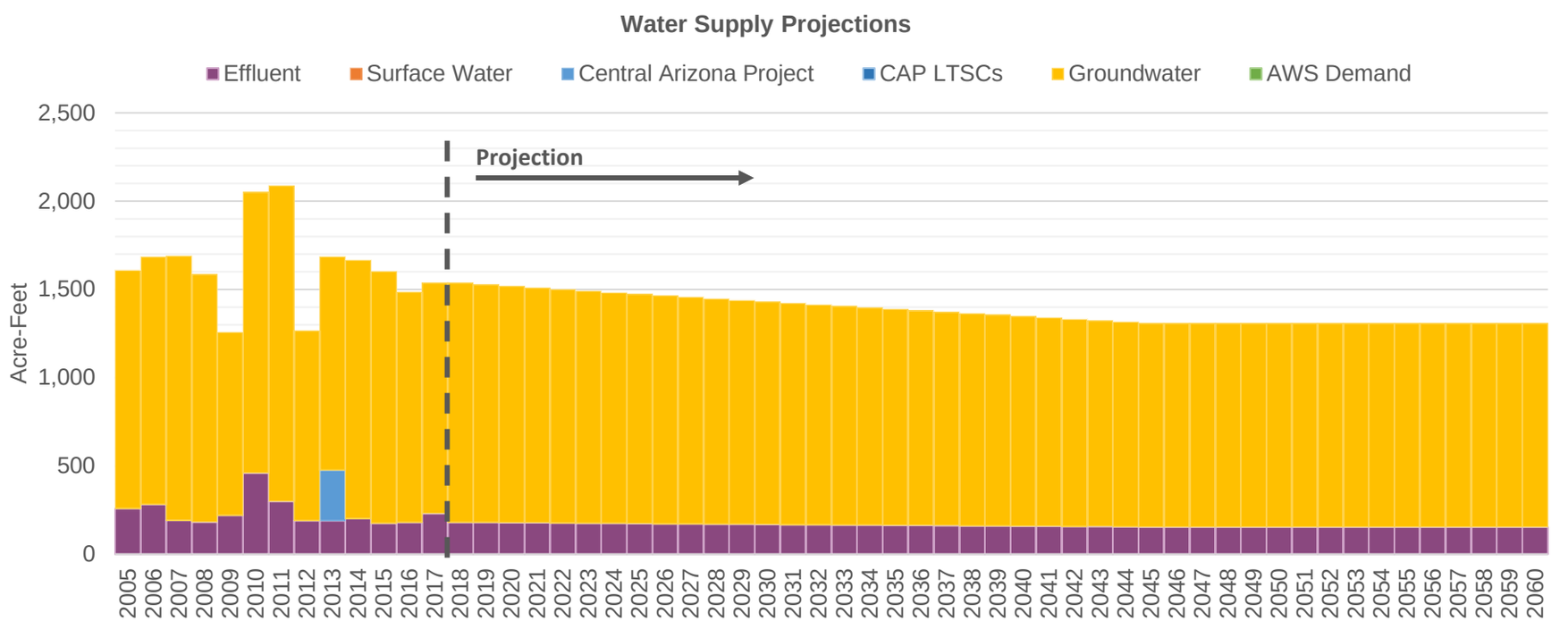
UniversityofAZ

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

UniversityofAZ

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

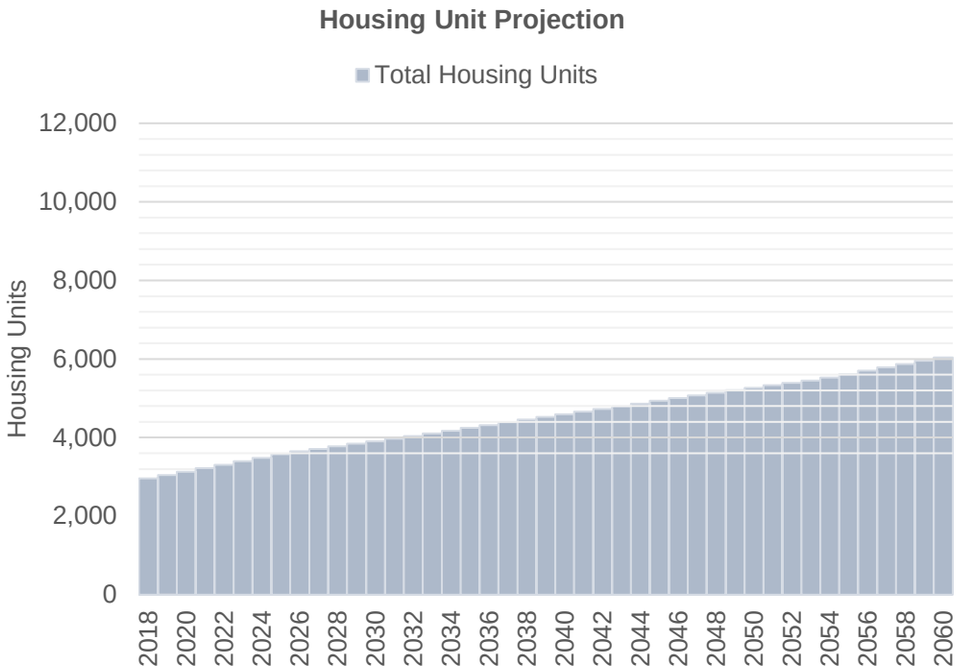
Water Supply Projections (Acre-Feet)

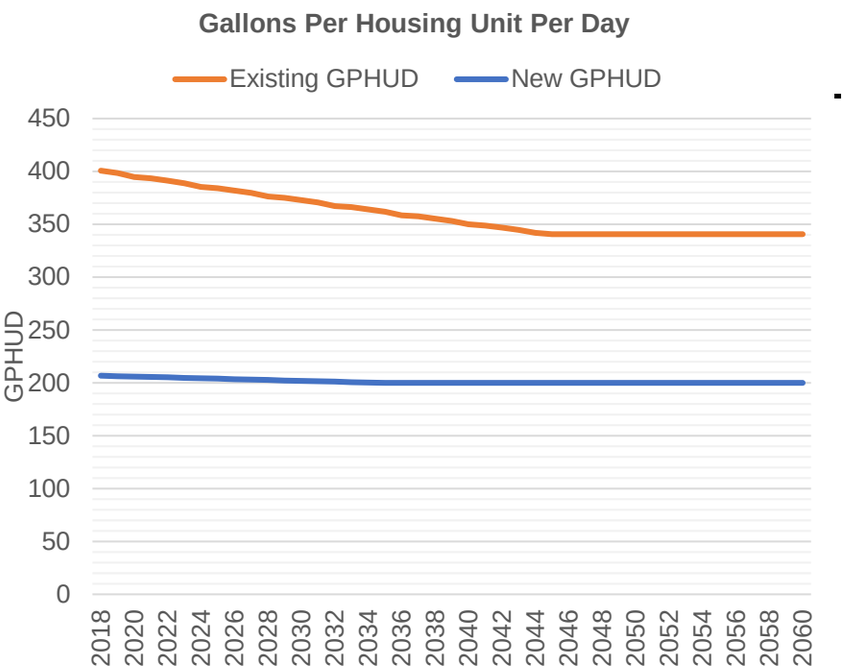
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	71	19,446	500	180	0	0	0	0	0	0	1,356	0
2019	71	19,329	499	180	0	0	0	0	0	0	1,347	0
2020	71	19,161	498	179	0	0	0	0	0	0	1,339	0
2021	71	19,098	497	178	0	0	0	0	0	0	1,331	0
2022	71	18,983	496	177	0	0	0	0	0	0	1,323	0
2023	71	18,870	495	176	0	0	0	0	0	0	1,315	0
2024	71	18,705	494	175	0	0	0	0	0	0	1,307	0
2025	71	18,644	493	174	0	0	0	0	0	0	1,299	0
2026	72	18,532	492	173	0	0	0	0	0	0	1,292	0
2027	72	18,421	491	172	0	0	0	0	0	0	1,284	0
2028	72	18,260	490	171	0	0	0	0	0	0	1,277	0
2029	72	18,200	489	170	0	0	0	0	0	0	1,269	0
2030	72	18,091	488	169	0	0	0	0	0	0	1,261	0
2031	72	17,983	487	168	0	0	0	0	0	0	1,254	0
2032	72	17,826	486	167	0	0	0	0	0	0	1,246	0
2033	73	17,767	485	166	0	0	0	0	0	0	1,239	0
2034	73	17,661	484	165	0	0	0	0	0	0	1,232	0
2035	73	17,555	483	164	0	0	0	0	0	0	1,224	0
2036	73	17,402	482	163	0	0	0	0	0	0	1,217	0
2037	73	17,345	481	162	0	0	0	0	0	0	1,210	0
2038	74	17,241	480	161	0	0	0	0	0	0	1,203	0
2039	74	17,137	479	160	0	0	0	0	0	0	1,196	0
2040	74	16,988	478	159	0	0	0	0	0	0	1,189	0
2041	74	16,932	477	158	0	0	0	0	0	0	1,181	0
2042	74	16,831	477	157	0	0	0	0	0	0	1,174	0
2043	74	16,730	476	156	0	0	0	0	0	0	1,167	0
2044	74	16,584	475	155	0	0	0	0	0	0	1,160	0
2045	75	16,530	475	154	0	0	0	0	0	0	1,154	0
2046	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2047	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2048	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2049	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2050	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2051	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2052	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2053	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2054	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2055	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2056	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2057	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2058	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2059	75	16,529	475	153	0	0	0	0	0	0	1,155	0
2060	75	16,529	475	153	0	0	0	0	0	0	1,155	0

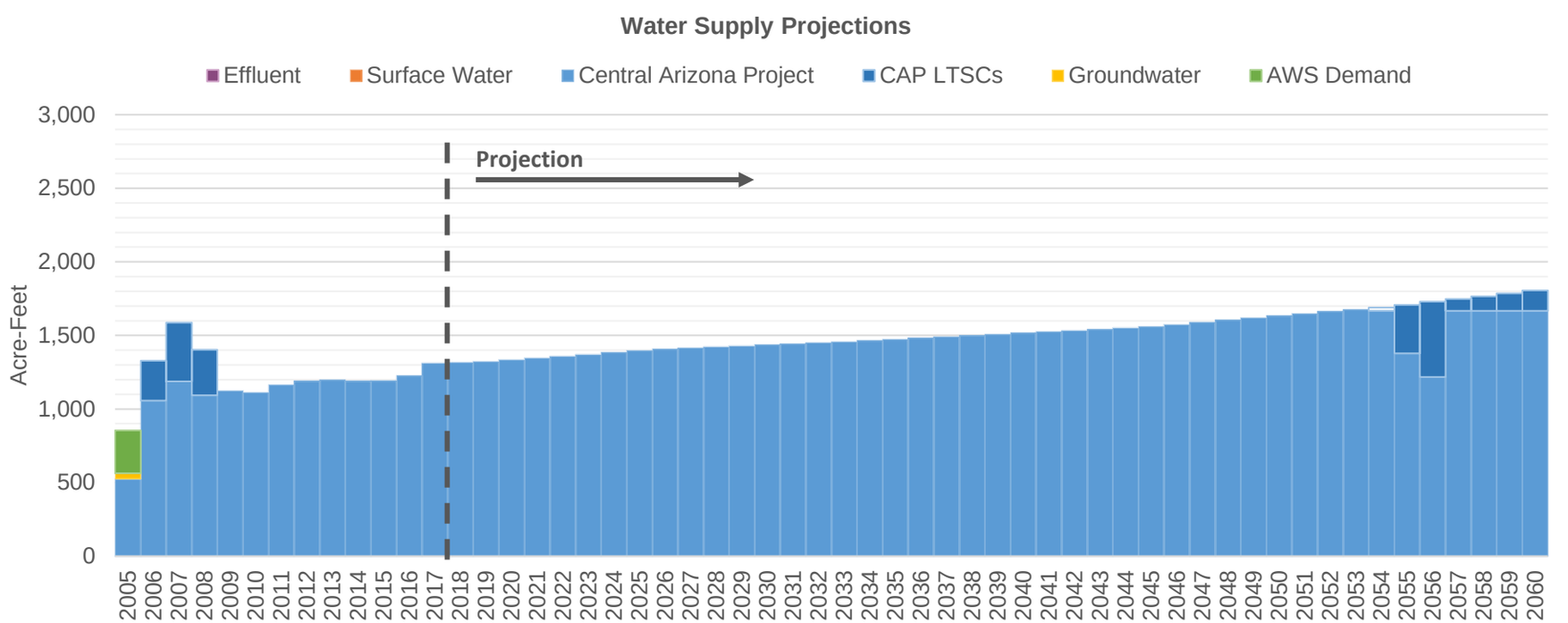
VailWC

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

VailWC

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions

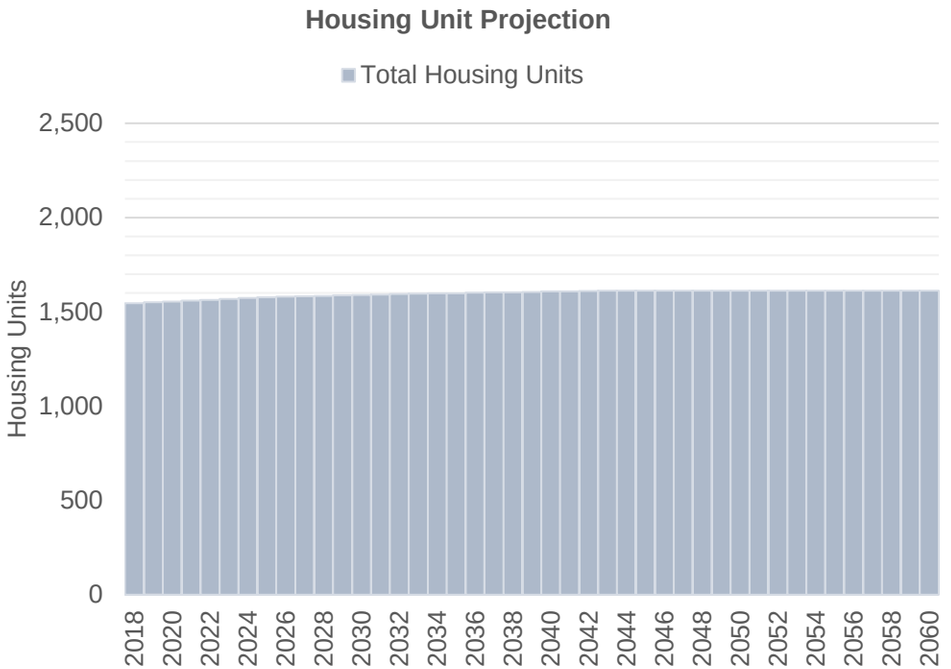
Water Supply Projections (Acre-Feet)

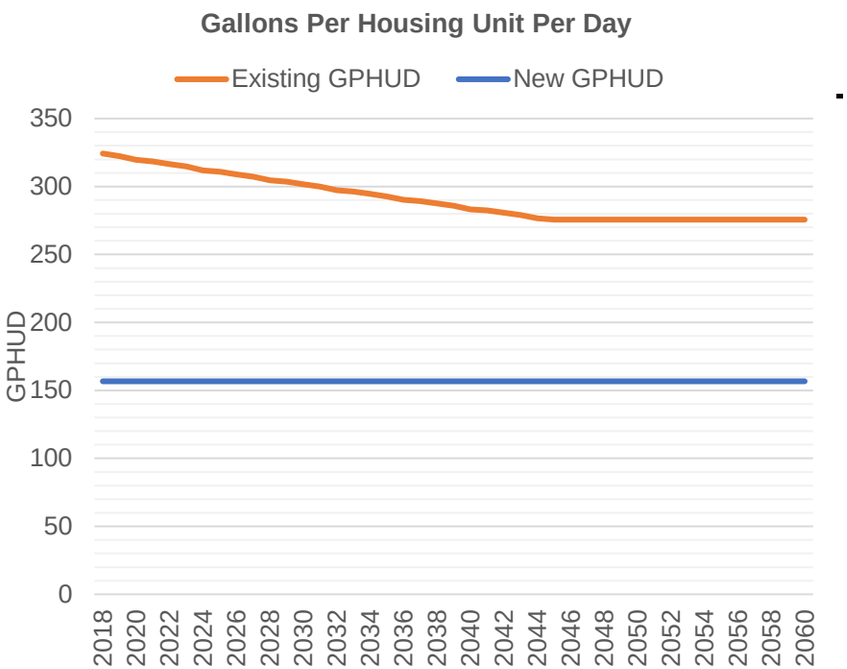
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,960	401	207	0	0	0	0	1,316	541	0	0	0
2019	3,046	398	206	0	0	0	0	1,322	535	0	0	0
2020	3,132	395	206	0	0	0	0	1,335	522	0	0	0
2021	3,220	394	206	0	0	0	0	1,347	510	0	0	0
2022	3,307	391	205	0	0	0	0	1,359	498	0	0	0
2023	3,396	389	205	0	0	0	0	1,371	486	0	0	0
2024	3,484	385	204	0	0	0	0	1,384	473	0	0	0
2025	3,573	384	204	0	0	0	0	1,396	461	0	0	0
2026	3,647	382	204	0	0	0	0	1,407	450	0	0	0
2027	3,713	380	203	0	0	0	0	1,415	442	0	0	0
2028	3,779	376	203	0	0	0	0	1,423	434	0	0	0
2029	3,843	375	202	0	0	0	0	1,429	428	0	0	0
2030	3,906	373	202	0	0	0	0	1,436	421	0	0	0
2031	3,973	371	201	0	0	0	0	1,443	414	0	0	0
2032	4.038	367	201	0	0	0	0	1.450	407	0	0	0
2033	4,103	366	201	0	0	0	0	1,457	400	0	0	0
2034	4,171	364	200	0	0	0	0	1,464	393	0	0	0
2035	4,244	362	200	0	0	0	0	1,472	385	0	0	0
2036	4,316	359	200	0	0	0	0	1,482	375	0	0	0
2037	4,387	357	200	0	0	0	0	1,490	367	0	0	0
2038	4,457	355	200	0	0	0	0	1,499	358	0	0	0
2039	4,526	353	200	0	0	0	0	1,507	22	0	0	0
2040	4,594	350	200	0	0	0	0	1,517	328	0	0	0
2041	4,661	349	200	0	0	0	0	1,524	333	0	0	0
2042	4,727	347	200	0	0	0	0	1,532	325	0	0	0
2043	4,795	345	200	0	0	0	0	1,540	317	0	0	0
2044	4,866	342	200	0	0	0	0	1,550	307	0	0	0
2045	4,935	341	200	0	0	0	0	1,558	299	0	0	0
2046	5,004	341	200	0	0	0	0	1,574	283	0	0	0
2047	5,071	341	200	0	0	0	0	1,589	268	0	0	0
2048	5,138	341	200	0	0	0	0	1,605	252	0	0	0
2049	5,203	341	200	0	0	0	0	1,619	238	0	0	0
2050	5,267	341	200	0	0	0	0	1,633	224	0	0	0
2051	5,329	341	200	0	0	0	0	1,647	210	0	0	0
2052	5,391	341	200	0	0	0	0	1,663	134	0	0	0
2053	5,451	341	200	0	0	0	0	1,675	122	0	0	0
2054	5,523	341	200	0	0	0	0	1,668	0	21	0	0
2055	5,613	341	200	0	0	0	0	1,378	0	329	0	0
2056	5,702	341	200	0	0	0	0	1,217	0	512	0	0
2057	5,788	341	200	0	0	0	0	1,668	0	79	0	0
2058	5,873	341	200	0	0	0	0	1,668	0	98	0	0
2059	5,955	341	200	0	0	0	0	1,668	0	117	0	0
2060	6,036	341	200	0	0	0	0	1,668	0	137	0	0

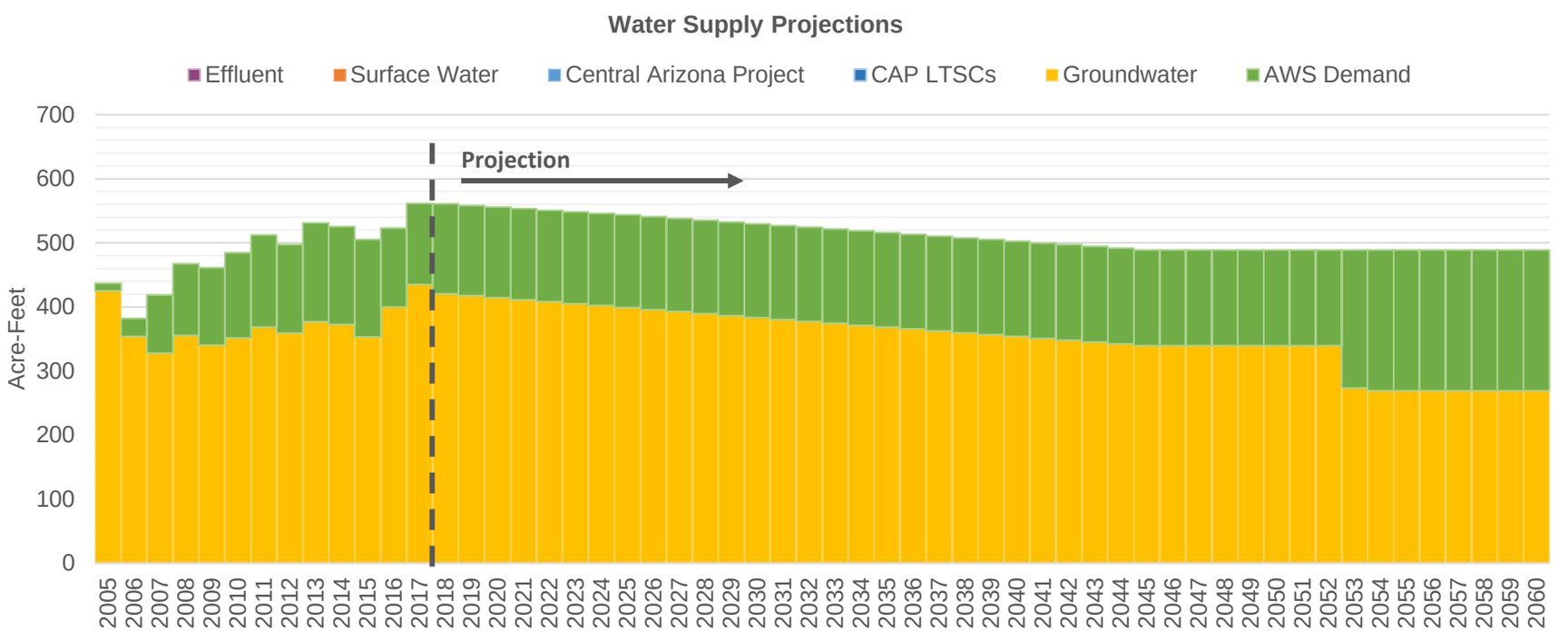
VoyagerWC

Central Arizona Project Service Area Model

B. Slow, Compact, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

VoyagerWC

B. Slow, Compact, Dry Climate [LSCRBS]

7/6/20 12:20 PM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,546	324	157	0	0	0	0	0	0	0	421	141
2019	1,551	322	157	0	0	0	0	0	0	0	418	141
2020	1,555	320	157	0	0	0	0	0	0	0	414	141
2021	1,560	318	157	0	0	0	0	0	0	0	411	142
2022	1,564	317	157	0	0	0	0	0	0	0	408	143
2023	1,569	315	157	0	0	0	0	0	0	0	405	143
2024	1,574	312	157	0	0	0	0	0	0	0	402	144
2025	1,578	311	157	0	0	0	0	0	0	0	399	145
2026	1,581	309	157	0	0	0	0	0	0	0	396	145
2027	1,583	307	157	0	0	0	0	0	0	0	393	145
2028	1,585	305	157	0	0	0	0	0	0	0	390	146
2029	1,587	304	157	0	0	0	0	0	0	0	386	146
2030	1,589	302	157	0	0	0	0	0	0	0	383	146
2031	1,592	300	157	0	0	0	0	0	0	0	380	146
2032	1,594	297	157	0	0	0	0	0	0	0	377	147
2033	1,596	296	157	0	0	0	0	0	0	0	374	147
2034	1,598	295	157	0	0	0	0	0	0	0	371	147
2035	1,599	293	157	0	0	0	0	0	0	0	368	148
2036	1,601	290	157	0	0	0	0	0	0	0	365	148
2037	1,603	289	157	0	0	0	0	0	0	0	362	148
2038	1,604	288	157	0	0	0	0	0	0	0	359	148
2039	1,606	286	157	0	0	0	0	0	0	0	357	148
2040	1,608	283	157	0	0	0	0	0	0	0	354	149
2041	1,609	282	157	0	0	0	0	0	0	0	351	149
2042	1,611	281	157	0	0	0	0	0	0	0	348	149
2043	1,612	279	157	0	0	0	0	0	0	0	345	149
2044	1,612	277	157	0	0	0	0	0	0	0	342	149
2045	1,612	276	157	0	0	0	0	0	0	0	339	149
2046	1,612	276	157	0	0	0	0	0	0	0	339	149
2047	1,612	276	157	0	0	0	0	0	0	0	339	149
2048	1,612	276	157	0	0	0	0	0	0	0	339	149
2049	1,612	276	157	0	0	0	0	0	0	0	339	149
2050	1,612	276	157	0	0	0	0	0	0	0	339	149
2051	1,612	276	157	0	0	0	0	0	0	0	339	149
2052	1,612	276	157	0	0	0	0	0	0	0	339	149
2053	1,612	276	157	0	0	0	0	0	0	0	273	215
2054	1,612	276	157	0	0	0	0	0	0	0	269	220
2055	1,612	276	157	0	0	0	0	0	0	0	269	220
2056	1,612	276	157	0	0	0	0	0	0	0	269	220
2057	1,612	276	157	0	0	0	0	0	0	0	269	220
2058	1,612	276	157	0	0	0	0	0	0	0	269	220
2059	1,612	276	157	0	0	0	0	0	0	0	269	220
2060	1,612	276	157	0	0	0	0	0	0	0	269	220

CAP:SAM Supply and Demand Projections by Water Provider

Scenario C

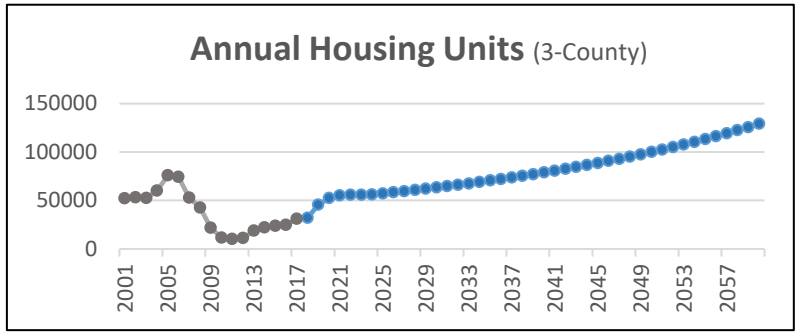
Climate: Best Case
Growth Rate: Rapid
Growth Pattern: Outward
Relative Risk: High

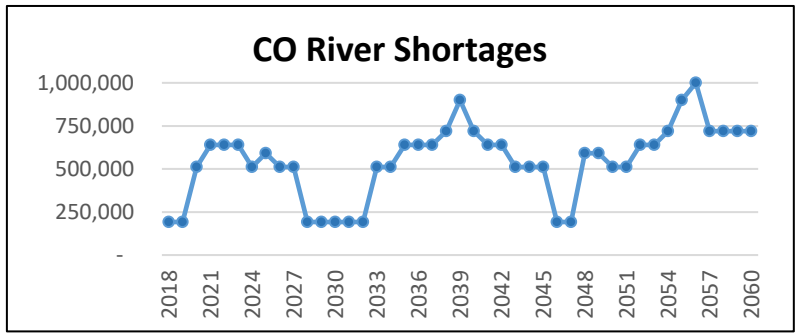
C. Rapid, Outward, Dry Climate [LSCRBS]

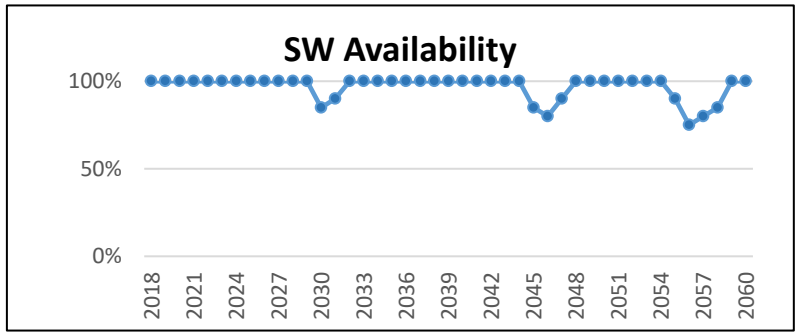
Run Date: 7/7/2020 **Filename:** CAPServiceArea_v3.50_LSCRBS_AC

Growth rate based on High growth series form AZ Dept. of Administration, and outward growth pattern. "Dry" = "Best Case

Allow Shortages	Yes	
Select CRSS Array	3	*3=Synthetic*
Use Specific Trace	Yes	
Selected Trace	2	*1=Moderate; 2=Deep; 3=Slight*
AWBA Max M&I	20%	
Surface Water Scenario	2	*1=No Reduction; 2=Occational; 3=Frequent*
Use CAP Buildup	Yes	
CAP Buildup Scenario	2	*1=2035; 2=2045*
HU Growth Pattern	3	*1=Baseline*
HU Forecast	2	*1=Use Curve; 2=Eller Forecast*
HU Curve	1	
HU Growth Start Rate	2%	
HU Ordinary Level	56,000	
HU Rate @ 50 yrs	3%	
GPHUD Change Existing	-0.6%	*per year*
GPHUD Max Change Existing	-15%	
GPHUD Min Existing	180	
GPHUD Scenario New	1	
GPHUD Change New	-0.2%	*per year*
Ag Climate Adjustment	0.1	
Ag Efficiency Increase	0.1%	*per year*
Ag Efficiency Goal	80%	
Ag Replace Crop CU	2.66	
Ag Intensity Scenario	2	
Ag Develop on Crops	60%	*Perecent of max on active Ag*
Ag Acres Replace Percent	0%	
Ag Replace Crop Year	2025	



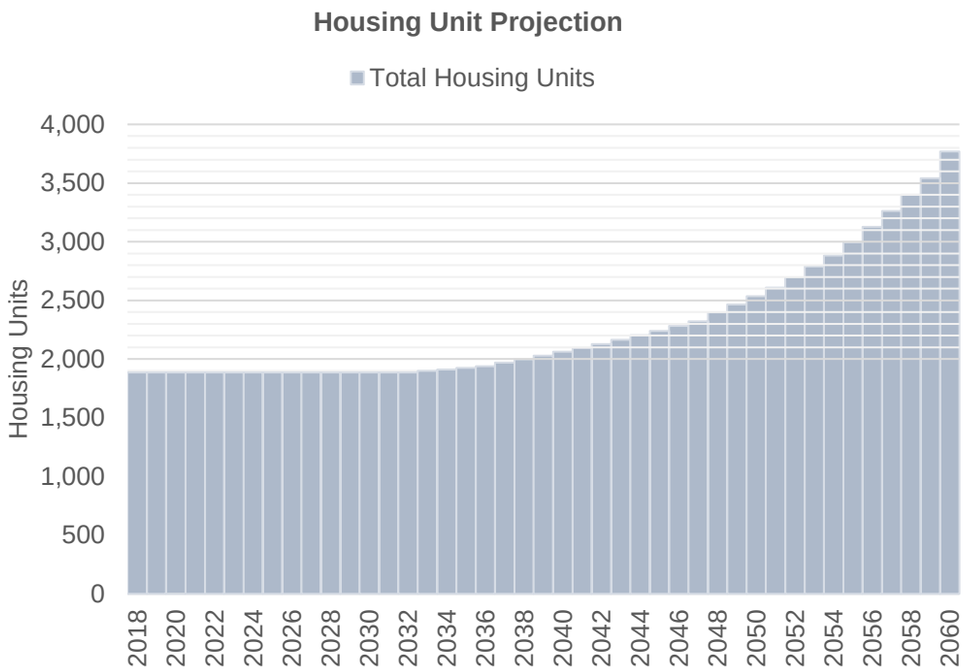


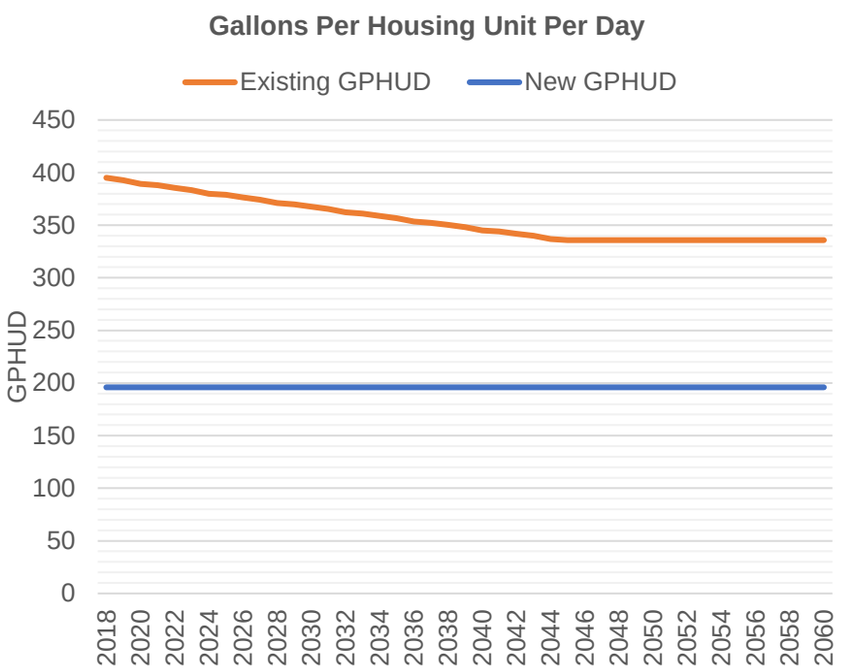


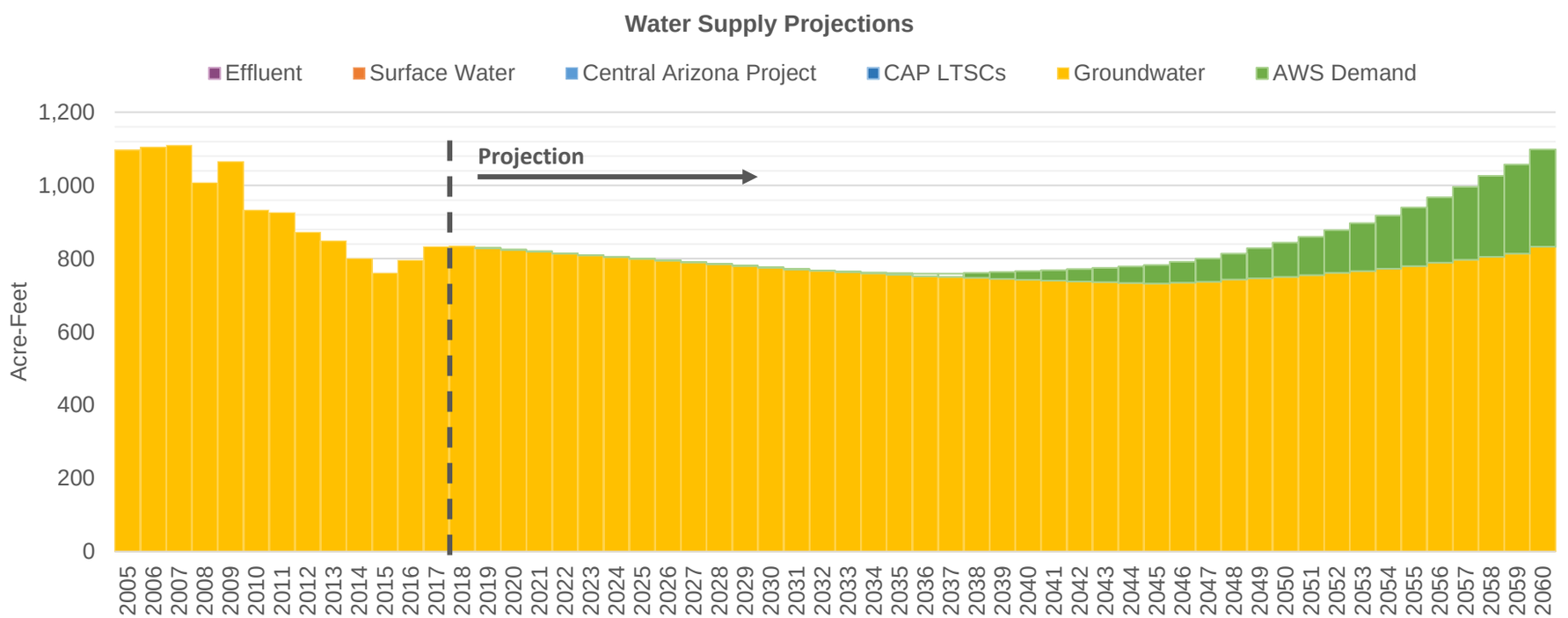
Central Arizona Project Service Area Model

AvraWaterCoop

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

AvraWaterCoop

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

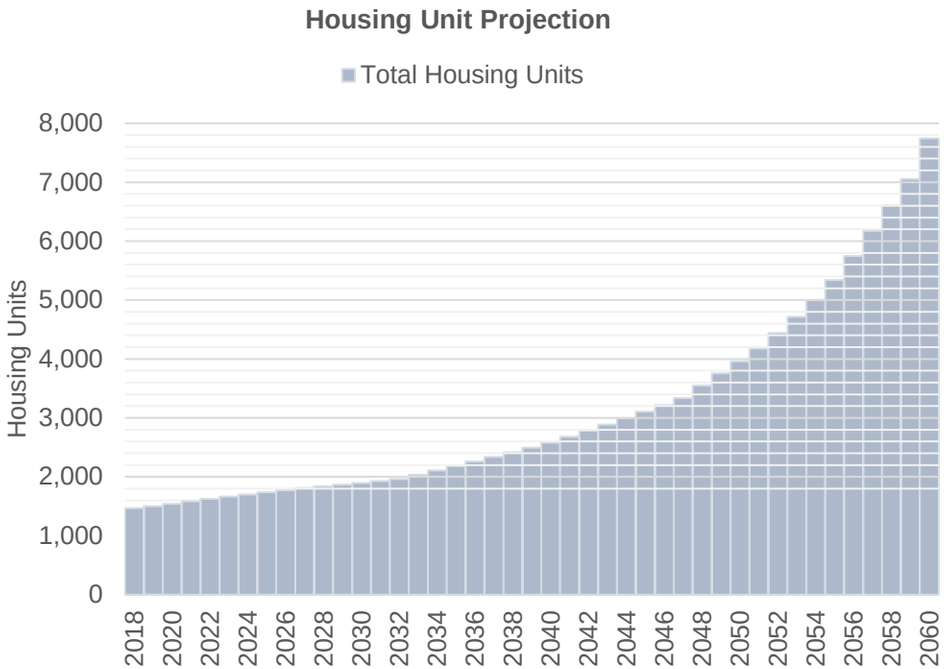
Water Supply Projections (Acre-Feet)

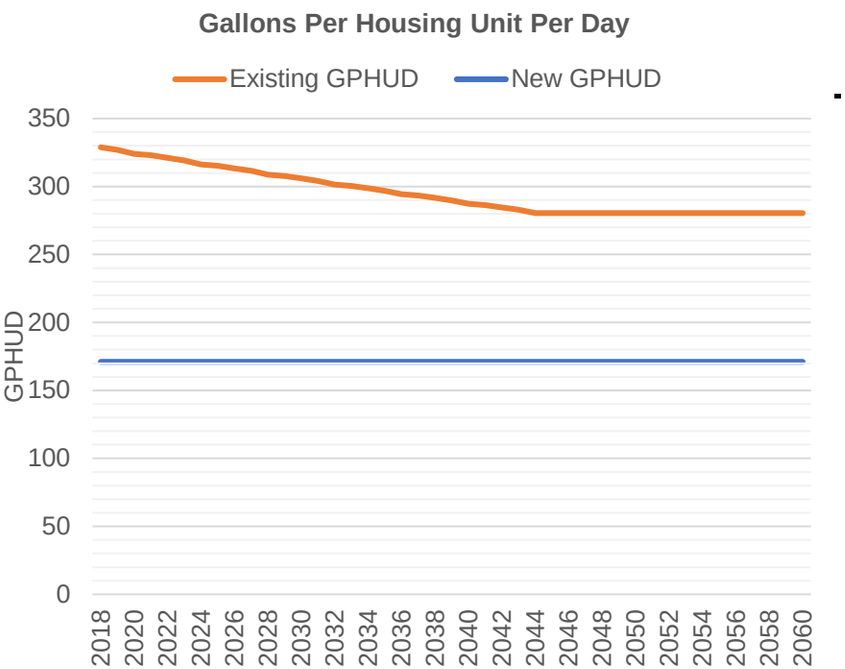
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,885	395	196	0	0	0	0	0	0	0	834	0
2019	1,885	393	196	0	0	0	0	0	0	0	829	0
2020	1,885	389	196	0	0	0	0	0	0	0	824	0
2021	1,885	388	196	0	0	0	0	0	0	0	819	0
2022	1,885	386	196	0	0	0	0	0	0	0	814	0
2023	1,885	383	196	0	0	0	0	0	0	0	809	0
2024	1,885	380	196	0	0	0	0	0	0	0	804	0
2025	1,885	379	196	0	0	0	0	0	0	0	800	0
2026	1,885	376	196	0	0	0	0	0	0	0	795	0
2027	1,885	374	196	0	0	0	0	0	0	0	790	0
2028	1,885	371	196	0	0	0	0	0	0	0	785	0
2029	1,885	370	196	0	0	0	0	0	0	0	781	0
2030	1,885	368	196	0	0	0	0	0	0	0	776	0
2031	1,885	365	196	0	0	0	0	0	0	0	771	0
2032	1,886	362	196	0	0	0	0	0	0	0	767	0
2033	1,899	361	196	0	0	0	0	0	0	0	763	0
2034	1,912	359	196	0	0	0	0	0	0	0	760	2
2035	1,925	357	196	0	0	0	0	0	0	0	756	4
2036	1,939	354	196	0	0	0	0	0	0	0	752	7
2037	1,969	352	196	0	0	0	0	0	0	0	750	9
2038	1,999	350	196	0	0	0	0	0	0	0	748	14
2039	2,030	348	196	0	0	0	0	0	0	0	745	18
2040	2,062	345	196	0	0	0	0	0	0	0	743	23
2041	2,095	344	196	0	0	0	0	0	0	0	740	29
2042	2,129	342	196	0	0	0	0	0	0	0	738	34
2043	2,165	340	196	0	0	0	0	0	0	0	736	39
2044	2,203	337	196	0	0	0	0	0	0	0	734	45
2045	2,242	336	196	0	0	0	0	0	0	0	732	51
2046	2,282	336	196	0	0	0	0	0	0	0	734	58
2047	2,323	336	196	0	0	0	0	0	0	0	737	64
2048	2,397	336	196	0	0	0	0	0	0	0	743	71
2049	2,467	336	196	0	0	0	0	0	0	0	747	82
2050	2,536	336	196	0	0	0	0	0	0	0	751	94
2051	2,609	336	196	0	0	0	0	0	0	0	755	105
2052	2,698	336	196	0	0	0	0	0	0	0	762	117
2053	2,789	336	196	0	0	0	0	0	0	0	767	131
2054	2,883	336	196	0	0	0	0	0	0	0	772	145
2055	2,994	336	196	0	0	0	0	0	0	0	780	160
2056	3,126	336	196	0	0	0	0	0	0	0	789	178
2057	3,261	336	196	0	0	0	0	0	0	0	797	199
2058	3,400	336	196	0	0	0	0	0	0	0	805	221
2059	3,542	336	196	0	0	0	0	0	0	0	814	243
2060	3,769	336	196	0	0	0	0	0	0	0	833	266

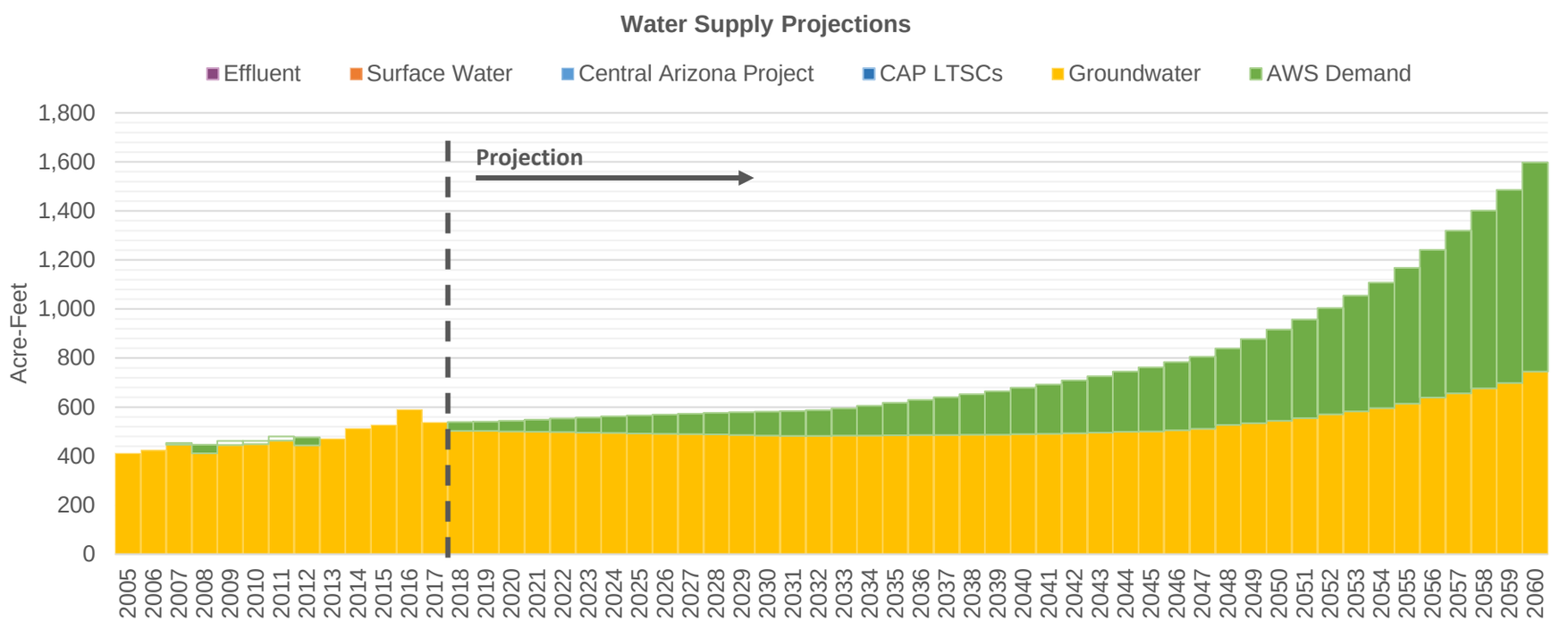
AZWCOracle

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

AZWCOracle

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

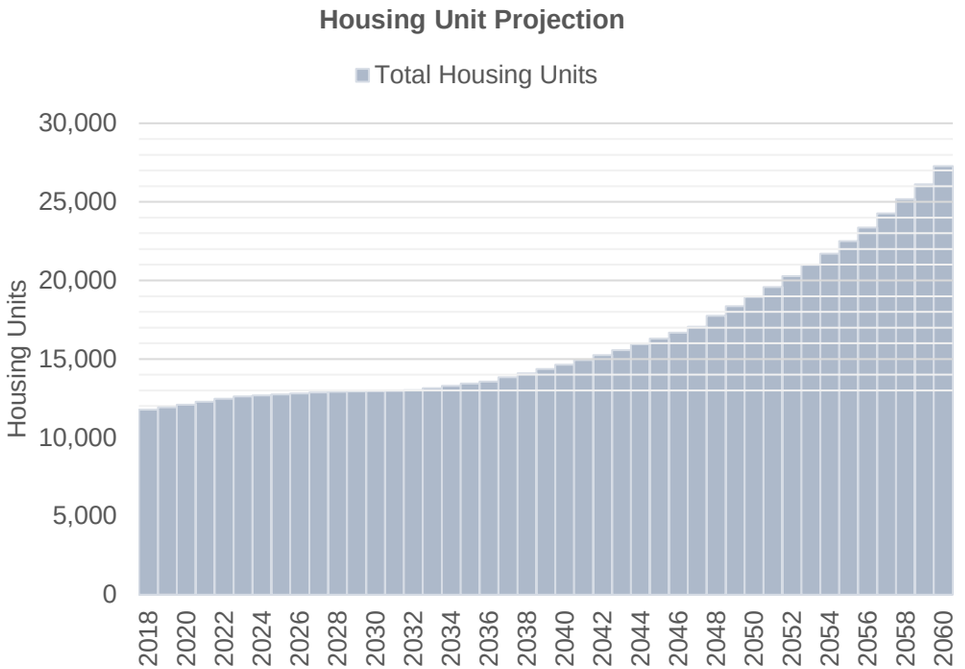
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

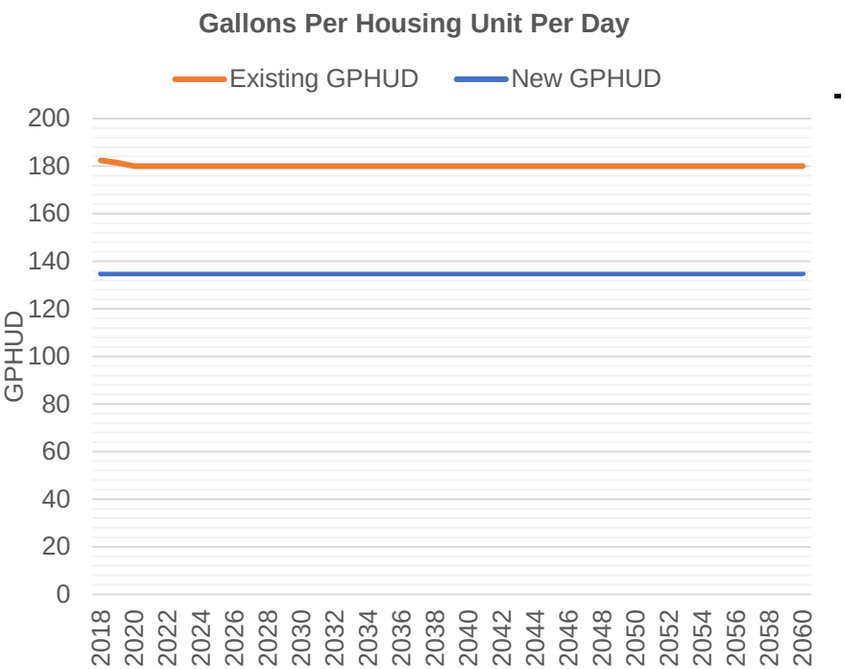
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,471	329	171	0	0	0	0	0	0	0	503	36
2019	1,505	327	171	0	0	0	0	0	0	0	503	37
2020	1,544	324	171	0	0	0	0	0	0	0	501	43
2021	1,585	323	171	0	0	0	0	0	0	0	499	49
2022	1,627	321	171	0	0	0	0	0	0	0	498	55
2023	1,666	319	171	0	0	0	0	0	0	0	496	62
2024	1,701	316	171	0	0	0	0	0	0	0	494	67
2025	1,737	315	171	0	0	0	0	0	0	0	493	73
2026	1,773	313	171	0	0	0	0	0	0	0	491	78
2027	1,810	312	171	0	0	0	0	0	0	0	490	83
2028	1,842	309	171	0	0	0	0	0	0	0	488	89
2029	1,870	308	171	0	0	0	0	0	0	0	486	93
2030	1,898	306	171	0	0	0	0	0	0	0	484	97
2031	1,928	304	171	0	0	0	0	0	0	0	483	101
2032	1.964	301	171	0	0	0	0	0	0	0	482	106
2033	2,036	300	171	0	0	0	0	0	0	0	484	111
2034	2,109	299	171	0	0	0	0	0	0	0	484	122
2035	2,184	297	171	0	0	0	0	0	0	0	485	132
2036	2,260	294	171	0	0	0	0	0	0	0	486	143
2037	2,337	293	171	0	0	0	0	0	0	0	486	154
2038	2,415	292	171	0	0	0	0	0	0	0	487	165
2039	2,496	290	171	0	0	0	0	0	0	0	488	177
2040	2,581	287	171	0	0	0	0	0	0	0	490	189
2041	2,680	286	171	0	0	0	0	0	0	0	492	201
2042	2,782	285	171	0	0	0	0	0	0	0	494	215
2043	2,888	283	171	0	0	0	0	0	0	0	496	230
2044	2,996	280	171	0	0	0	0	0	0	0	499	246
2045	3,107	280	171	0	0	0	0	0	0	0	501	262
2046	3,221	280	171	0	0	0	0	0	0	0	506	278
2047	3,337	280	171	0	0	0	0	0	0	0	511	294
2048	3,552	280	171	0	0	0	0	0	0	0	527	311
2049	3,757	280	171	0	0	0	0	0	0	0	535	343
2050	3,959	280	171	0	0	0	0	0	0	0	544	373
2051	4,176	280	171	0	0	0	0	0	0	0	555	402
2052	4,443	280	171	0	0	0	0	0	0	0	571	434
2053	4,716	280	171	0	0	0	0	0	0	0	582	473
2054	4,997	280	171	0	0	0	0	0	0	0	595	512
2055	5,338	280	171	0	0	0	0	0	0	0	614	553
2056	5,750	280	171	0	0	0	0	0	0	0	639	603
2057	6,173	280	171	0	0	0	0	0	0	0	656	663
2058	6,607	280	171	0	0	0	0	0	0	0	677	725
2059	7,053	280	171	0	0	0	0	0	0	0	698	788
2060	7,747	280	171	0	0	0	0	0	0	0	745	853

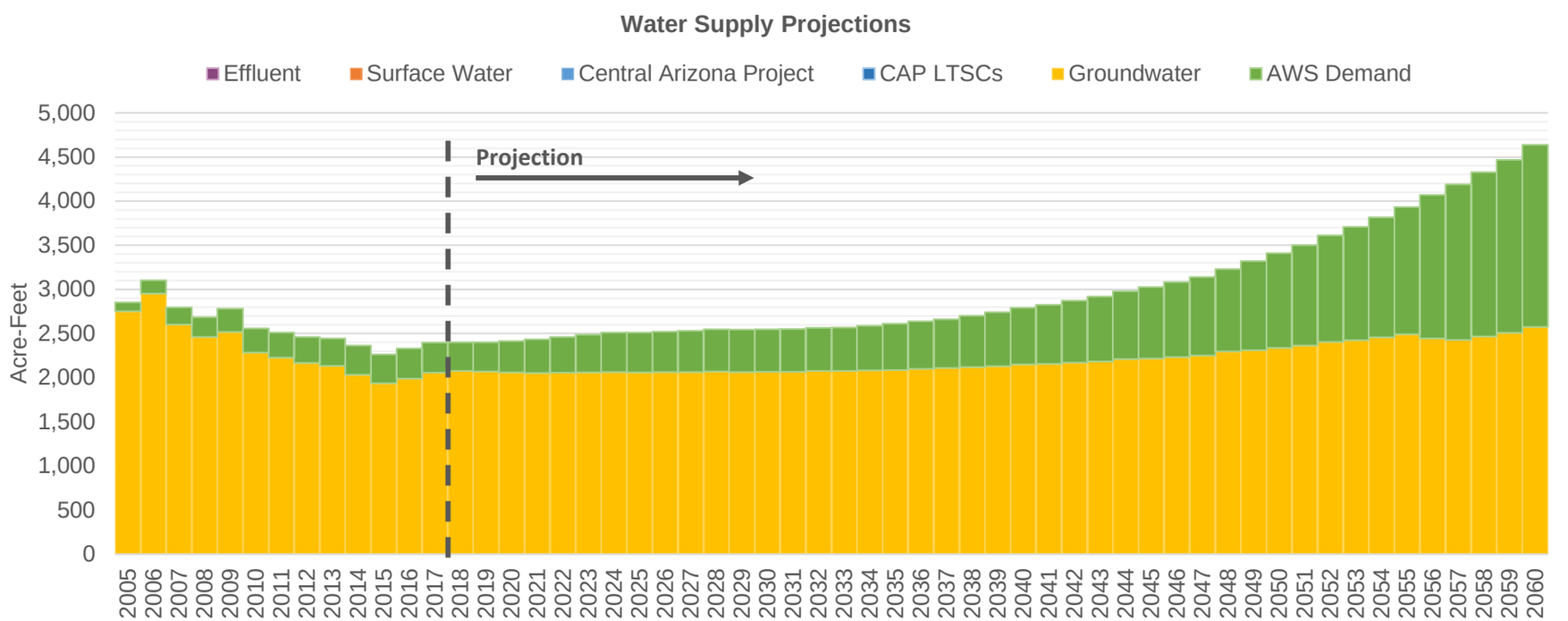
Central Arizona Project Service Area Model

CommWaterGreenVly

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

CommWaterGre

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

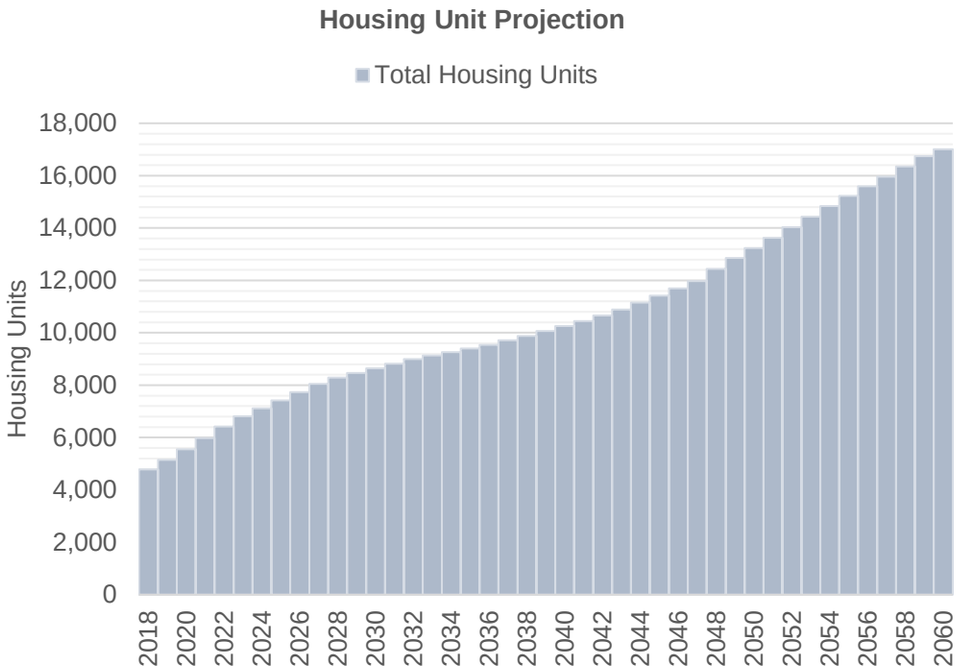
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

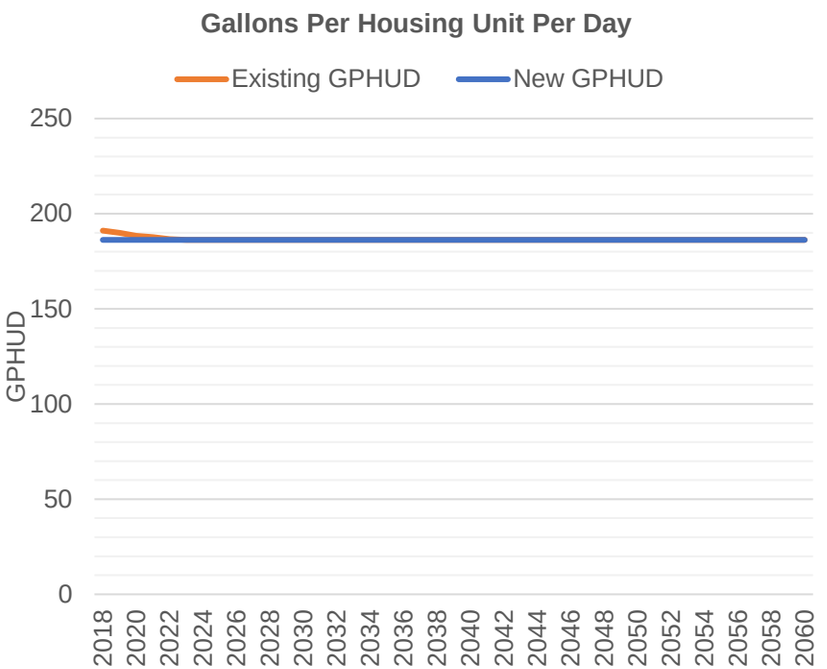
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	11,773	182	135	0	0	0	0	0	0	0	2,078	322
2019	11,925	181	135	0	0	0	0	0	0	0	2,070	330
2020	12,101	180	135	0	0	0	0	0	0	0	2,059	355
2021	12,285	180	135	0	0	0	0	0	0	0	2,053	382
2022	12,472	180	135	0	0	0	0	0	0	0	2,058	405
2023	12,618	180	135	0	0	0	0	0	0	0	2,060	428
2024	12,679	180	135	0	0	0	0	0	0	0	2,064	446
2025	12,741	180	135	0	0	0	0	0	0	0	2,059	454
2026	12,805	180	135	0	0	0	0	0	0	0	2,061	461
2027	12,869	180	135	0	0	0	0	0	0	0	2,064	468
2028	12,909	180	135	0	0	0	0	0	0	0	2,071	476
2029	12,932	180	135	0	0	0	0	0	0	0	2,064	480
2030	12,954	180	135	0	0	0	0	0	0	0	2,065	483
2031	12,977	180	135	0	0	0	0	0	0	0	2,066	485
2032	13.019	180	135	0	0	0	0	0	0	0	2.075	488
2033	13,152	180	135	0	0	0	0	0	0	0	2,077	493
2034	13,288	180	135	0	0	0	0	0	0	0	2,082	508
2035	13,428	180	135	0	0	0	0	0	0	0	2,088	523
2036	13,571	180	135	0	0	0	0	0	0	0	2,101	539
2037	13,829	180	135	0	0	0	0	0	0	0	2,108	554
2038	14,093	180	135	0	0	0	0	0	0	0	2,120	582
2039	14,363	180	135	0	0	0	0	0	0	0	2,131	611
2040	14,641	180	135	0	0	0	0	0	0	0	2,151	640
2041	14,936	180	135	0	0	0	0	0	0	0	2,156	671
2042	15,238	180	135	0	0	0	0	0	0	0	2,169	703
2043	15,572	180	135	0	0	0	0	0	0	0	2,185	736
2044	15,931	180	135	0	0	0	0	0	0	0	2,209	772
2045	16,299	180	135	0	0	0	0	0	0	0	2,216	811
2046	16,675	180	135	0	0	0	0	0	0	0	2,232	851
2047	17,061	180	135	0	0	0	0	0	0	0	2,249	892
2048	17,740	180	135	0	0	0	0	0	0	0	2,296	934
2049	18,358	180	135	0	0	0	0	0	0	0	2,312	1,008
2050	18,952	180	135	0	0	0	0	0	0	0	2,336	1,075
2051	19,574	180	135	0	0	0	0	0	0	0	2,363	1,140
2052	20,267	180	135	0	0	0	0	0	0	0	2,405	1,208
2053	20,977	180	135	0	0	0	0	0	0	0	2,425	1,283
2054	21,706	180	135	0	0	0	0	0	0	0	2,457	1,360
2055	22,501	180	135	0	0	0	0	0	0	0	2,492	1,440
2056	23,371	180	135	0	0	0	0	0	0	0	2,443	1,626
2057	24,263	180	135	0	0	0	0	0	0	0	2,427	1,764
2058	25,179	180	135	0	0	0	0	0	0	0	2,467	1,861
2059	26,120	180	135	0	0	0	0	0	0	0	2,507	1,961
2060	27,268	180	135	0	0	0	0	0	0	0	2,575	2,063

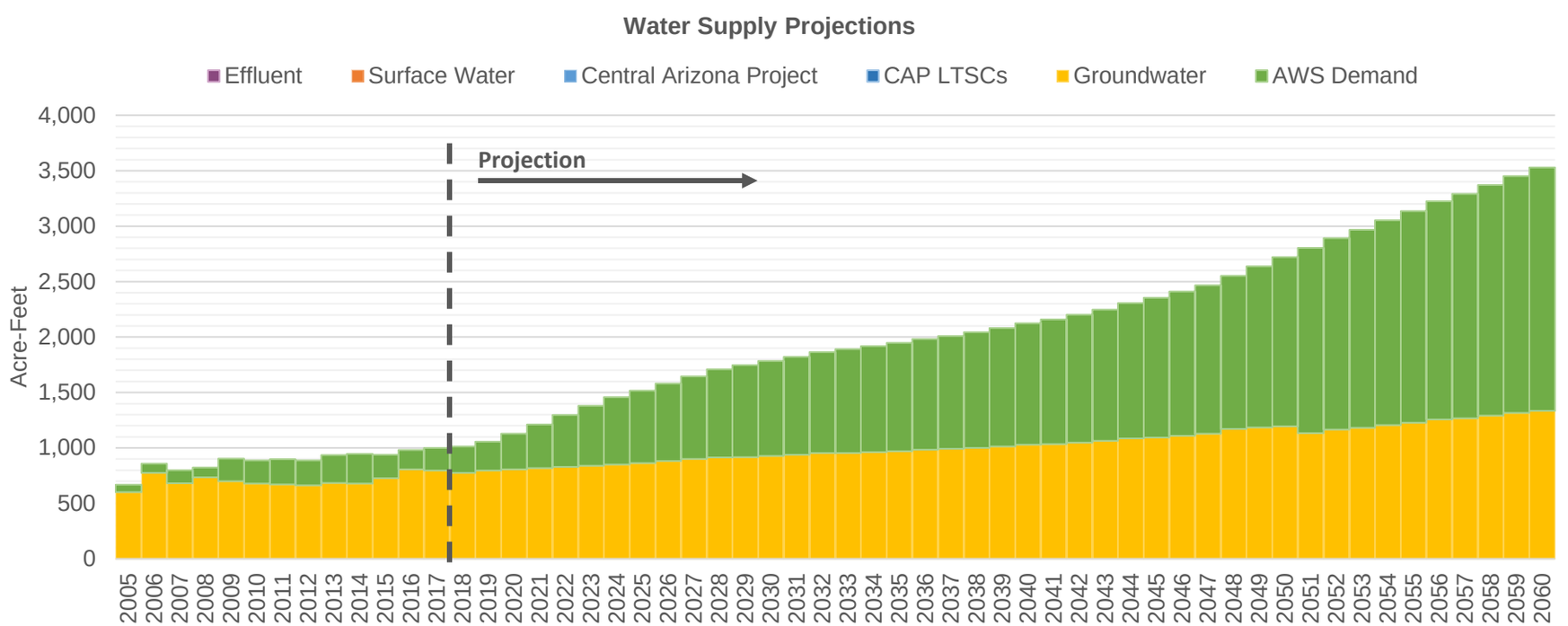
FarmersWC

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

FarmersWC

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

Water Supply Projections (Acre-Feet)

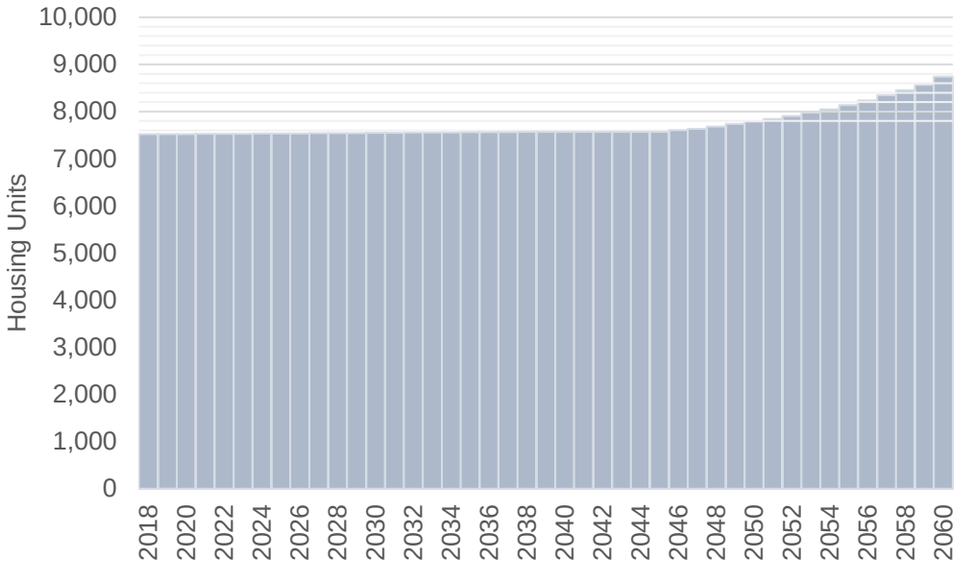
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,787	191	186	0	0	0	0	0	0	0	774	238
2019	5,143	190	186	0	0	0	0	0	0	0	797	258
2020	5,555	188	186	0	0	0	0	0	0	0	809	321
2021	5,986	188	186	0	0	0	0	0	0	0	817	394
2022	6,423	187	186	0	0	0	0	0	0	0	829	467
2023	6,816	186	186	0	0	0	0	0	0	0	840	541
2024	7,116	186	186	0	0	0	0	0	0	0	850	607
2025	7,421	186	186	0	0	0	0	0	0	0	864	653
2026	7,733	186	186	0	0	0	0	0	0	0	882	698
2027	8,051	186	186	0	0	0	0	0	0	0	901	745
2028	8,286	186	186	0	0	0	0	0	0	0	916	793
2029	8,461	186	186	0	0	0	0	0	0	0	918	828
2030	8,640	186	186	0	0	0	0	0	0	0	929	855
2031	8,823	186	186	0	0	0	0	0	0	0	940	882
2032	9.001	186	186	0	0	0	0	0	0	0	955	909
2033	9,131	186	186	0	0	0	0	0	0	0	955	936
2034	9,264	186	186	0	0	0	0	0	0	0	963	955
2035	9,400	186	186	0	0	0	0	0	0	0	971	975
2036	9,540	186	186	0	0	0	0	0	0	0	985	996
2037	9,711	186	186	0	0	0	0	0	0	0	991	1,017
2038	9,886	186	186	0	0	0	0	0	0	0	1,001	1,043
2039	10,066	186	186	0	0	0	0	0	0	0	1,012	1,069
2040	10,252	186	186	0	0	0	0	0	0	0	1,029	1,096
2041	10,453	186	186	0	0	0	0	0	0	0	1,036	1,124
2042	10,659	186	186	0	0	0	0	0	0	0	1,048	1,154
2043	10,895	186	186	0	0	0	0	0	0	0	1,063	1,185
2044	11,154	186	186	0	0	0	0	0	0	0	1,086	1,221
2045	11,420	186	186	0	0	0	0	0	0	0	1,095	1,260
2046	11,691	186	186	0	0	0	0	0	0	0	1,111	1,300
2047	11,970	186	186	0	0	0	0	0	0	0	1,128	1,340
2048	12,442	186	186	0	0	0	0	0	0	0	1,171	1,382
2049	12,852	186	186	0	0	0	0	0	0	0	1,185	1,453
2050	13,239	186	186	0	0	0	0	0	0	0	1,196	1,526
2051	13,633	186	186	0	0	0	0	0	0	0	1,134	1,669
2052	14,026	186	186	0	0	0	0	0	0	0	1,165	1,728
2053	14,429	186	186	0	0	0	0	0	0	0	1,181	1,787
2054	14,842	186	186	0	0	0	0	0	0	0	1,205	1,848
2055	15,233	186	186	0	0	0	0	0	0	0	1,227	1,910
2056	15,595	186	186	0	0	0	0	0	0	0	1,256	1,968
2057	15,966	186	186	0	0	0	0	0	0	0	1,269	2,023
2058	16,347	186	186	0	0	0	0	0	0	0	1,292	2,079
2059	16,739	186	186	0	0	0	0	0	0	0	1,315	2,136
2060	17,007	186	186	0	0	0	0	0	0	0	1,335	2,195

Central Arizona Project Service Area Model

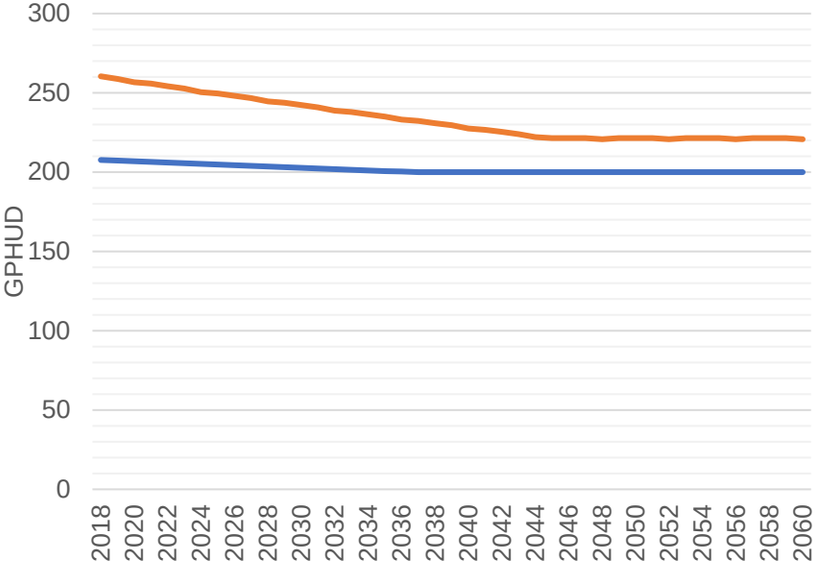
FWID

C. Rapid, Outward, Dry Climate [LSCRBS]

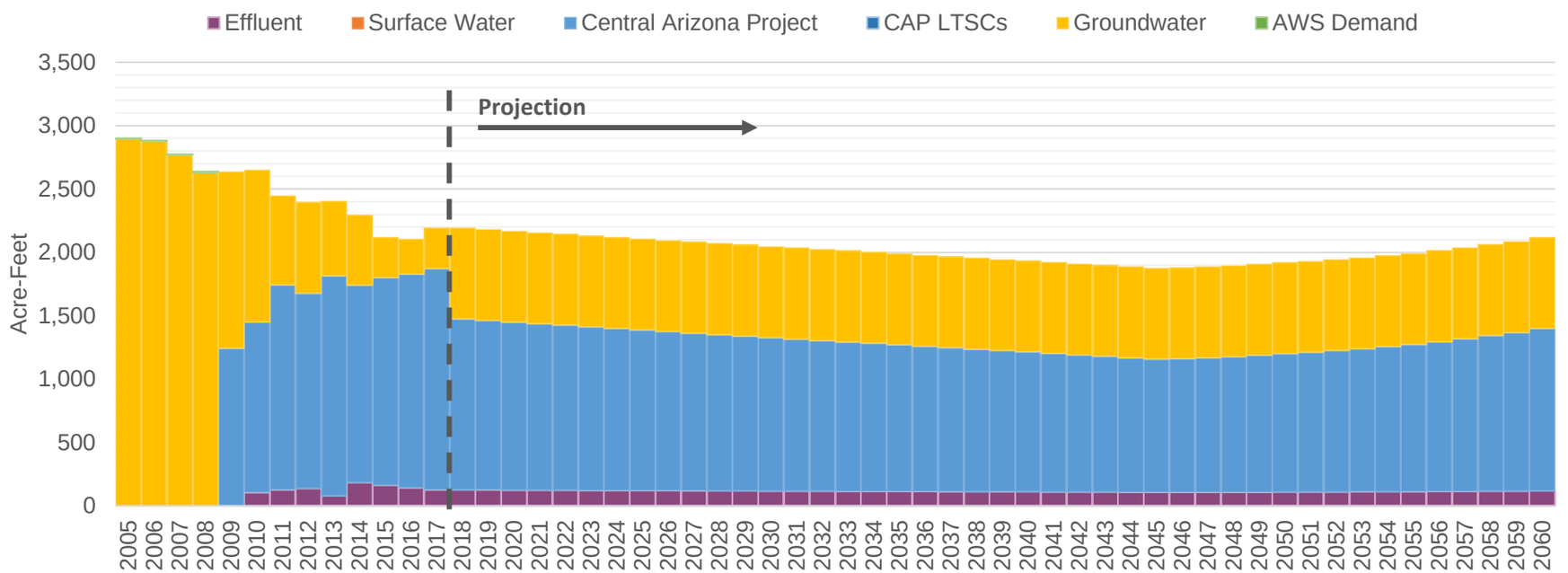
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

FWID

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

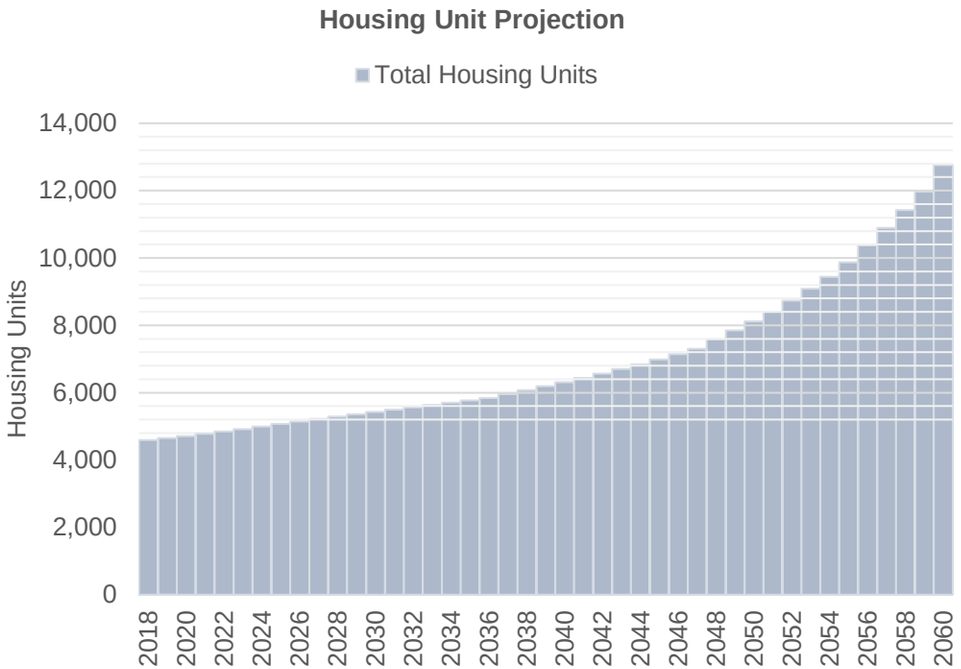
Water Supply Projections (Acre-Feet)

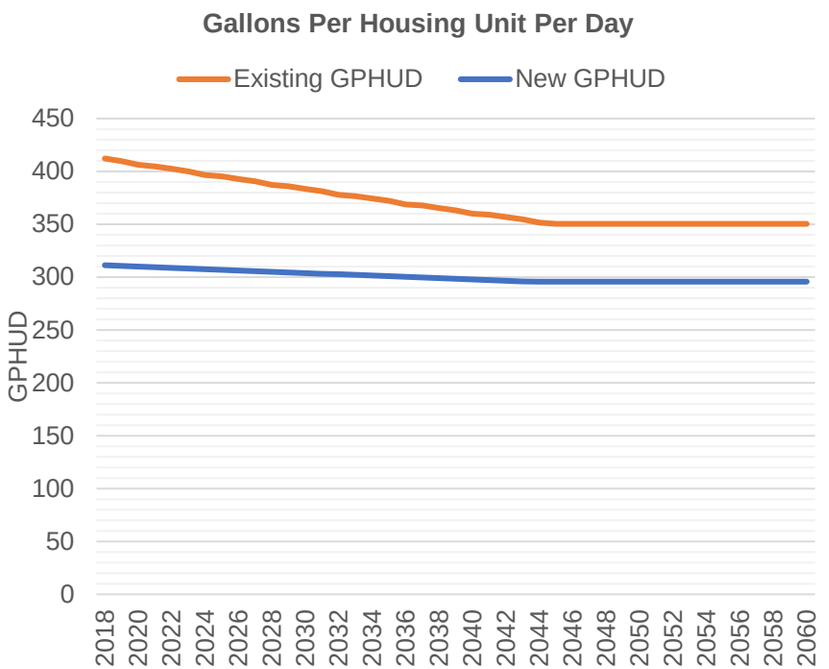
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	7,522	260	208	125	0	0	0	1,350	1,523	0	719	0
2019	7,523	259	207	125	0	0	0	1,337	1,536	0	719	0
2020	7,525	257	207	124	0	0	0	1,325	1,548	0	719	0
2021	7,528	256	206	124	0	0	0	1,313	1,560	0	719	0
2022	7,530	254	206	123	0	0	0	1,302	1,571	0	719	0
2023	7,532	253	206	122	0	0	0	1,290	1,583	0	719	0
2024	7,534	251	205	121	0	0	0	1,279	1,594	0	719	0
2025	7,537	250	205	121	0	0	0	1,267	1,606	0	719	0
2026	7,539	248	204	120	0	0	0	1,255	1,618	0	719	0
2027	7,541	247	204	119	0	0	0	1,244	1,629	0	719	0
2028	7,544	245	204	119	0	0	0	1,233	1,640	0	719	0
2029	7,546	244	203	118	0	0	0	1,222	1,651	0	719	0
2030	7,549	242	203	117	0	0	0	1,211	1,662	0	719	0
2031	7,551	241	202	117	0	0	0	1,200	1,673	0	719	0
2032	7,554	239	202	116	0	0	0	1,189	1,684	0	719	0
2033	7,556	238	202	115	0	0	0	1,178	1,695	0	719	0
2034	7,559	237	201	115	0	0	0	1,167	1,706	0	719	0
2035	7,561	235	201	114	0	0	0	1,156	1,717	0	719	0
2036	7,564	233	200	113	0	0	0	1,146	1,727	0	719	0
2037	7,567	232	200	113	0	0	0	1,135	1,738	0	719	0
2038	7,570	231	200	112	0	0	0	1,125	1,748	0	719	0
2039	7,573	230	200	111	0	0	0	1,115	1,252	0	719	0
2040	7,574	228	200	111	0	0	0	1,104	1,751	0	719	0
2041	7,574	227	200	110	0	0	0	1,093	1,780	0	719	0
2042	7,574	225	200	110	0	0	0	1,082	1,791	0	719	0
2043	7,574	224	200	109	0	0	0	1,071	1,802	0	719	0
2044	7,574	222	200	108	0	0	0	1,061	1,812	0	719	0
2045	7,574	221	200	108	0	0	0	1,050	1,823	0	719	0
2046	7,603	221	200	107	0	0	0	1,054	1,819	0	719	0
2047	7,632	221	200	107	0	0	0	1,060	1,813	0	719	0
2048	7,686	221	200	107	0	0	0	1,070	1,803	0	719	0
2049	7,738	221	200	108	0	0	0	1,080	1,793	0	719	0
2050	7,788	221	200	109	0	0	0	1,091	1,782	0	719	0
2051	7,843	221	200	109	0	0	0	1,103	1,770	0	719	0
2052	7,910	221	200	110	0	0	0	1,115	1,665	0	719	0
2053	7,979	221	200	111	0	0	0	1,130	1,651	0	719	0
2054	8,049	221	200	112	0	0	0	1,144	1,436	0	719	0
2055	8,135	221	200	113	0	0	0	1,161	971	0	719	0
2056	8,239	221	200	114	0	0	0	1,182	702	0	719	0
2057	8,346	221	200	115	0	0	0	1,204	1,377	0	719	0
2058	8,455	221	200	116	0	0	0	1,227	1,354	0	719	0
2059	8,567	221	200	117	0	0	0	1,250	1,330	0	719	0
2060	8,743	221	200	119	0	0	0	1,281	1,299	0	719	0

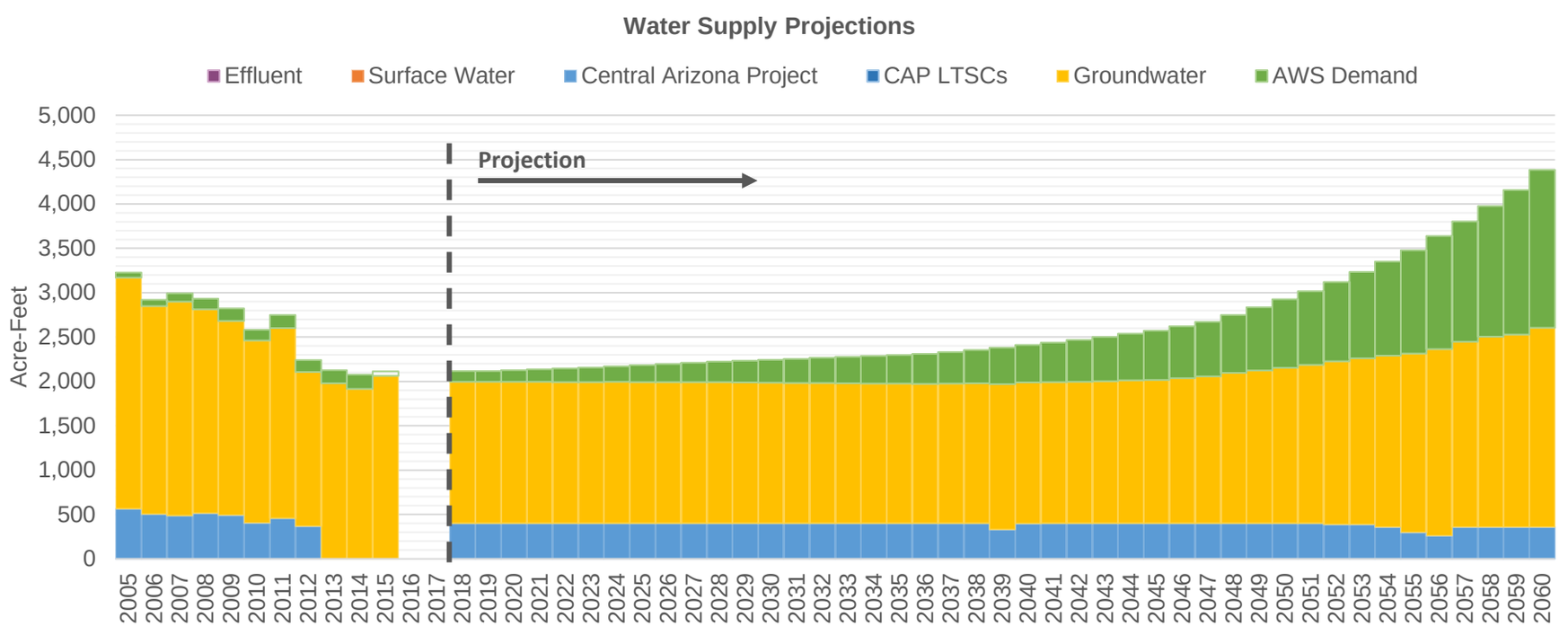
Central Arizona Project Service Area Model

GVDWID

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

GVDWID

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

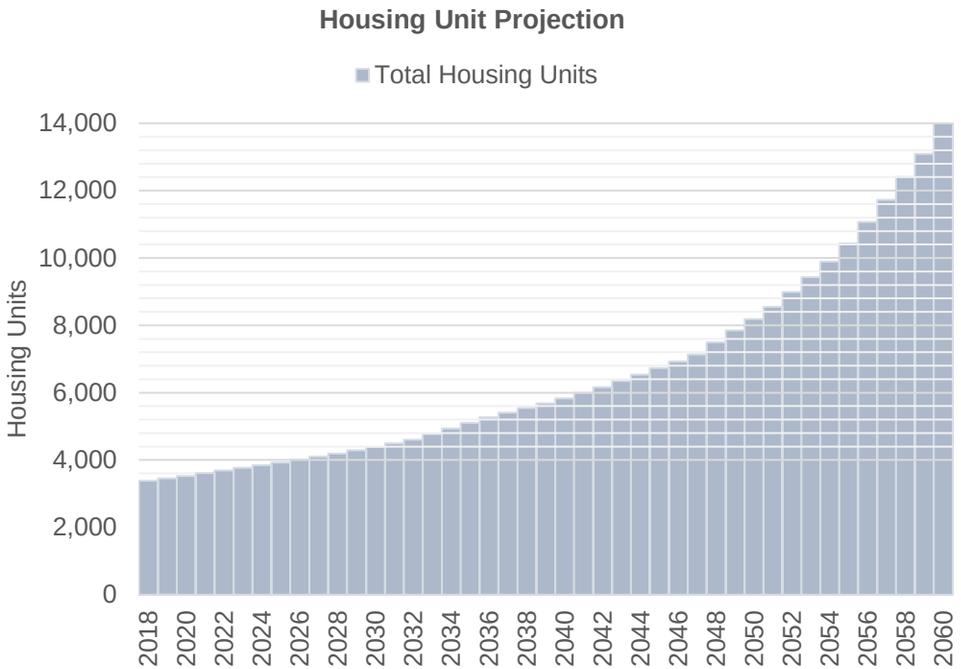
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

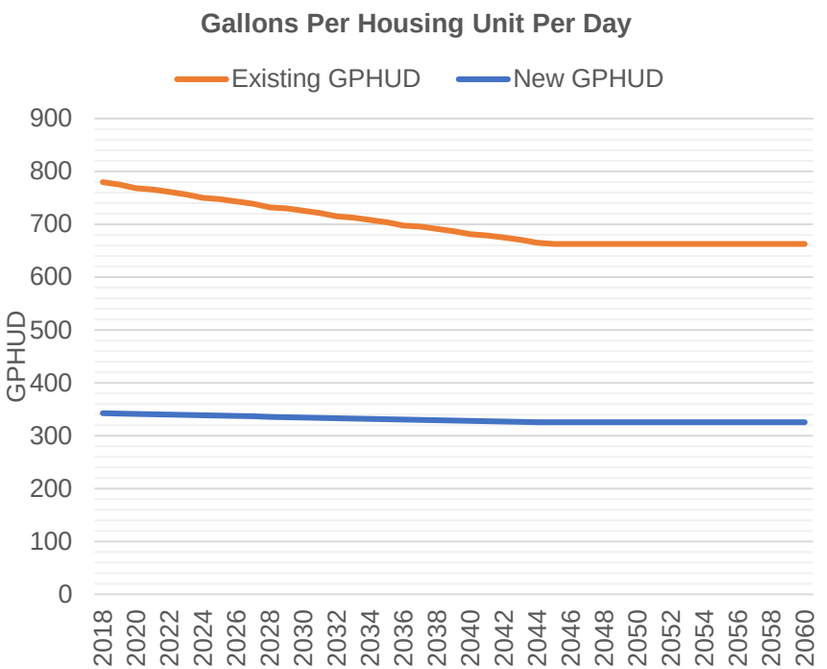
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,595	412	311	0	0	0	399	0	0	0	1,599	119
2019	4,651	410	311	0	0	0	399	0	0	0	1,596	122
2020	4,715	406	310	0	0	0	399	0	0	0	1,596	131
2021	4,783	405	309	0	0	0	399	0	0	0	1,596	141
2022	4,851	402	309	0	0	0	399	0	0	0	1,595	152
2023	4,921	400	308	0	0	0	399	0	0	0	1,595	163
2024	4,994	397	308	0	0	0	399	0	0	0	1,596	175
2025	5,069	395	307	0	0	0	399	0	0	0	1,595	188
2026	5,145	393	306	0	0	0	399	0	0	0	1,595	202
2027	5,223	391	306	0	0	0	399	0	0	0	1,595	216
2028	5,293	387	305	0	0	0	399	0	0	0	1,594	230
2029	5,358	386	304	0	0	0	399	0	0	0	1,591	244
2030	5,425	384	304	0	0	0	399	0	0	0	1,588	256
2031	5,492	381	303	0	0	0	399	0	0	0	1,585	270
2032	5.561	378	303	0	0	0	399	0	0	0	1.584	283
2033	5,630	377	302	0	0	0	399	0	0	0	1,580	296
2034	5,699	374	301	0	0	0	399	0	0	0	1,578	310
2035	5,771	372	301	0	0	0	399	0	0	0	1,576	324
2036	5,844	369	300	0	0	0	399	0	0	0	1,575	338
2037	5,956	368	300	0	0	0	399	0	0	0	1,578	352
2038	6,071	365	299	0	0	0	399	0	0	0	1,581	375
2039	6,189	363	298	0	0	0	329	0	0	0	1,641	412
2040	6,309	360	298	0	0	0	396	0	0	0	1,592	422
2041	6,435	359	297	0	0	0	399	0	0	0	1,593	446
2042	6,563	357	297	0	0	0	399	0	0	0	1,598	471
2043	6,700	355	296	0	0	0	399	0	0	0	1,604	497
2044	6,844	352	296	0	0	0	399	0	0	0	1,613	525
2045	6,992	350	296	0	0	0	399	0	0	0	1,619	554
2046	7,143	350	296	0	0	0	399	0	0	0	1,638	585
2047	7,298	350	296	0	0	0	399	0	0	0	1,657	616
2048	7,582	350	296	0	0	0	399	0	0	0	1,698	650
2049	7,851	350	296	0	0	0	399	0	0	0	1,726	712
2050	8,114	350	296	0	0	0	399	0	0	0	1,755	771
2051	8,396	350	296	0	0	0	399	0	0	0	1,787	829
2052	8,737	350	296	0	0	0	386	0	0	0	1,840	896
2053	9,087	350	296	0	0	0	386	0	0	0	1,874	972
2054	9,445	350	296	0	0	0	358	0	0	0	1,931	1,060
2055	9,872	350	296	0	0	0	296	0	0	0	2,019	1,165
2056	10,377	350	296	0	0	0	262	0	0	0	2,102	1,276
2057	10,895	350	296	0	0	0	358	0	0	0	2,091	1,355
2058	11,426	350	296	0	0	0	358	0	0	0	2,146	1,473
2059	11,972	350	296	0	0	0	358	0	0	0	2,168	1,629
2060	12,761	350	296	0	0	0	358	0	0	0	2,245	1,780

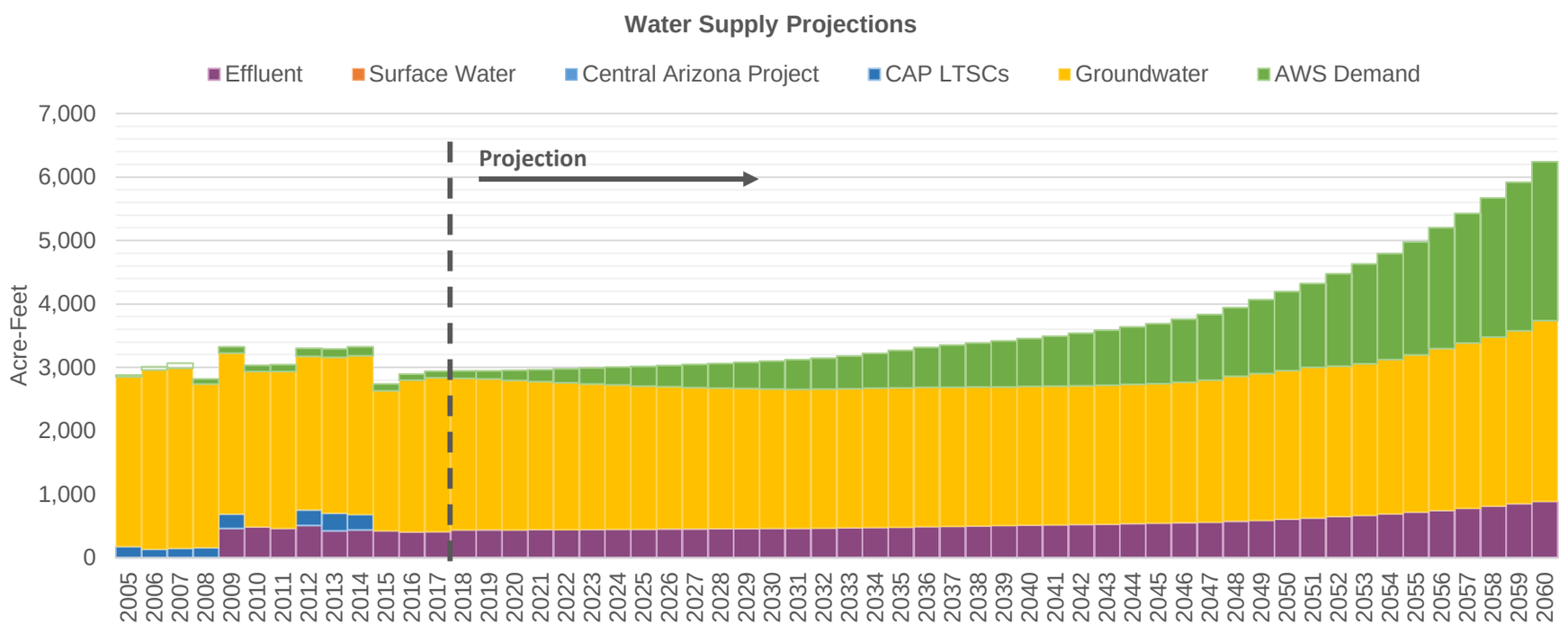
LagoDelOro

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LagoDelOro

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

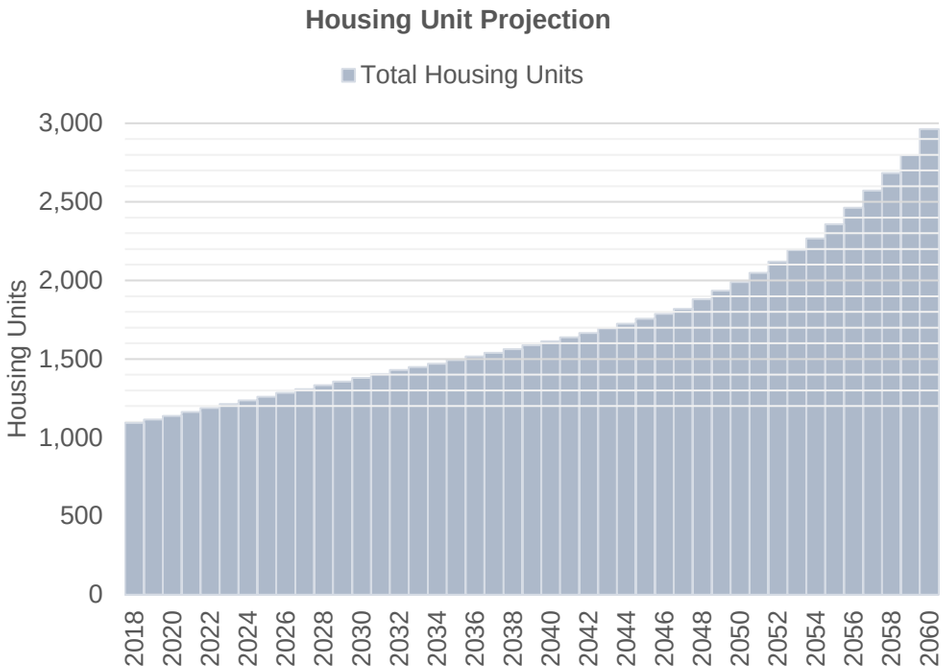
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

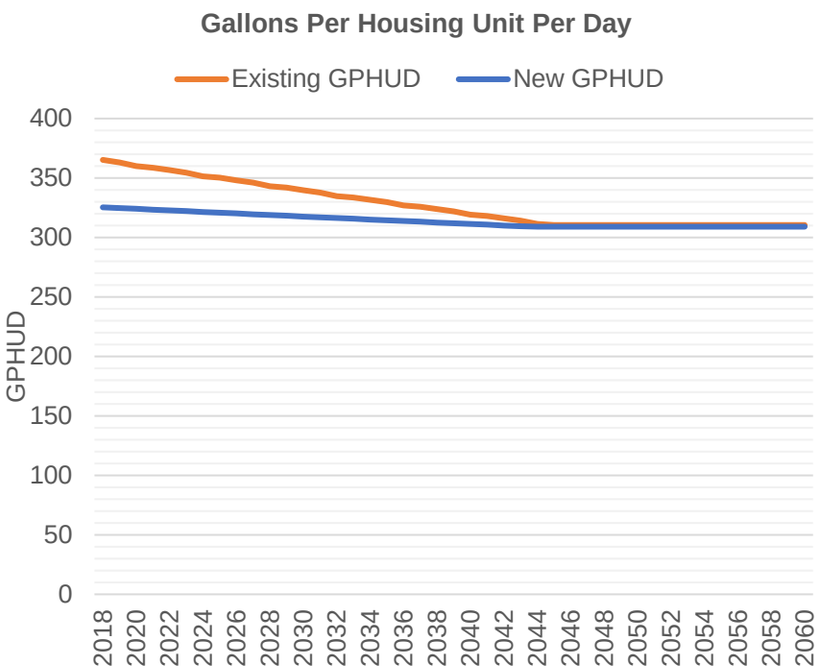
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,387	780	343	441	0	0	0	0	0	0	2,387	116
2019	3,452	775	342	441	0	0	0	0	0	0	2,376	126
2020	3,528	768	341	441	0	0	0	0	0	0	2,356	155
2021	3,607	766	341	442	0	0	0	0	0	0	2,333	190
2022	3,687	761	340	444	0	0	0	0	0	0	2,313	220
2023	3,767	757	339	446	0	0	0	0	0	0	2,293	251
2024	3,848	750	339	448	0	0	0	0	0	0	2,275	281
2025	3,930	748	338	450	0	0	0	0	0	0	2,256	311
2026	4,014	743	337	452	0	0	0	0	0	0	2,242	336
2027	4,100	739	337	454	0	0	0	0	0	0	2,229	363
2028	4,192	732	336	456	0	0	0	0	0	0	2,219	388
2029	4,290	730	335	459	0	0	0	0	0	0	2,207	414
2030	4,390	725	335	461	0	0	0	0	0	0	2,198	441
2031	4,492	721	334	464	0	0	0	0	0	0	2,192	465
2032	4.604	715	333	467	0	0	0	0	0	0	2.190	487
2033	4,766	712	333	471	0	0	0	0	0	0	2,194	512
2034	4,932	708	332	476	0	0	0	0	0	0	2,197	549
2035	5,101	704	331	483	0	0	0	0	0	0	2,197	586
2036	5,273	698	331	489	0	0	0	0	0	0	2,200	625
2037	5,407	695	330	496	0	0	0	0	0	0	2,192	664
2038	5,543	691	329	502	0	0	0	0	0	0	2,188	694
2039	5,683	687	329	507	0	0	0	0	0	0	2,186	725
2040	5,830	681	328	512	0	0	0	0	0	0	2,187	756
2041	5,996	679	327	518	0	0	0	0	0	0	2,186	790
2042	6,167	675	327	523	0	0	0	0	0	0	2,188	827
2043	6,347	671	326	530	0	0	0	0	0	0	2,189	866
2044	6,536	665	326	537	0	0	0	0	0	0	2,195	906
2045	6,729	663	326	545	0	0	0	0	0	0	2,196	949
2046	6,927	663	326	553	0	0	0	0	0	0	2,216	993
2047	7,130	663	326	563	0	0	0	0	0	0	2,234	1,037
2048	7,499	663	326	574	0	0	0	0	0	0	2,284	1,084
2049	7,847	663	326	591	0	0	0	0	0	0	2,311	1,168
2050	8,188	663	326	610	0	0	0	0	0	0	2,340	1,246
2051	8,551	663	326	628	0	0	0	0	0	0	2,373	1,322
2052	8,987	663	326	648	0	0	0	0	0	0	2,372	1,455
2053	9,434	663	326	670	0	0	0	0	0	0	2,386	1,574
2054	9,892	663	326	694	0	0	0	0	0	0	2,427	1,675
2055	10,434	663	326	718	0	0	0	0	0	0	2,481	1,778
2056	11,073	663	326	746	0	0	0	0	0	0	2,552	1,902
2057	11,729	663	326	779	0	0	0	0	0	0	2,604	2,046
2058	12,402	663	326	813	0	0	0	0	0	0	2,664	2,194
2059	13,092	663	326	849	0	0	0	0	0	0	2,726	2,345
2060	14,107	663	326	887	0	0	0	0	0	0	2,850	2,504

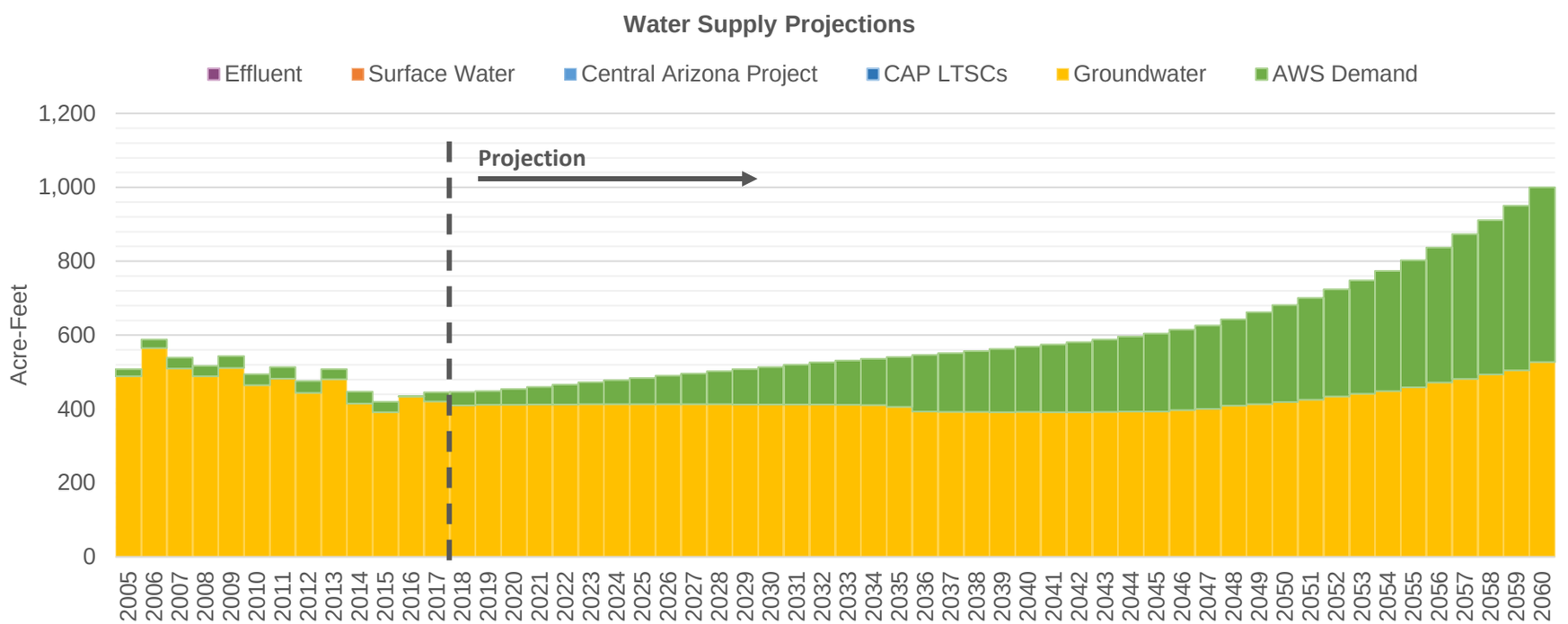
LasQuintas

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LasQuintas

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

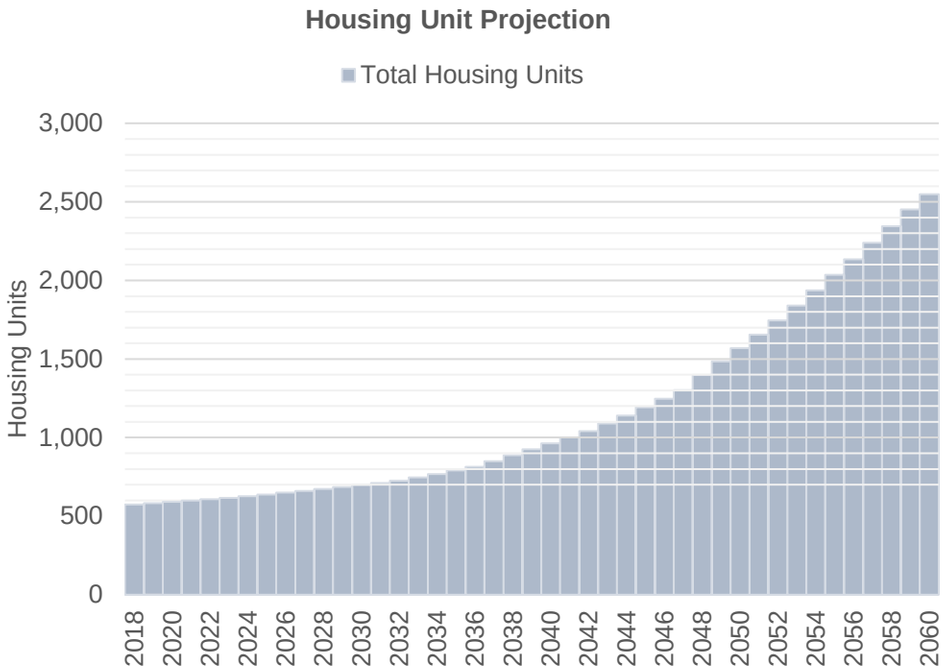
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

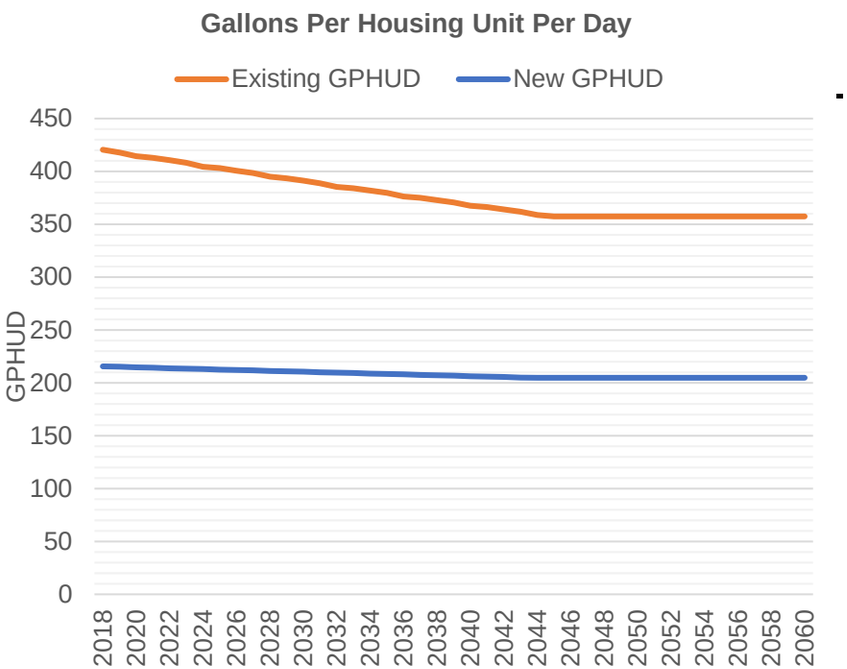
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,094	365	325	0	0	0	0	0	0	0	410	36
2019	1,115	363	325	0	0	0	0	0	0	0	411	37
2020	1,138	360	324	0	0	0	0	0	0	0	412	42
2021	1,163	359	323	0	0	0	0	0	0	0	412	47
2022	1,188	357	323	0	0	0	0	0	0	0	413	53
2023	1,213	354	322	0	0	0	0	0	0	0	413	60
2024	1,236	351	321	0	0	0	0	0	0	0	413	66
2025	1,260	350	321	0	0	0	0	0	0	0	413	71
2026	1,284	348	320	0	0	0	0	0	0	0	413	77
2027	1,309	346	320	0	0	0	0	0	0	0	413	83
2028	1,333	343	319	0	0	0	0	0	0	0	413	89
2029	1,356	342	318	0	0	0	0	0	0	0	413	96
2030	1,380	340	318	0	0	0	0	0	0	0	412	101
2031	1,405	338	317	0	0	0	0	0	0	0	412	107
2032	1,429	335	316	0	0	0	0	0	0	0	413	114
2033	1,450	334	316	0	0	0	0	0	0	0	411	120
2034	1,471	332	315	0	0	0	0	0	0	0	411	125
2035	1,493	330	314	0	0	0	0	0	0	0	406	135
2036	1,516	327	314	0	0	0	0	0	0	0	393	153
2037	1,539	326	313	0	0	0	0	0	0	0	392	159
2038	1,563	324	313	0	0	0	0	0	0	0	392	165
2039	1,588	322	312	0	0	0	0	0	0	0	392	171
2040	1,613	319	311	0	0	0	0	0	0	0	392	177
2041	1,639	318	311	0	0	0	0	0	0	0	392	183
2042	1,666	316	310	0	0	0	0	0	0	0	392	189
2043	1,695	314	309	0	0	0	0	0	0	0	392	196
2044	1,725	311	309	0	0	0	0	0	0	0	393	203
2045	1,755	310	309	0	0	0	0	0	0	0	394	211
2046	1,787	310	309	0	0	0	0	0	0	0	397	218
2047	1,819	310	309	0	0	0	0	0	0	0	400	226
2048	1,879	310	309	0	0	0	0	0	0	0	409	234
2049	1,935	310	309	0	0	0	0	0	0	0	414	248
2050	1,990	310	309	0	0	0	0	0	0	0	419	262
2051	2,049	310	309	0	0	0	0	0	0	0	425	275
2052	2,120	310	309	0	0	0	0	0	0	0	434	290
2053	2,193	310	309	0	0	0	0	0	0	0	441	307
2054	2,268	310	309	0	0	0	0	0	0	0	449	325
2055	2,357	310	309	0	0	0	0	0	0	0	459	344
2056	2,463	310	309	0	0	0	0	0	0	0	472	365
2057	2,571	310	309	0	0	0	0	0	0	0	482	391
2058	2,683	310	309	0	0	0	0	0	0	0	493	418
2059	2,797	310	309	0	0	0	0	0	0	0	505	445
2060	2,962	310	309	0	0	0	0	0	0	0	527	473

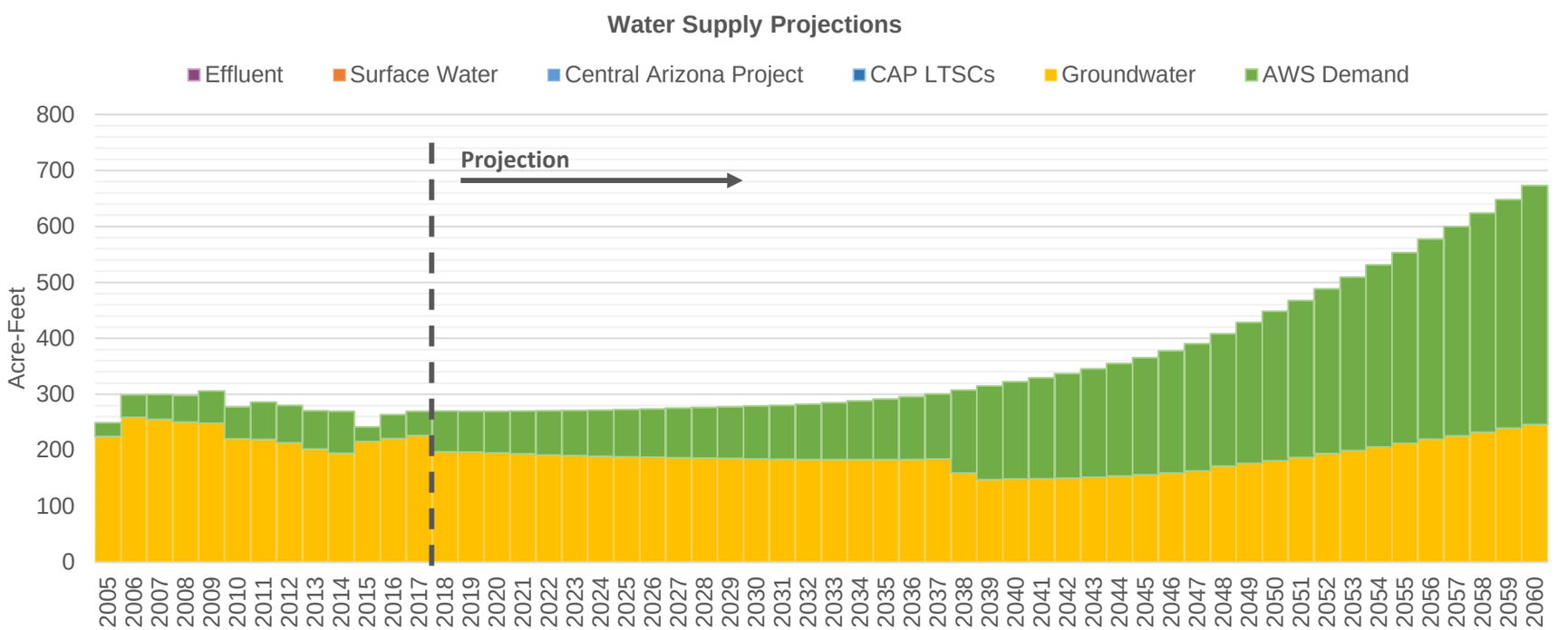
LosCerros

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LosCerros

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	575	421	216	0	0	0	0	0	0	0	198	73
2019	582	418	215	0	0	0	0	0	0	0	197	73
2020	590	414	215	0	0	0	0	0	0	0	195	75
2021	599	413	214	0	0	0	0	0	0	0	193	77
2022	607	411	214	0	0	0	0	0	0	0	192	79
2023	616	408	213	0	0	0	0	0	0	0	190	81
2024	627	404	213	0	0	0	0	0	0	0	189	83
2025	638	403	213	0	0	0	0	0	0	0	188	85
2026	650	401	212	0	0	0	0	0	0	0	188	86
2027	661	398	212	0	0	0	0	0	0	0	187	89
2028	673	395	211	0	0	0	0	0	0	0	186	90
2029	686	394	211	0	0	0	0	0	0	0	185	92
2030	698	391	210	0	0	0	0	0	0	0	185	95
2031	711	389	210	0	0	0	0	0	0	0	184	97
2032	726	385	210	0	0	0	0	0	0	0	183	99
2033	747	384	209	0	0	0	0	0	0	0	183	101
2034	768	382	209	0	0	0	0	0	0	0	183	105
2035	790	380	208	0	0	0	0	0	0	0	183	109
2036	813	376	208	0	0	0	0	0	0	0	183	112
2037	849	375	208	0	0	0	0	0	0	0	185	116
2038	887	373	207	0	0	0	0	0	0	0	160	148
2039	925	371	207	0	0	0	0	0	0	0	147	168
2040	964	367	206	0	0	0	0	0	0	0	149	174
2041	1,002	366	206	0	0	0	0	0	0	0	149	181
2042	1,042	364	205	0	0	0	0	0	0	0	150	187
2043	1,089	362	205	0	0	0	0	0	0	0	152	193
2044	1,140	359	205	0	0	0	0	0	0	0	154	201
2045	1,193	357	205	0	0	0	0	0	0	0	156	210
2046	1,247	357	205	0	0	0	0	0	0	0	159	218
2047	1,302	357	205	0	0	0	0	0	0	0	163	227
2048	1,399	357	205	0	0	0	0	0	0	0	172	236
2049	1,485	357	205	0	0	0	0	0	0	0	176	253
2050	1,568	357	205	0	0	0	0	0	0	0	181	267
2051	1,654	357	205	0	0	0	0	0	0	0	187	280
2052	1,746	357	205	0	0	0	0	0	0	0	194	295
2053	1,840	357	205	0	0	0	0	0	0	0	199	310
2054	1,936	357	205	0	0	0	0	0	0	0	206	325
2055	2,035	357	205	0	0	0	0	0	0	0	212	341
2056	2,135	357	205	0	0	0	0	0	0	0	220	358
2057	2,239	357	205	0	0	0	0	0	0	0	226	374
2058	2,344	357	205	0	0	0	0	0	0	0	232	391
2059	2,453	357	205	0	0	0	0	0	0	0	240	409
2060	2,549	357	205	0	0	0	0	0	0	0	246	427

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]

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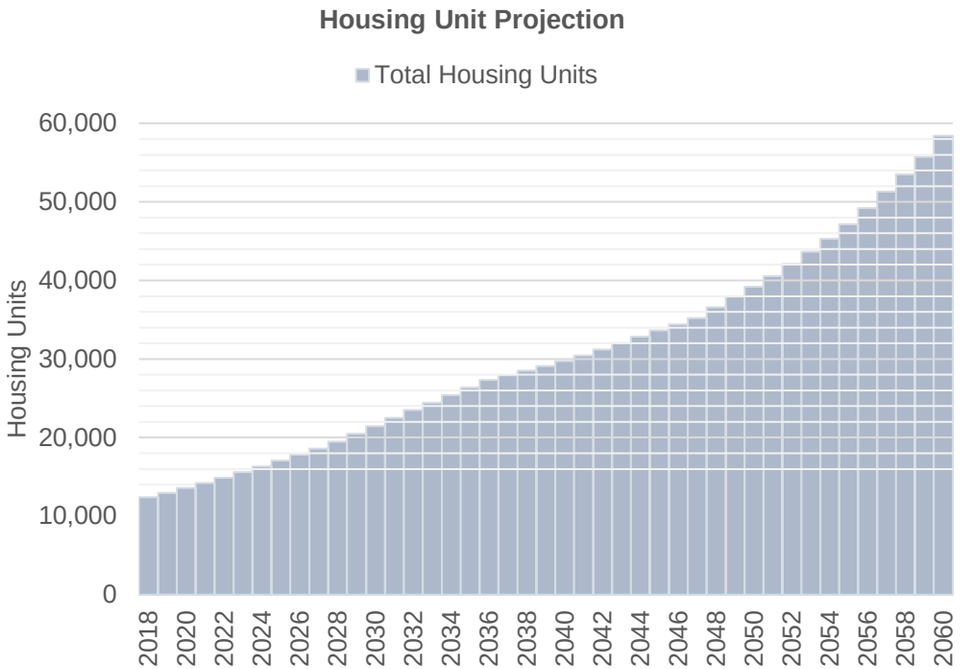

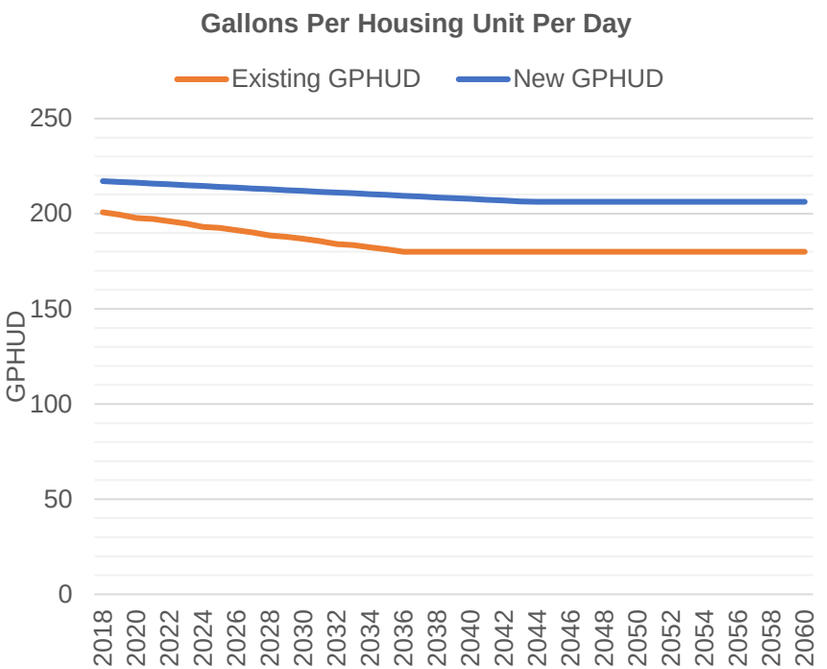

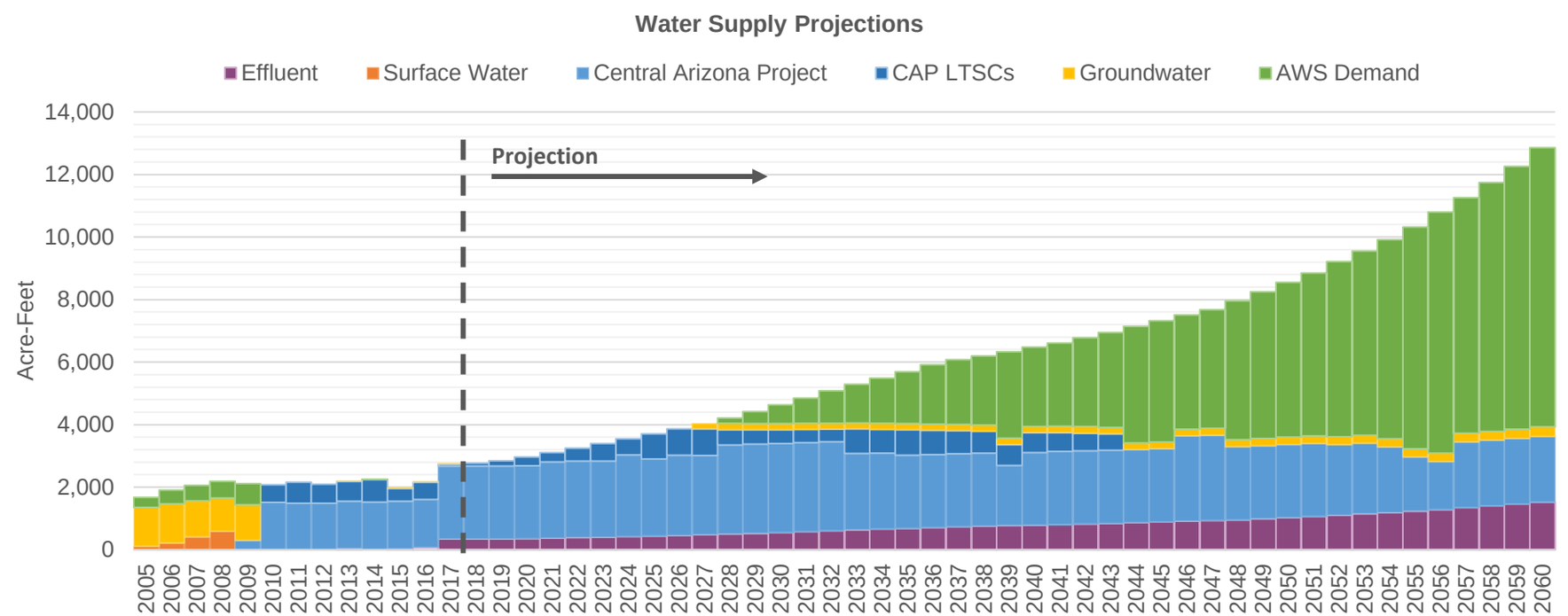

Central Arizona Project Service Area Model

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C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

Water Supply Projections (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	12,394	201	217	345	0	0	0	2,336	0	89	0	0
2019	12,942	200	217	345	0	0	0	2,336	0	159	0	0
2020	13,575	198	216	354	0	0	0	2,336	0	278	0	0
2021	14,237	197	216	369	0	0	0	2,435	0	302	0	0
2022	14,907	196	215	387	0	0	0	2,446	0	417	0	0
2023	15,596	195	215	405	0	0	0	2,427	0	565	0	0
2024	16,322	193	215	423	0	0	0	2,608	0	520	0	0
2025	17,063	192	214	442	0	0	0	2,456	0	809	0	0
2026	17,818	191	214	461	0	0	0	2,559	0	849	0	0
2027	18,590	190	213	482	0	0	0	2,536	0	846	169	0
2028	19,480	189	213	502	0	0	0	2,851	0	488	200	175
2029	20,463	188	212	525	0	0	0	2,851	0	464	198	378
2030	21,466	187	212	550	0	0	0	2,851	0	441	197	594
2031	22,491	186	212	577	0	0	0	2,851	0	419	196	811
2032	23,515	184	211	604	0	0	0	2,851	0	398	195	1,035
2033	24,443	183	211	633	0	0	0	2,445	0	784	195	1,229
2034	25,392	182	210	658	0	0	0	2,431	0	759	196	1,443
2035	26,361	181	210	683	0	0	0	2,336	0	816	196	1,660
2036	27,347	180	209	708	0	0	0	2,336	0	775	198	1,896
2037	27,915	180	209	736	0	0	0	2,336	0	736	199	2,065
2038	28,496	180	209	756	0	0	0	2,336	0	699	201	2,207
2039	29,090	180	208	772	0	0	0	1,924	0	664	203	2,765
2040	29,718	180	208	788	0	0	0	2,321	0	631	205	2,536
2041	30,449	180	207	807	0	0	0	2,336	0	600	208	2,663
2042	31,197	180	207	823	0	0	0	2,336	0	570	210	2,837
2043	31,993	180	207	843	0	0	0	2,336	0	524	213	3,030
2044	32,828	180	206	865	0	0	0	2,336	0	0	216	3,732
2045	33,662	180	206	890	0	0	0	2,336	0	0	219	3,877
2046	34,418	180	206	911	0	0	0	2,726	0	0	222	3,646
2047	35,192	180	206	934	0	0	0	2,726	0	0	226	3,796
2048	36,608	180	206	956	0	0	0	2,336	0	0	230	4,435
2049	37,922	180	206	990	0	0	0	2,336	0	0	233	4,691
2050	39,197	180	206	1,027	0	0	0	2,336	0	0	238	4,949
2051	40,542	180	206	1,064	0	0	0	2,336	0	0	242	5,210
2052	42,090	180	206	1,102	0	0	0	2,261	0	0	247	5,602
2053	43,677	180	206	1,147	0	0	0	2,261	0	0	253	5,889
2054	45,305	180	206	1,189	0	0	0	2,098	0	0	258	6,374
2055	47,136	180	206	1,235	0	0	0	1,734	0	0	265	7,086
2056	49,199	180	206	1,285	0	0	0	1,531	0	0	271	7,712
2057	51,317	180	206	1,344	0	0	0	2,098	0	0	278	7,531
2058	53,490	180	206	1,401	0	0	0	2,098	0	0	286	7,963
2059	55,720	180	206	1,462	0	0	0	2,098	0	0	294	8,402
2060	58,412	180	206	1,526	0	0	0	2,098	0	0	303	8,933

Central Arizona Project Service Area Model

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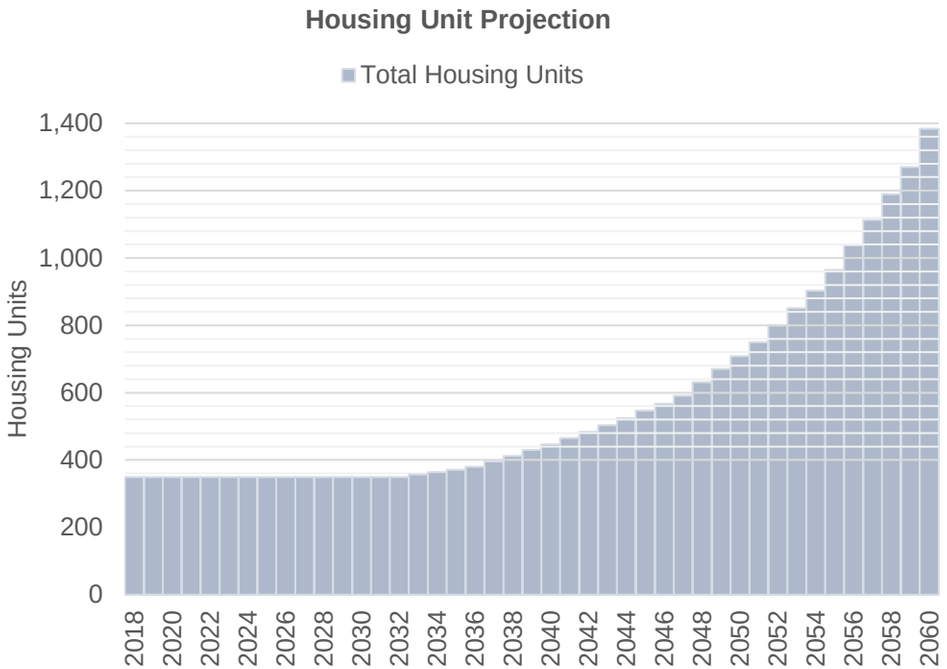
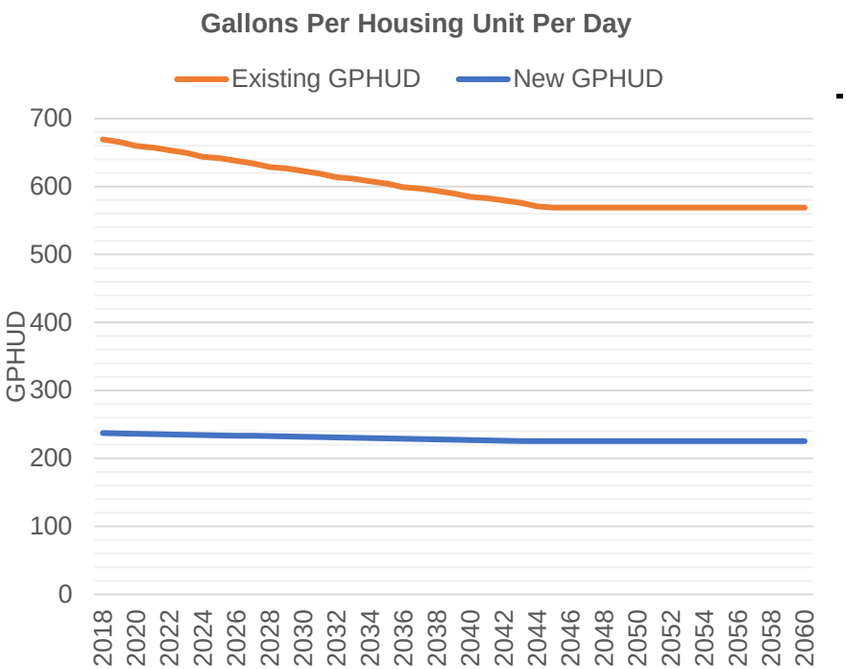
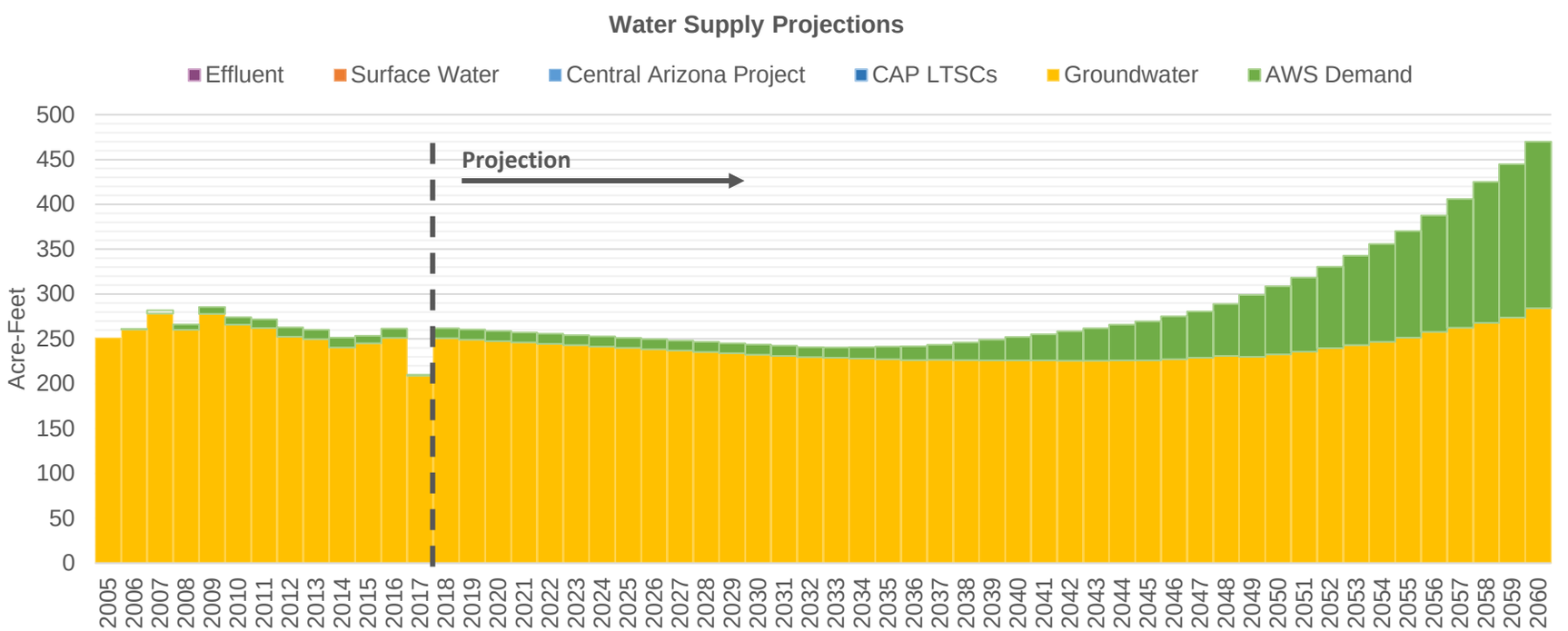
C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

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C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

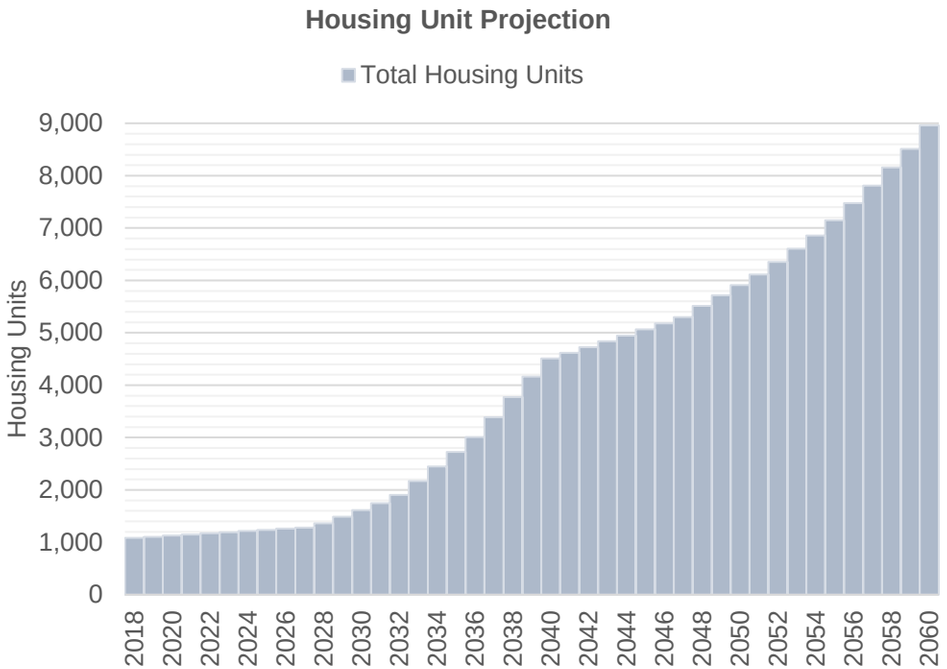
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

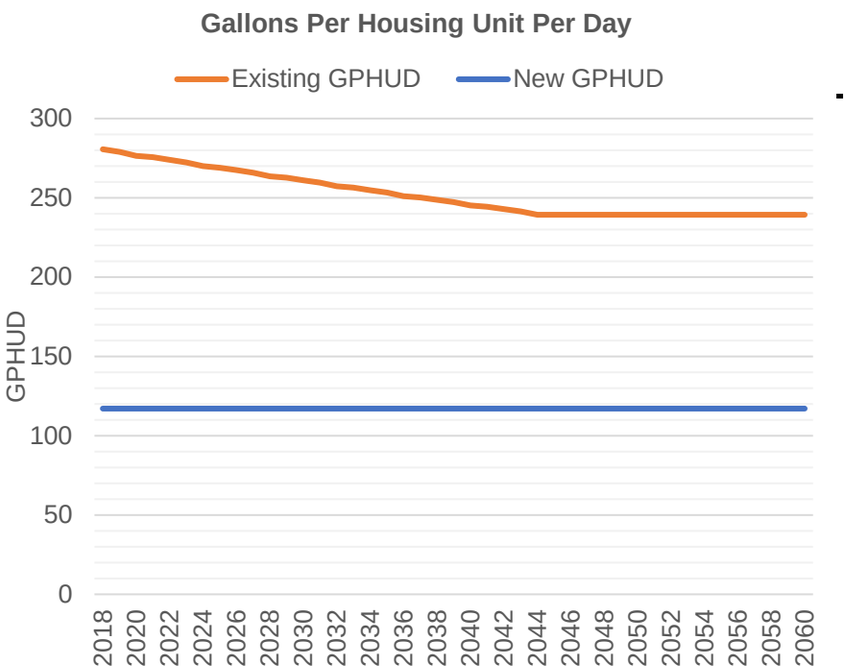
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	349	669	237	0	0	0	0	0	0	0	251	11
2019	349	665	237	0	0	0	0	0	0	0	249	11
2020	349	660	236	0	0	0	0	0	0	0	248	11
2021	349	657	236	0	0	0	0	0	0	0	246	11
2022	349	653	235	0	0	0	0	0	0	0	245	11
2023	349	649	235	0	0	0	0	0	0	0	243	11
2024	349	644	234	0	0	0	0	0	0	0	241	11
2025	349	642	234	0	0	0	0	0	0	0	240	11
2026	349	638	234	0	0	0	0	0	0	0	238	11
2027	349	634	233	0	0	0	0	0	0	0	237	11
2028	349	629	233	0	0	0	0	0	0	0	235	11
2029	349	626	232	0	0	0	0	0	0	0	234	11
2030	349	623	232	0	0	0	0	0	0	0	232	11
2031	349	619	231	0	0	0	0	0	0	0	231	11
2032	349	614	231	0	0	0	0	0	0	0	230	11
2033	357	612	230	0	0	0	0	0	0	0	229	11
2034	364	608	230	0	0	0	0	0	0	0	228	13
2035	371	604	229	0	0	0	0	0	0	0	227	14
2036	379	599	229	0	0	0	0	0	0	0	226	15
2037	395	597	228	0	0	0	0	0	0	0	227	17
2038	412	593	228	0	0	0	0	0	0	0	226	20
2039	429	590	228	0	0	0	0	0	0	0	226	23
2040	446	585	227	0	0	0	0	0	0	0	226	26
2041	465	583	227	0	0	0	0	0	0	0	226	29
2042	483	579	226	0	0	0	0	0	0	0	226	33
2043	503	576	226	0	0	0	0	0	0	0	226	36
2044	524	571	225	0	0	0	0	0	0	0	226	40
2045	546	569	225	0	0	0	0	0	0	0	226	44
2046	567	569	225	0	0	0	0	0	0	0	228	48
2047	590	569	225	0	0	0	0	0	0	0	229	51
2048	631	569	225	0	0	0	0	0	0	0	231	58
2049	670	569	225	0	0	0	0	0	0	0	230	69
2050	708	569	225	0	0	0	0	0	0	0	233	76
2051	749	569	225	0	0	0	0	0	0	0	236	83
2052	799	569	225	0	0	0	0	0	0	0	240	90
2053	850	569	225	0	0	0	0	0	0	0	243	100
2054	902	569	225	0	0	0	0	0	0	0	247	109
2055	964	569	225	0	0	0	0	0	0	0	252	119
2056	1,037	569	225	0	0	0	0	0	0	0	258	130
2057	1,112	569	225	0	0	0	0	0	0	0	263	143
2058	1,189	569	225	0	0	0	0	0	0	0	268	157
2059	1,269	569	225	0	0	0	0	0	0	0	274	171
2060	1,383	569	225	0	0	0	0	0	0	0	284	186

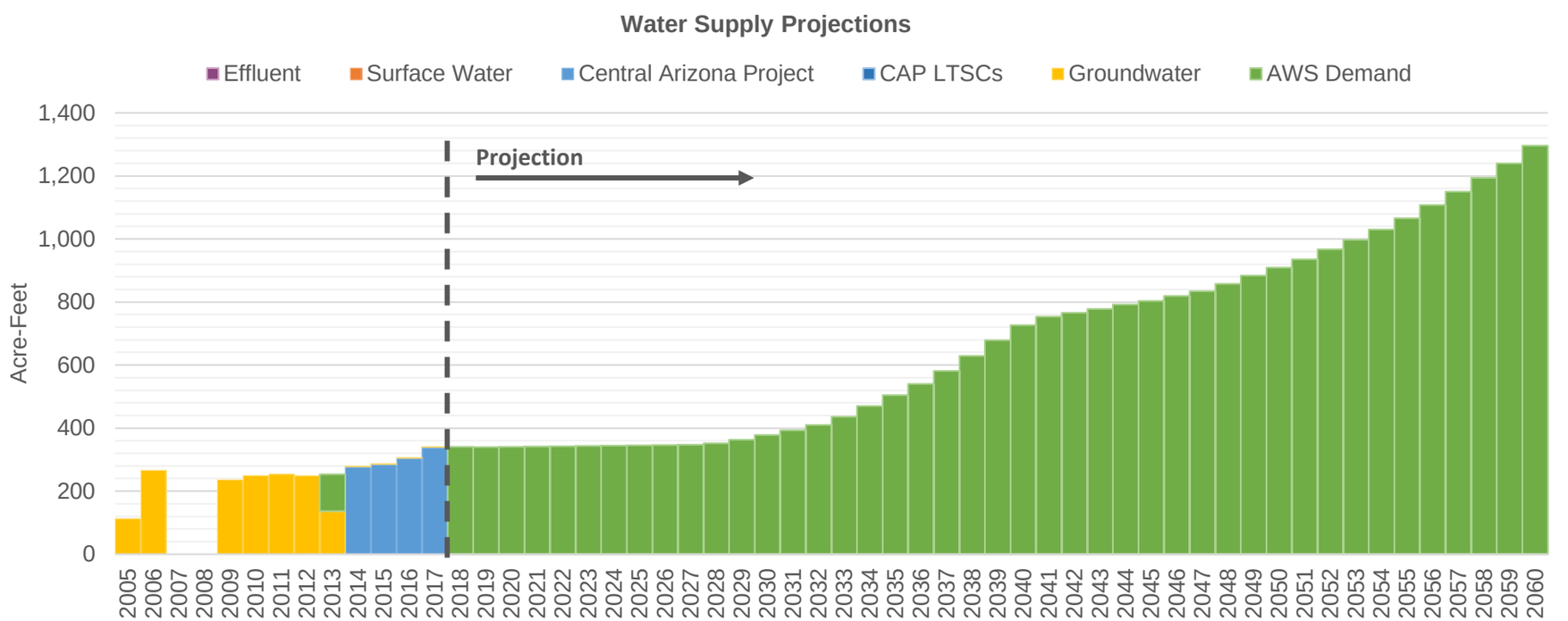
MetroDiablo

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroDiablo

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

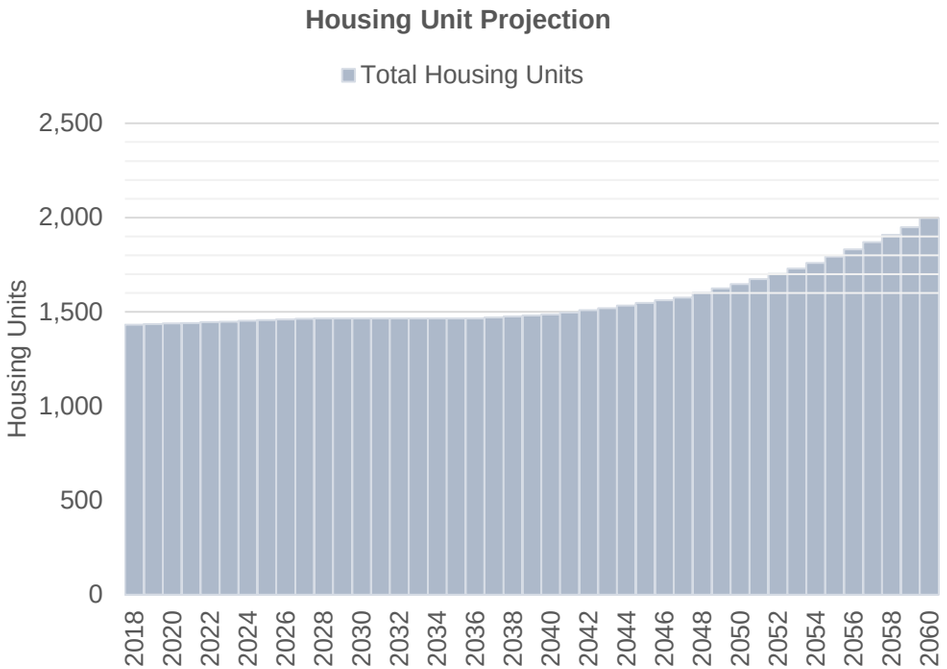
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

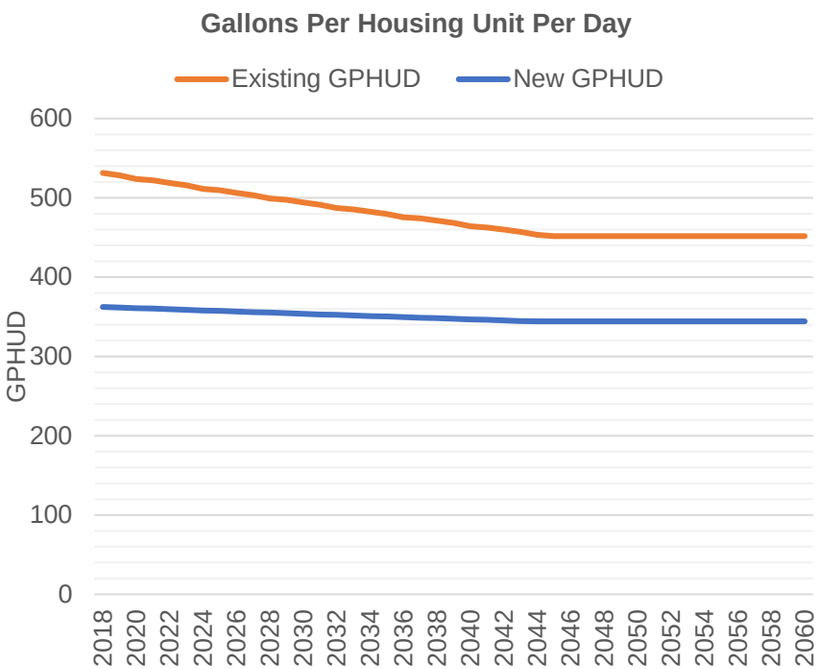
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,087	281	117	0	0	0	0	0	0	0	0	340
2019	1,106	279	117	0	0	0	0	0	0	0	0	340
2020	1,127	277	117	0	0	0	0	0	0	0	0	341
2021	1,149	276	117	0	0	0	0	0	0	0	0	341
2022	1,172	274	117	0	0	0	0	0	0	0	0	342
2023	1,194	272	117	0	0	0	0	0	0	0	0	343
2024	1,216	270	117	0	0	0	0	0	0	0	0	344
2025	1,238	269	117	0	0	0	0	0	0	0	0	345
2026	1,260	267	117	0	0	0	0	0	0	0	0	346
2027	1,283	266	117	0	0	0	0	0	0	0	0	347
2028	1,365	264	117	0	0	0	0	0	0	0	0	352
2029	1,490	263	117	0	0	0	0	0	0	0	0	364
2030	1,618	261	117	0	0	0	0	0	0	0	0	378
2031	1,749	260	117	0	0	0	0	0	0	0	0	393
2032	1.903	257	117	0	0	0	0	0	0	0	0	410
2033	2,171	256	117	0	0	0	0	0	0	0	0	436
2034	2,445	255	117	0	0	0	0	0	0	0	0	470
2035	2,725	253	117	0	0	0	0	0	0	0	0	504
2036	3,012	251	117	0	0	0	0	0	0	0	0	540
2037	3,388	250	117	0	0	0	0	0	0	0	0	581
2038	3,773	249	117	0	0	0	0	0	0	0	0	629
2039	4,167	247	117	0	0	0	0	0	0	0	0	679
2040	4,514	245	117	0	0	0	0	0	0	0	0	727
2041	4,620	244	117	0	0	0	0	0	0	0	0	753
2042	4,728	243	117	0	0	0	0	0	0	0	0	766
2043	4,838	241	117	0	0	0	0	0	0	0	0	778
2044	4,949	239	117	0	0	0	0	0	0	0	0	792
2045	5,063	239	117	0	0	0	0	0	0	0	0	804
2046	5,179	239	117	0	0	0	0	0	0	0	0	819
2047	5,298	239	117	0	0	0	0	0	0	0	0	834
2048	5,513	239	117	0	0	0	0	0	0	0	0	858
2049	5,714	239	117	0	0	0	0	0	0	0	0	884
2050	5,909	239	117	0	0	0	0	0	0	0	0	910
2051	6,116	239	117	0	0	0	0	0	0	0	0	936
2052	6,356	239	117	0	0	0	0	0	0	0	0	967
2053	6,603	239	117	0	0	0	0	0	0	0	0	997
2054	6,857	239	117	0	0	0	0	0	0	0	0	1,030
2055	7,145	239	117	0	0	0	0	0	0	0	0	1,066
2056	7,473	239	117	0	0	0	0	0	0	0	0	1,108
2057	7,809	239	117	0	0	0	0	0	0	0	0	1,150
2058	8,155	239	117	0	0	0	0	0	0	0	0	1,194
2059	8,509	239	117	0	0	0	0	0	0	0	0	1,240
2060	8,959	239	117	0	0	0	0	0	0	0	0	1,296

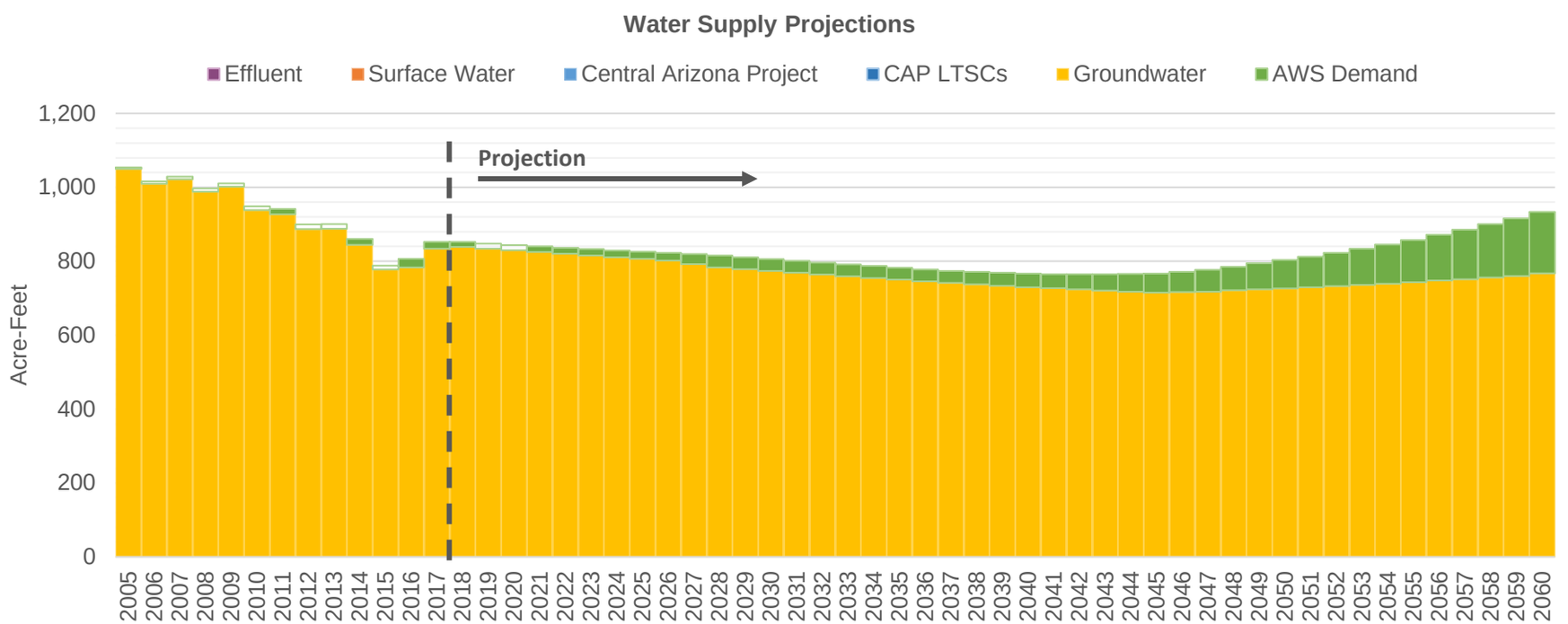
MetroHub

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroHub

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

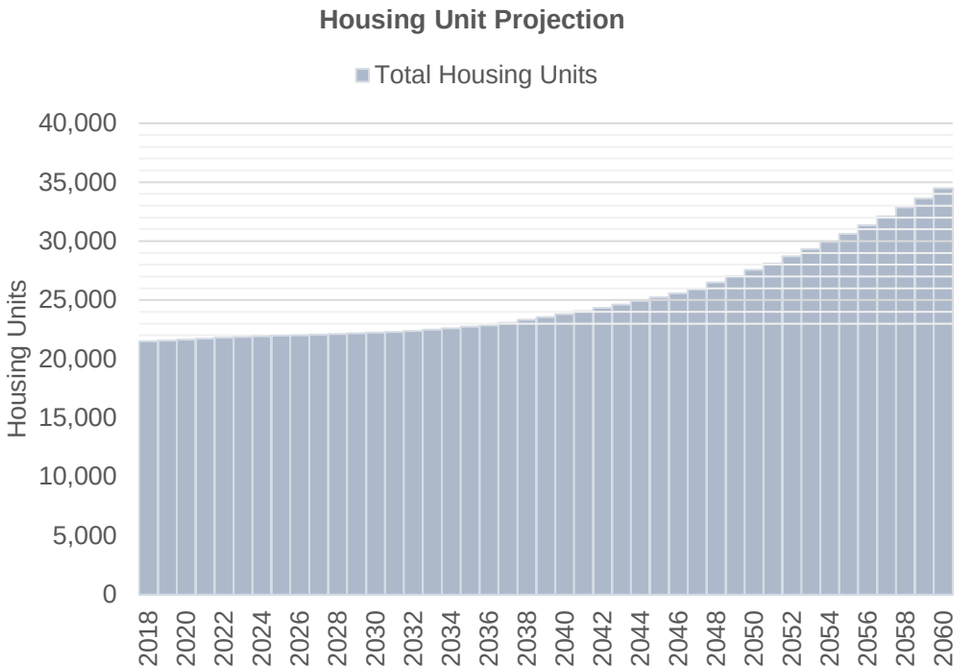
Water Supply Projections (Acre-Feet)

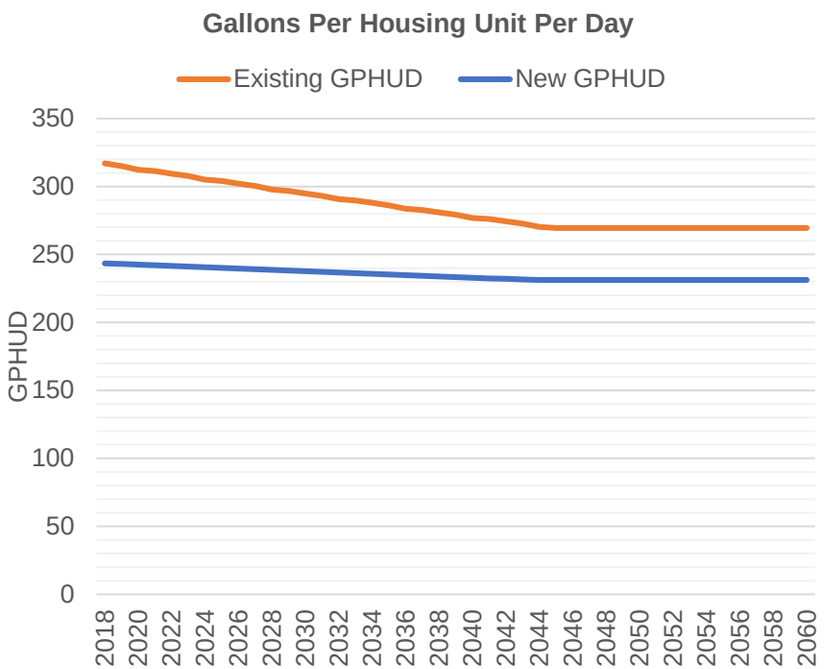
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,432	531	362	0	0	0	0	0	0	0	839	13
2019	1,435	528	362	0	0	0	0	0	0	0	834	13
2020	1,438	524	361	0	0	0	0	0	0	0	830	14
2021	1,441	522	360	0	0	0	0	0	0	0	825	15
2022	1,445	519	360	0	0	0	0	0	0	0	820	16
2023	1,448	516	359	0	0	0	0	0	0	0	815	17
2024	1,452	511	358	0	0	0	0	0	0	0	811	18
2025	1,456	509	357	0	0	0	0	0	0	0	806	20
2026	1,460	506	357	0	0	0	0	0	0	0	802	21
2027	1,464	503	356	0	0	0	0	0	0	0	792	27
2028	1,465	499	355	0	0	0	0	0	0	0	783	32
2029	1,465	497	355	0	0	0	0	0	0	0	778	32
2030	1,465	494	354	0	0	0	0	0	0	0	774	32
2031	1,465	491	353	0	0	0	0	0	0	0	769	32
2032	1,465	487	352	0	0	0	0	0	0	0	764	32
2033	1,465	486	352	0	0	0	0	0	0	0	759	32
2034	1,465	483	351	0	0	0	0	0	0	0	755	32
2035	1,465	480	350	0	0	0	0	0	0	0	750	32
2036	1,465	476	350	0	0	0	0	0	0	0	745	32
2037	1,470	474	349	0	0	0	0	0	0	0	742	32
2038	1,475	471	348	0	0	0	0	0	0	0	738	34
2039	1,480	468	347	0	0	0	0	0	0	0	734	35
2040	1,486	464	347	0	0	0	0	0	0	0	730	37
2041	1,497	463	346	0	0	0	0	0	0	0	727	38
2042	1,508	460	345	0	0	0	0	0	0	0	724	41
2043	1,520	457	345	0	0	0	0	0	0	0	721	44
2044	1,534	453	344	0	0	0	0	0	0	0	718	48
2045	1,547	452	344	0	0	0	0	0	0	0	715	52
2046	1,561	452	344	0	0	0	0	0	0	0	716	55
2047	1,575	452	344	0	0	0	0	0	0	0	718	59
2048	1,601	452	344	0	0	0	0	0	0	0	722	63
2049	1,625	452	344	0	0	0	0	0	0	0	724	70
2050	1,648	452	344	0	0	0	0	0	0	0	726	77
2051	1,673	452	344	0	0	0	0	0	0	0	729	83
2052	1,701	452	344	0	0	0	0	0	0	0	733	90
2053	1,730	452	344	0	0	0	0	0	0	0	736	98
2054	1,760	452	344	0	0	0	0	0	0	0	739	106
2055	1,793	452	344	0	0	0	0	0	0	0	743	114
2056	1,831	452	344	0	0	0	0	0	0	0	748	124
2057	1,869	452	344	0	0	0	0	0	0	0	752	134
2058	1,909	452	344	0	0	0	0	0	0	0	756	145
2059	1,949	452	344	0	0	0	0	0	0	0	760	156
2060	1,998	452	344	0	0	0	0	0	0	0	767	167

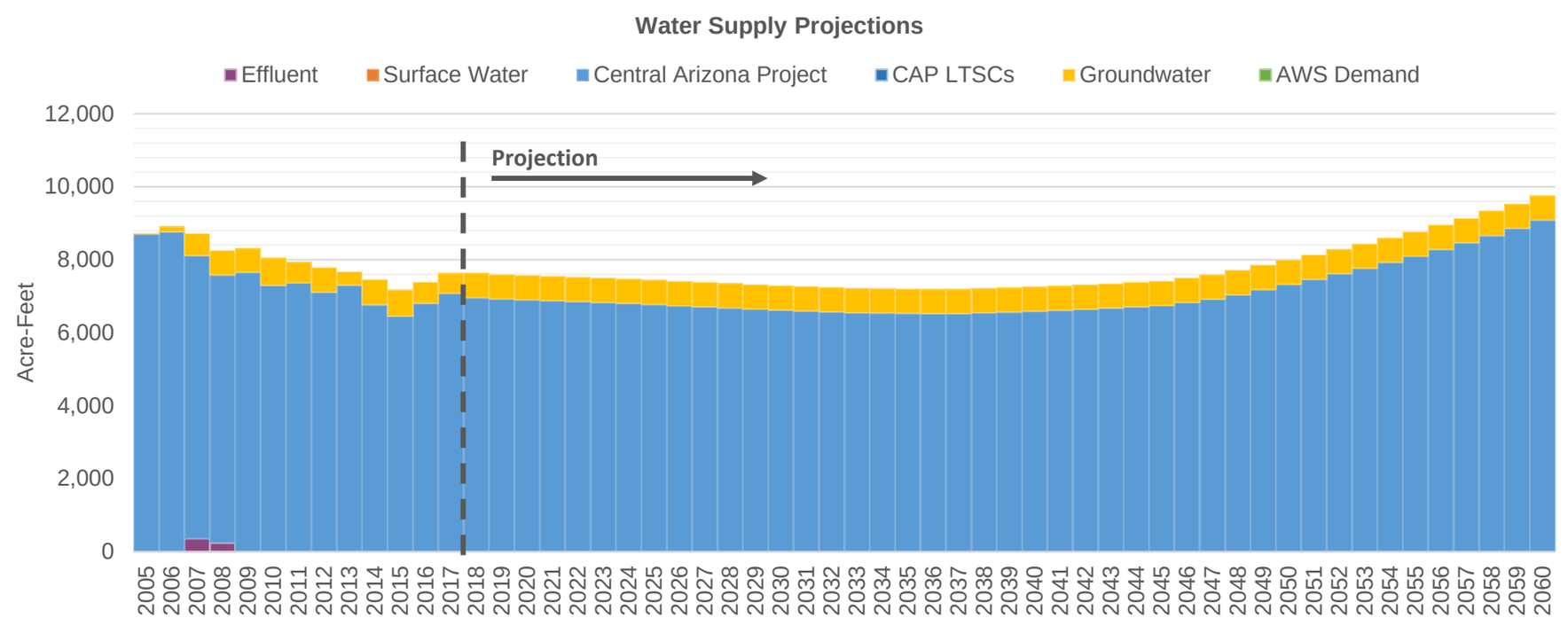
Central Arizona Project Service Area Model

MetroMain

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroMain

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

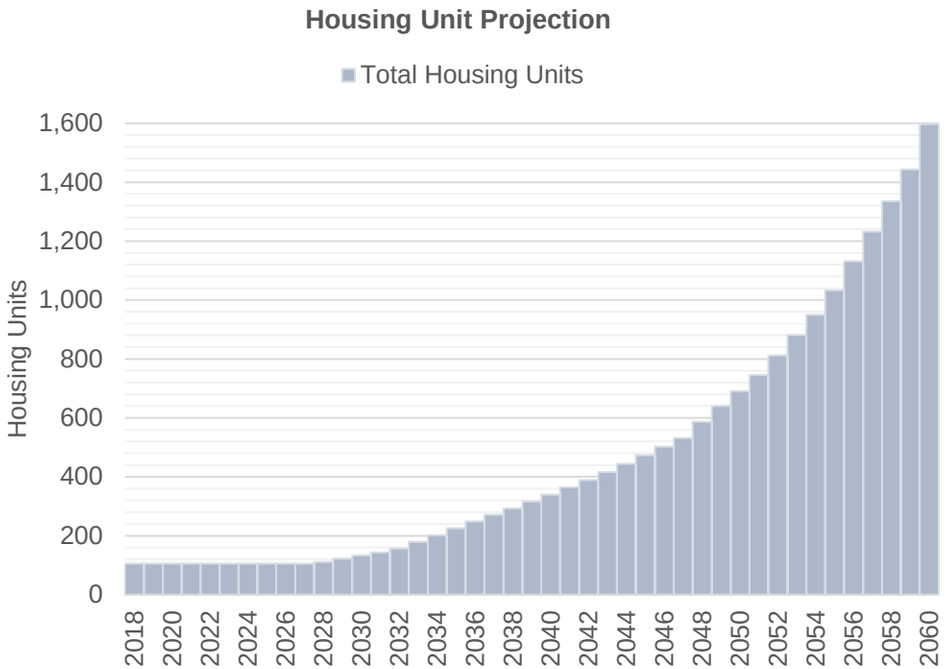
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

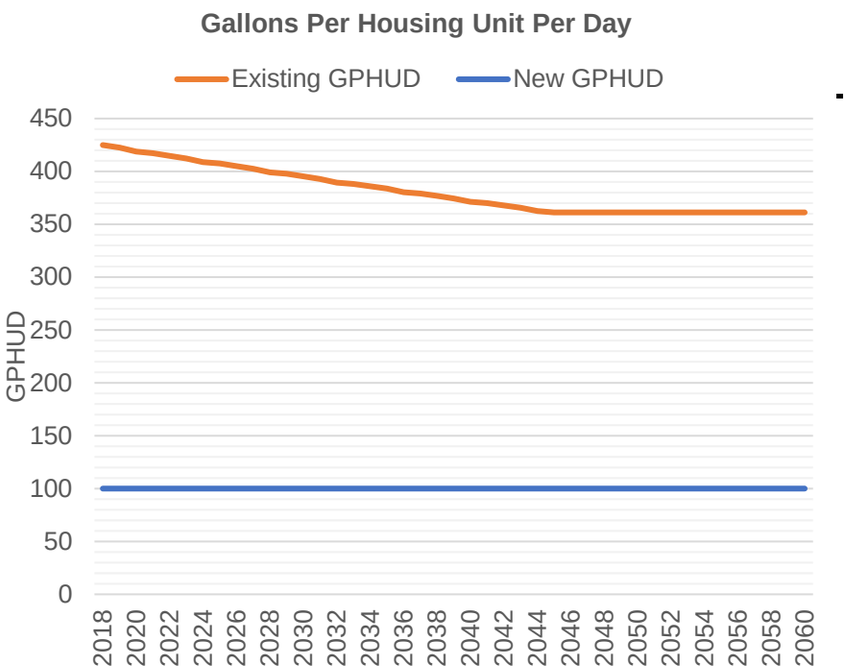
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	21,497	317	243	0	0	0	0	6,962	6,498	0	668	0
2019	21,564	315	243	0	0	0	0	6,928	6,532	0	668	0
2020	21,640	312	242	0	0	0	0	6,902	6,558	0	668	0
2021	21,720	311	242	0	0	0	0	6,878	6,582	0	668	0
2022	21,802	310	241	0	0	0	0	6,855	6,605	0	668	0
2023	21,873	308	241	0	0	0	0	6,831	6,629	0	668	0
2024	21,922	305	241	0	0	0	0	6,803	6,657	0	668	0
2025	21,972	304	240	0	0	0	0	6,771	6,689	0	668	0
2026	22,023	302	240	0	0	0	0	6,741	6,719	0	668	0
2027	22,075	300	239	0	0	0	0	6,710	6,750	0	668	0
2028	22,129	298	239	0	0	0	0	6,681	6,779	0	668	0
2029	22,183	297	238	0	0	0	0	6,652	6,808	0	668	0
2030	22,239	295	238	0	0	0	0	6,623	6,837	0	668	0
2031	22,296	293	237	0	0	0	0	6,595	6,865	0	668	0
2032	22,364	291	237	0	0	0	0	6,570	6,890	0	668	0
2033	22,483	290	236	0	0	0	0	6,552	6,908	0	668	0
2034	22,605	288	236	0	0	0	0	6,541	6,919	0	668	0
2035	22,729	286	235	0	0	0	0	6,531	6,929	0	668	0
2036	22,857	284	235	0	0	0	0	6,523	6,937	0	668	0
2037	23,085	283	234	0	0	0	0	6,528	6,932	0	668	0
2038	23,318	281	234	0	0	0	0	6,546	6,914	0	668	0
2039	23,557	279	233	0	0	0	0	6,567	4,520	0	668	0
2040	23,803	277	233	0	0	0	0	6,590	6,782	0	668	0
2041	24,069	276	232	0	0	0	0	6,614	6,846	0	668	0
2042	24,341	274	232	0	0	0	0	6,643	6,817	0	668	0
2043	24,627	273	232	0	0	0	0	6,674	6,786	0	668	0
2044	24,926	270	231	0	0	0	0	6,712	6,748	0	668	0
2045	25,236	269	231	0	0	0	0	6,749	6,711	0	668	0
2046	25,566	269	231	0	0	0	0	6,832	6,628	0	668	0
2047	25,904	269	231	0	0	0	0	6,918	6,542	0	668	0
2048	26,499	269	231	0	0	0	0	7,043	6,417	0	668	0
2049	27,040	269	231	0	0	0	0	7,186	6,274	0	668	0
2050	27,561	269	231	0	0	0	0	7,324	6,136	0	668	0
2051	28,105	269	231	0	0	0	0	7,462	5,998	0	668	0
2052	28,706	269	231	0	0	0	0	7,615	5,410	0	668	0
2053	29,322	269	231	0	0	0	0	7,768	5,257	0	668	0
2054	29,954	269	231	0	0	0	0	7,929	4,162	0	668	0
2055	30,628	269	231	0	0	0	0	8,099	1,892	0	668	0
2056	31,350	269	231	0	0	0	0	8,286	537	0	668	0
2057	32,091	269	231	0	0	0	0	8,469	3,622	0	668	0
2058	32,851	269	231	0	0	0	0	8,663	3,428	0	668	0
2059	33,631	269	231	0	0	0	0	8,863	3,228	0	668	0
2060	34,480	269	231	0	0	0	0	9,083	3,009	0	668	0

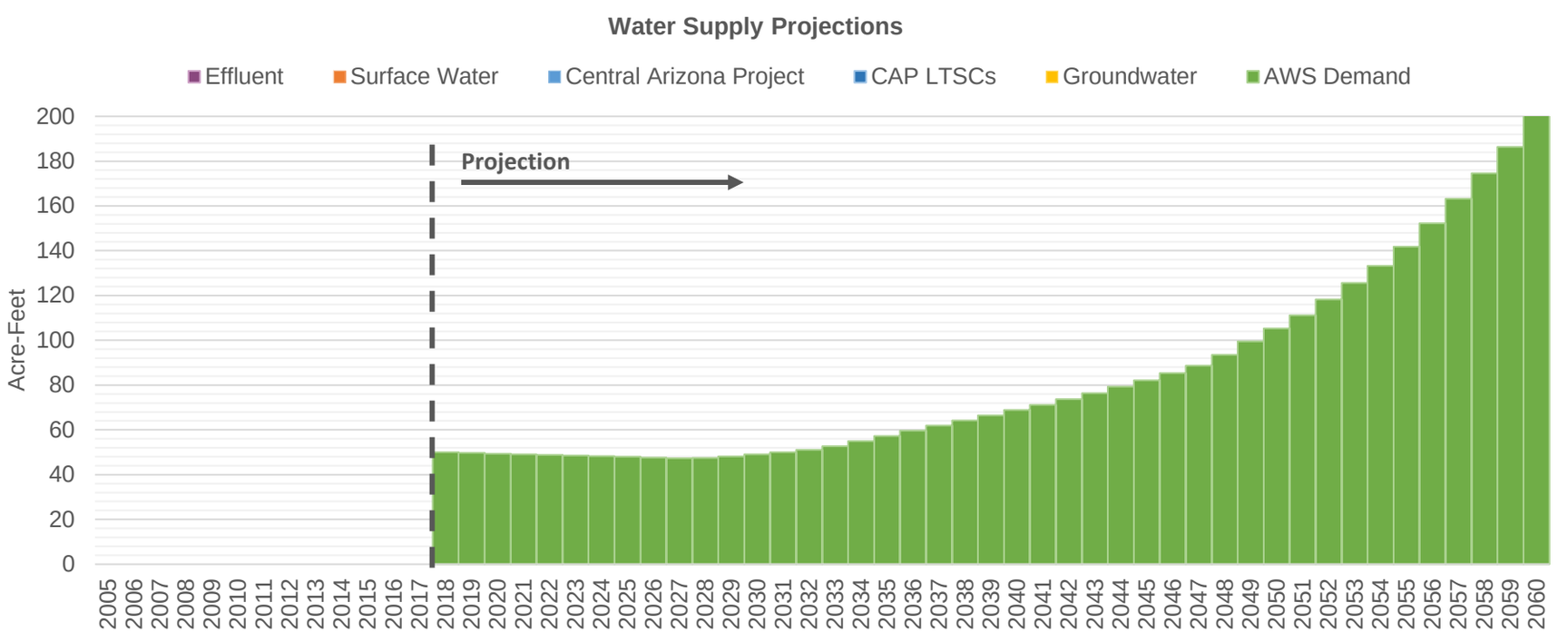
MetroWest

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroWest

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

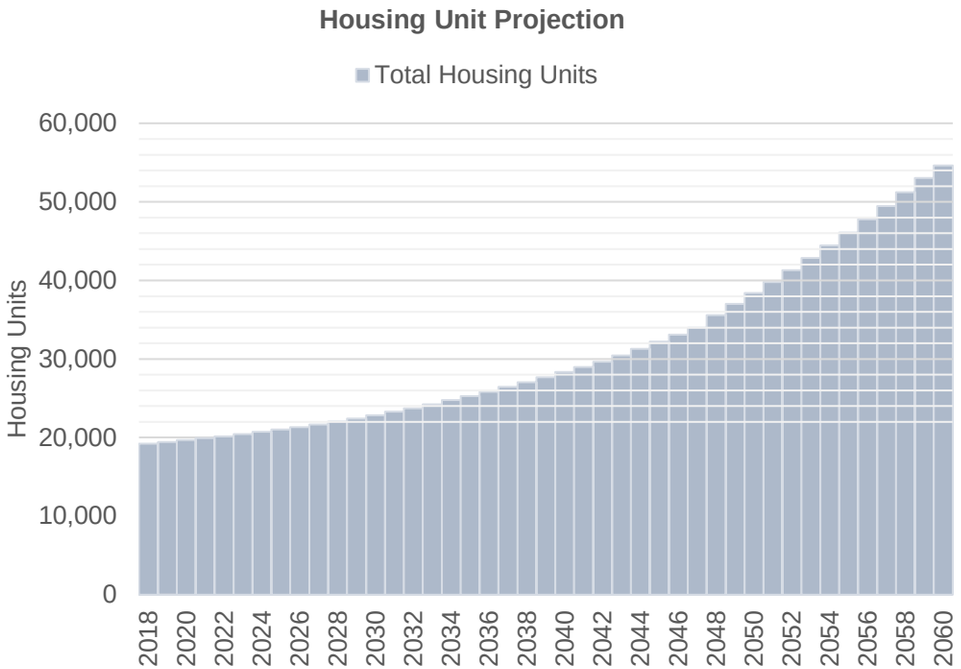
Water Supply Projections (Acre-Feet)

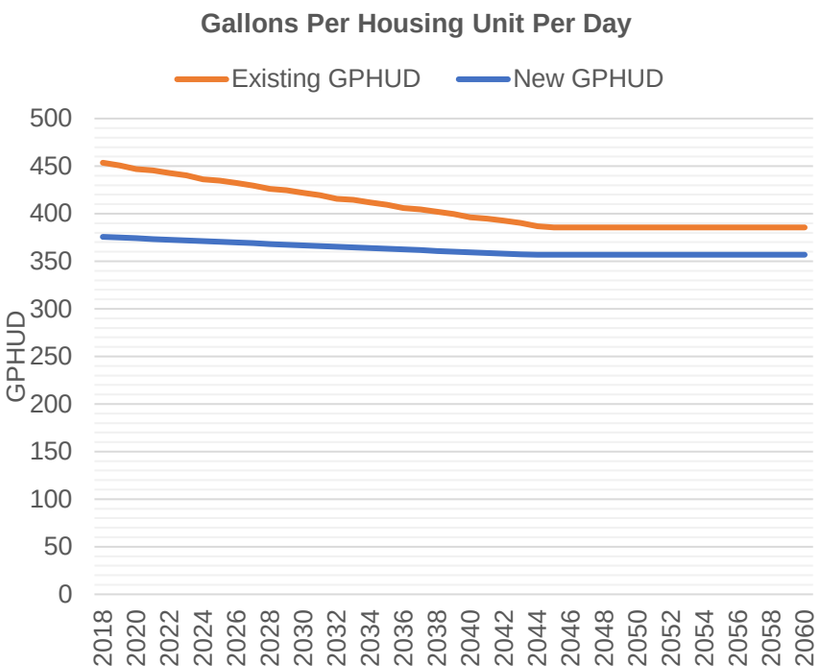
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	105	425	100	0	0	0	0	0	0	0	0	50
2019	105	422	100	0	0	0	0	0	0	0	0	50
2020	105	419	100	0	0	0	0	0	0	0	0	49
2021	105	417	100	0	0	0	0	0	0	0	0	49
2022	105	415	100	0	0	0	0	0	0	0	0	49
2023	105	412	100	0	0	0	0	0	0	0	0	49
2024	105	409	100	0	0	0	0	0	0	0	0	48
2025	105	407	100	0	0	0	0	0	0	0	0	48
2026	105	405	100	0	0	0	0	0	0	0	0	48
2027	105	403	100	0	0	0	0	0	0	0	0	47
2028	111	399	100	0	0	0	0	0	0	0	0	47
2029	122	398	100	0	0	0	0	0	0	0	0	48
2030	133	395	100	0	0	0	0	0	0	0	0	49
2031	144	393	100	0	0	0	0	0	0	0	0	50
2032	157	390	100	0	0	0	0	0	0	0	0	51
2033	179	388	100	0	0	0	0	0	0	0	0	53
2034	202	386	100	0	0	0	0	0	0	0	0	55
2035	225	384	100	0	0	0	0	0	0	0	0	57
2036	249	380	100	0	0	0	0	0	0	0	0	60
2037	271	379	100	0	0	0	0	0	0	0	0	62
2038	293	377	100	0	0	0	0	0	0	0	0	64
2039	316	375	100	0	0	0	0	0	0	0	0	66
2040	340	371	100	0	0	0	0	0	0	0	0	69
2041	364	370	100	0	0	0	0	0	0	0	0	71
2042	389	368	100	0	0	0	0	0	0	0	0	74
2043	416	366	100	0	0	0	0	0	0	0	0	76
2044	444	362	100	0	0	0	0	0	0	0	0	79
2045	473	361	100	0	0	0	0	0	0	0	0	82
2046	502	361	100	0	0	0	0	0	0	0	0	85
2047	532	361	100	0	0	0	0	0	0	0	0	89
2048	587	361	100	0	0	0	0	0	0	0	0	94
2049	640	361	100	0	0	0	0	0	0	0	0	99
2050	691	361	100	0	0	0	0	0	0	0	0	105
2051	746	361	100	0	0	0	0	0	0	0	0	111
2052	812	361	100	0	0	0	0	0	0	0	0	118
2053	881	361	100	0	0	0	0	0	0	0	0	126
2054	950	361	100	0	0	0	0	0	0	0	0	133
2055	1,033	361	100	0	0	0	0	0	0	0	0	142
2056	1,132	361	100	0	0	0	0	0	0	0	0	152
2057	1,233	361	100	0	0	0	0	0	0	0	0	163
2058	1,336	361	100	0	0	0	0	0	0	0	0	175
2059	1,443	361	100	0	0	0	0	0	0	0	0	186
2060	1,597	361	100	0	0	0	0	0	0	0	0	201

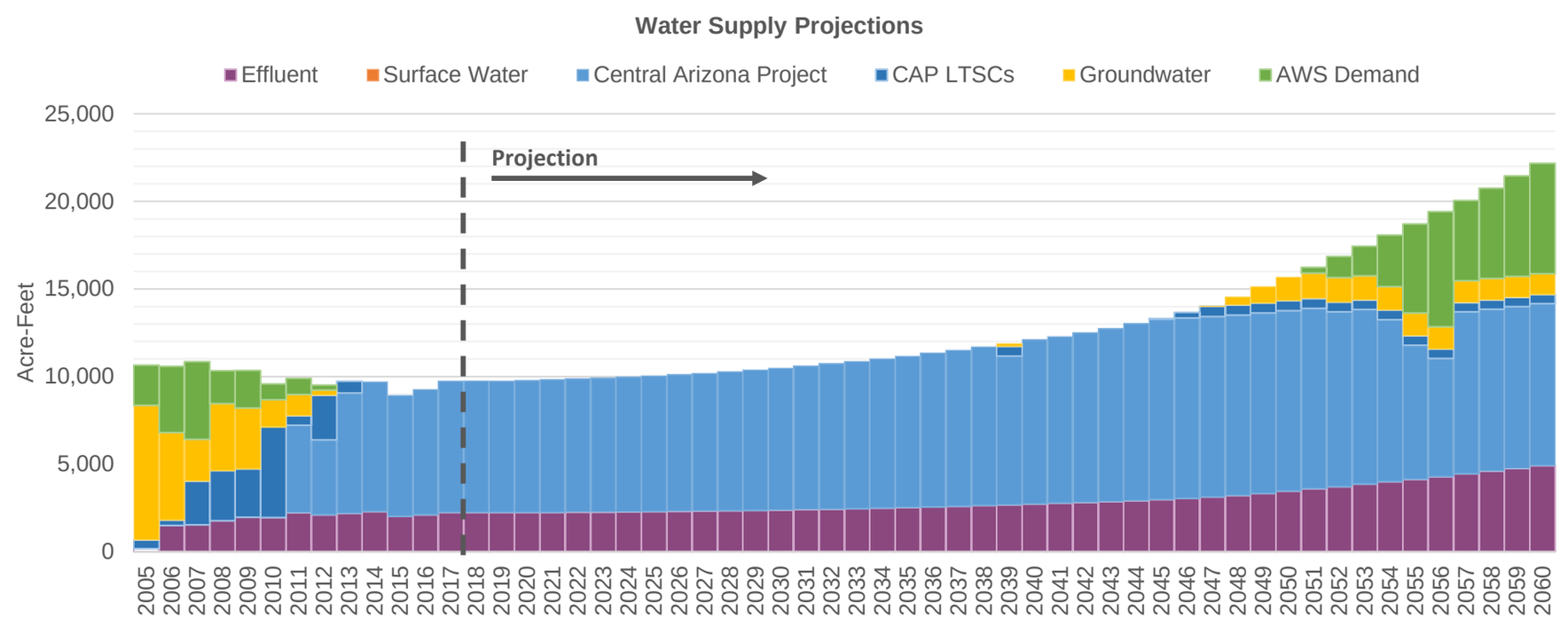
OroValley

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

OroValley

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

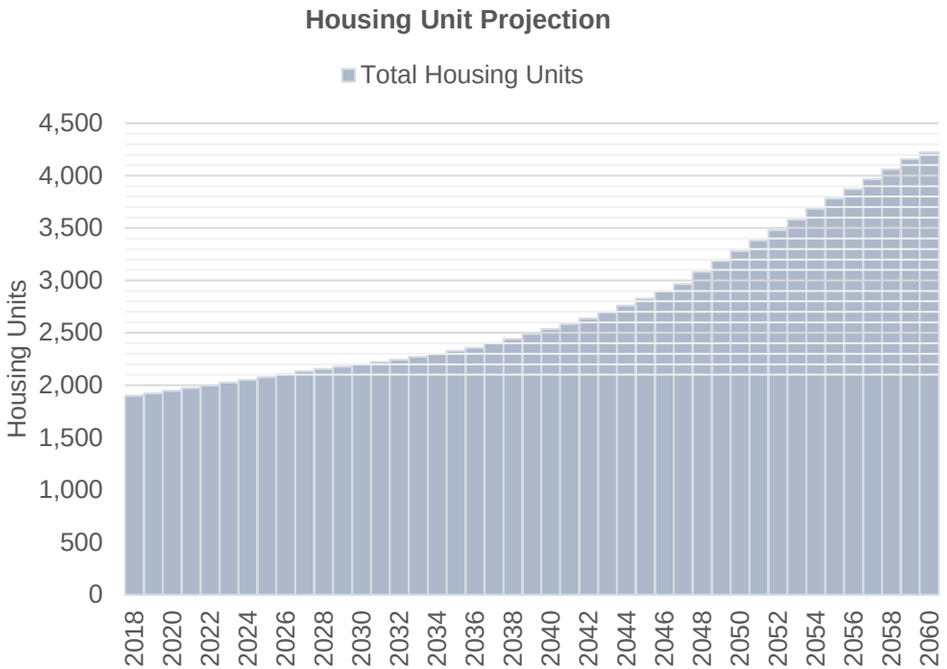
Water Supply Projections (Acre-Feet)

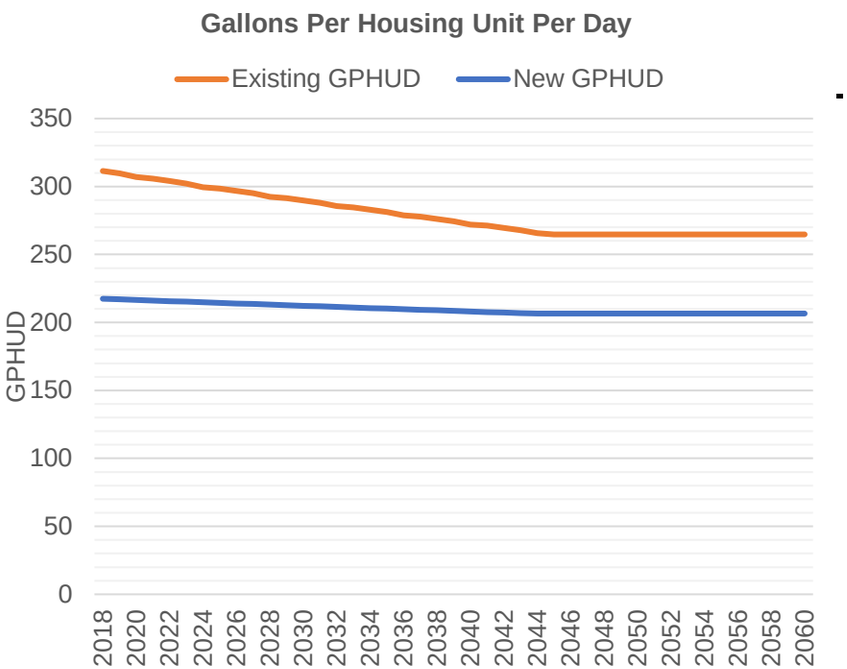
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	19,239	454	376	2,232	0	0	0	7,524	2,781	0	0	0
2019	19,441	451	375	2,232	0	0	0	7,522	2,783	0	0	0
2020	19,675	447	374	2,231	0	0	0	7,556	2,749	0	0	0
2021	19,919	445	373	2,239	0	0	0	7,590	2,715	0	0	0
2022	20,166	443	373	2,249	0	0	0	7,625	2,680	0	0	0
2023	20,430	440	372	2,259	0	0	0	7,663	2,642	0	0	0
2024	20,727	436	371	2,270	0	0	0	7,712	2,593	0	0	0
2025	21,029	435	370	2,284	0	0	0	7,764	2,541	0	0	0
2026	21,338	432	370	2,299	0	0	0	7,818	2,487	0	0	0
2027	21,653	430	369	2,314	0	0	0	7,874	2,431	0	0	0
2028	22,023	426	368	2,331	0	0	0	7,944	2,361	0	0	0
2029	22,434	425	367	2,351	0	0	0	8,025	2,280	0	0	0
2030	22,854	422	367	2,374	0	0	0	8,115	2,190	0	0	0
2031	23,283	419	366	2,400	0	0	0	8,206	2,099	0	0	0
2032	23.731	416	365	2.426	0	0	0	8.307	1.998	0	0	0
2033	24,242	414	365	2,455	0	0	0	8,412	1,893	0	0	0
2034	24,764	412	364	2,486	0	0	0	8,534	1,771	0	0	0
2035	25,297	409	363	2,521	0	0	0	8,656	1,649	0	0	0
2036	25,843	406	362	2,557	0	0	0	8,788	1,517	0	0	0
2037	26,446	405	362	2,596	0	0	0	8,918	1,387	0	0	0
2038	27,062	402	361	2,634	0	0	0	9,068	1,237	0	0	0
2039	27,693	400	360	2,677	0	0	0	8,488	0	560	171	0
2040	28,337	396	359	2,721	0	0	0	9,383	855	0	0	0
2041	28,988	395	359	2,769	0	0	0	9,527	778	0	0	0
2042	29,654	393	358	2,813	0	0	0	9,689	616	0	0	0
2043	30,438	390	357	2,860	0	0	0	9,873	432	0	0	0
2044	31,312	387	357	2,913	0	0	0	10,109	196	0	0	0
2045	32,202	386	357	2,979	0	0	0	10,305	0	27	0	0
2046	33,091	386	357	3,045	0	0	0	10,305	0	317	0	0
2047	34,002	386	357	3,127	0	0	0	10,305	0	578	17	0
2048	35,591	386	357	3,209	0	0	0	10,305	0	573	457	0
2049	37,016	386	357	3,327	0	0	0	10,305	0	567	930	0
2050	38,382	386	357	3,461	0	0	0	10,305	0	561	1,359	0
2051	39,797	386	357	3,589	0	0	0	10,305	0	556	1,457	336
2052	41,315	386	357	3,716	0	0	0	9,972	0	550	1,416	1,199
2053	42,871	386	357	3,855	0	0	0	9,972	0	545	1,377	1,694
2054	44,467	386	357	3,991	0	0	0	9,257	0	539	1,342	2,944
2055	46,099	386	357	4,135	0	0	0	7,649	0	534	1,310	5,092
2056	47,767	386	357	4,282	0	0	0	6,755	0	528	1,281	6,563
2057	49,479	386	357	4,440	0	0	0	9,257	0	523	1,254	4,580
2058	51,236	386	357	4,588	0	0	0	9,257	0	518	1,230	5,154
2059	53,039	386	357	4,746	0	0	0	9,257	0	513	1,209	5,734
2060	54,646	386	357	4,909	0	0	0	9,257	0	508	1,190	6,315

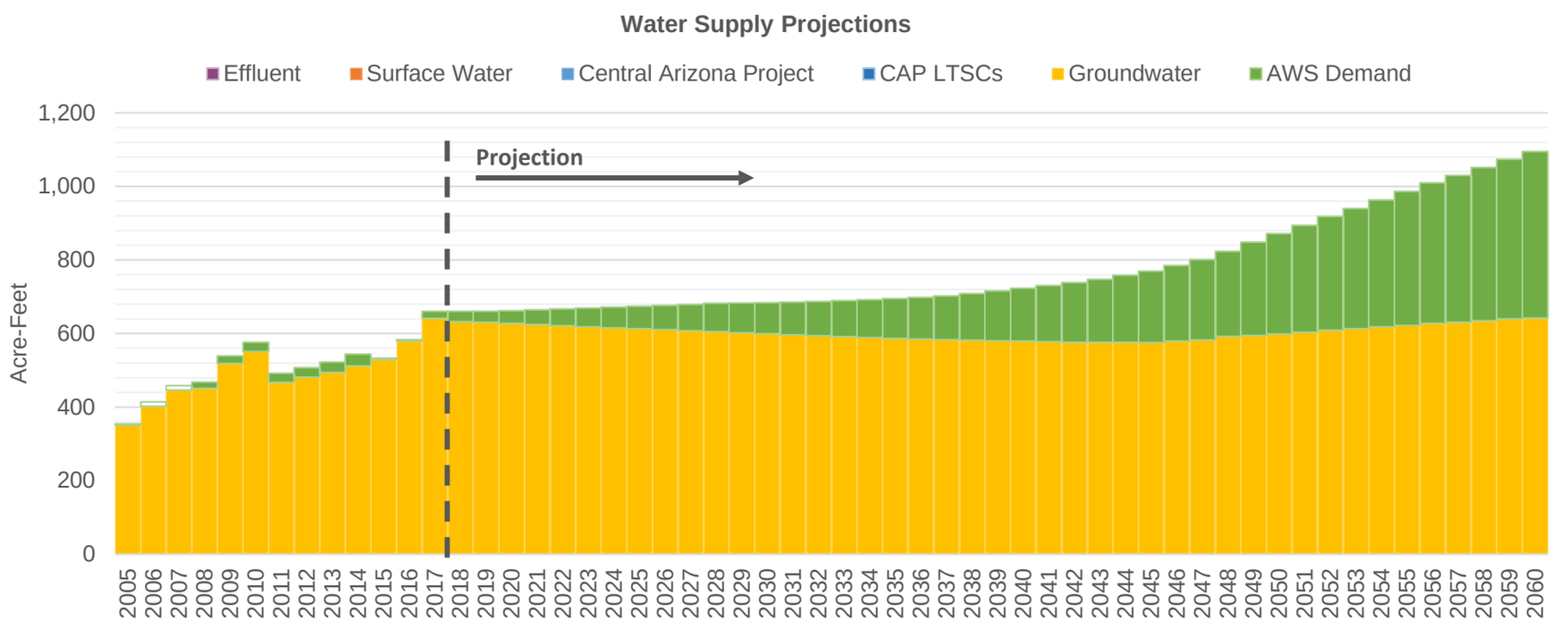
QuailCreek

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

QuailCreek

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

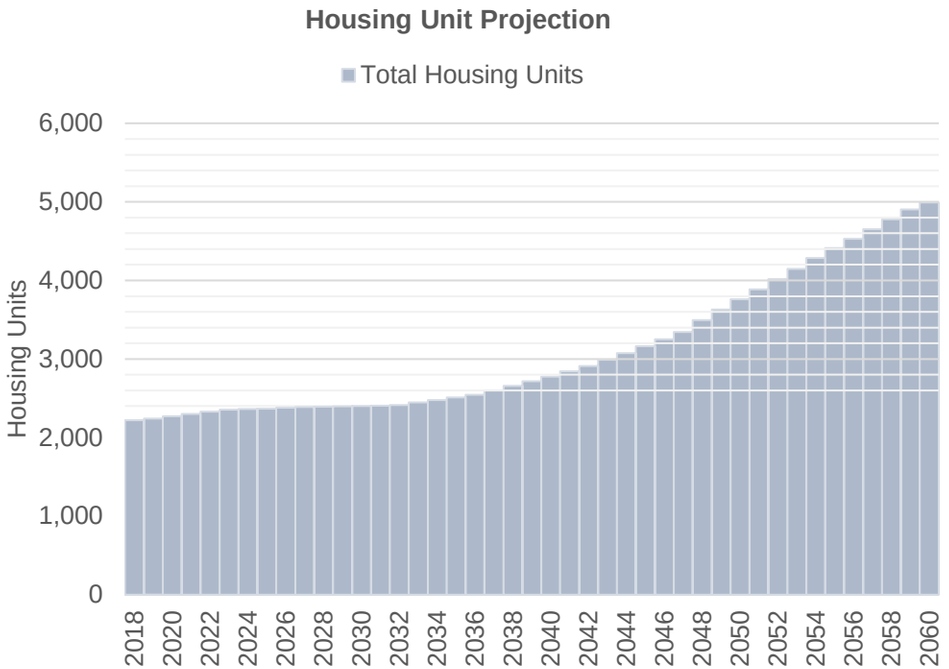
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

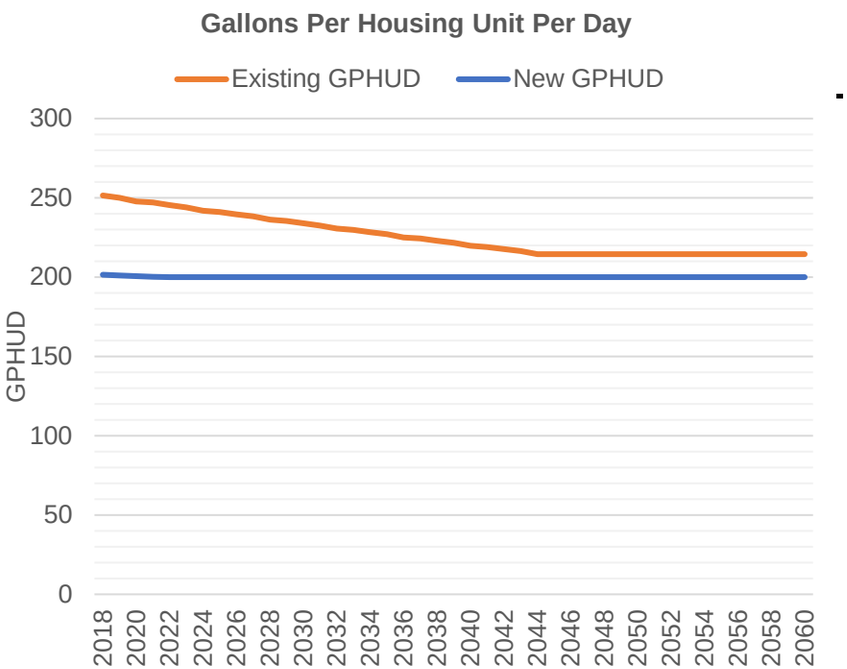
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,899	311	217	0	0	0	0	0	0	0	633	28
2019	1,920	310	217	0	0	0	0	0	0	0	631	30
2020	1,945	307	217	0	0	0	0	0	0	0	628	34
2021	1,971	306	216	0	0	0	0	0	0	0	624	40
2022	1,997	304	216	0	0	0	0	0	0	0	621	45
2023	2,024	302	215	0	0	0	0	0	0	0	618	51
2024	2,050	300	215	0	0	0	0	0	0	0	616	56
2025	2,077	299	214	0	0	0	0	0	0	0	613	61
2026	2,104	297	214	0	0	0	0	0	0	0	610	66
2027	2,132	295	214	0	0	0	0	0	0	0	608	71
2028	2,156	292	213	0	0	0	0	0	0	0	605	77
2029	2,176	292	213	0	0	0	0	0	0	0	602	81
2030	2,198	290	212	0	0	0	0	0	0	0	599	85
2031	2,220	288	212	0	0	0	0	0	0	0	596	89
2032	2,243	286	211	0	0	0	0	0	0	0	594	93
2033	2,270	285	211	0	0	0	0	0	0	0	592	98
2034	2,298	283	211	0	0	0	0	0	0	0	589	103
2035	2,327	281	210	0	0	0	0	0	0	0	587	108
2036	2,356	279	210	0	0	0	0	0	0	0	585	113
2037	2,399	278	209	0	0	0	0	0	0	0	584	119
2038	2,443	276	209	0	0	0	0	0	0	0	582	127
2039	2,488	274	208	0	0	0	0	0	0	0	581	135
2040	2,535	272	208	0	0	0	0	0	0	0	580	143
2041	2,585	271	208	0	0	0	0	0	0	0	578	152
2042	2,636	270	207	0	0	0	0	0	0	0	577	161
2043	2,696	268	207	0	0	0	0	0	0	0	576	171
2044	2,760	266	207	0	0	0	0	0	0	0	576	182
2045	2,827	265	207	0	0	0	0	0	0	0	576	194
2046	2,895	265	207	0	0	0	0	0	0	0	579	206
2047	2,965	265	207	0	0	0	0	0	0	0	582	219
2048	3,083	265	207	0	0	0	0	0	0	0	592	232
2049	3,185	265	207	0	0	0	0	0	0	0	595	254
2050	3,282	265	207	0	0	0	0	0	0	0	599	272
2051	3,381	265	207	0	0	0	0	0	0	0	604	290
2052	3,479	265	207	0	0	0	0	0	0	0	609	309
2053	3,580	265	207	0	0	0	0	0	0	0	613	327
2054	3,683	265	207	0	0	0	0	0	0	0	618	345
2055	3,781	265	207	0	0	0	0	0	0	0	622	364
2056	3,872	265	207	0	0	0	0	0	0	0	627	383
2057	3,965	265	207	0	0	0	0	0	0	0	631	399
2058	4,060	265	207	0	0	0	0	0	0	0	635	417
2059	4,158	265	207	0	0	0	0	0	0	0	640	434
2060	4,225	265	207	0	0	0	0	0	0	0	642	452

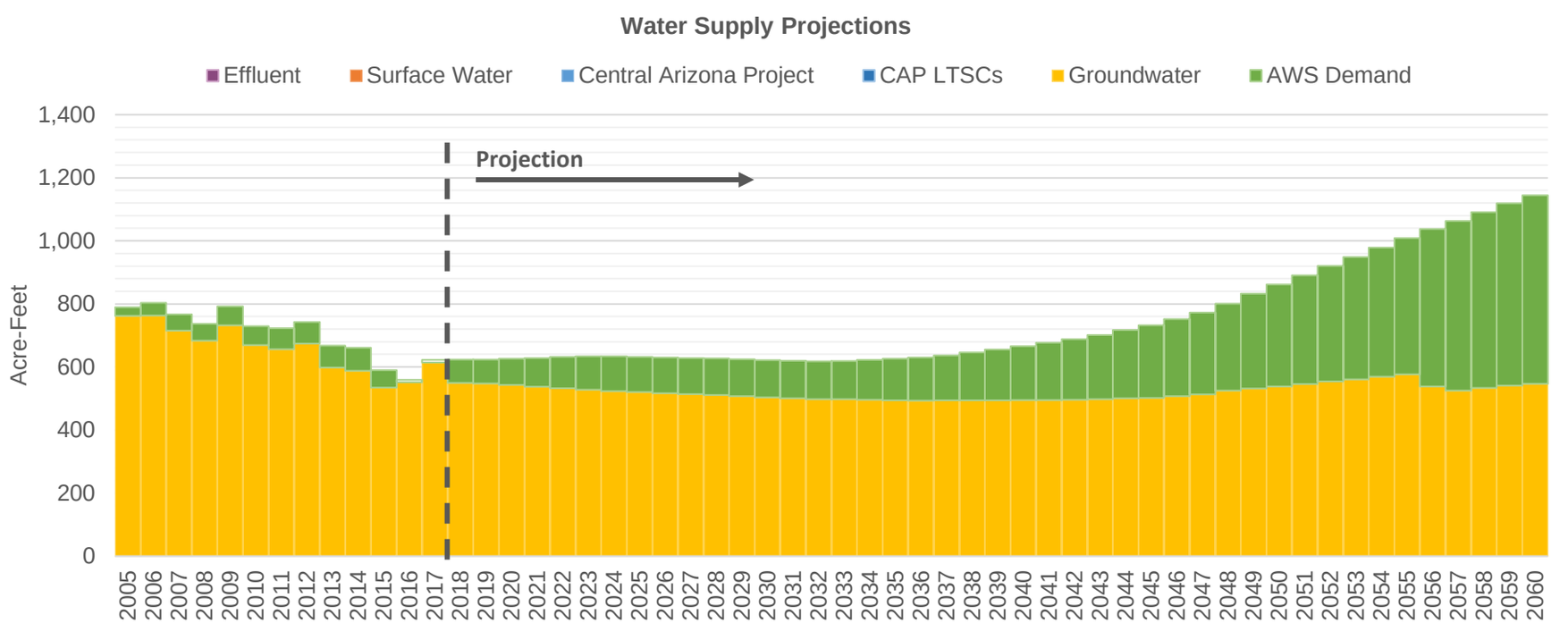
RayWC

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

RayWC

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

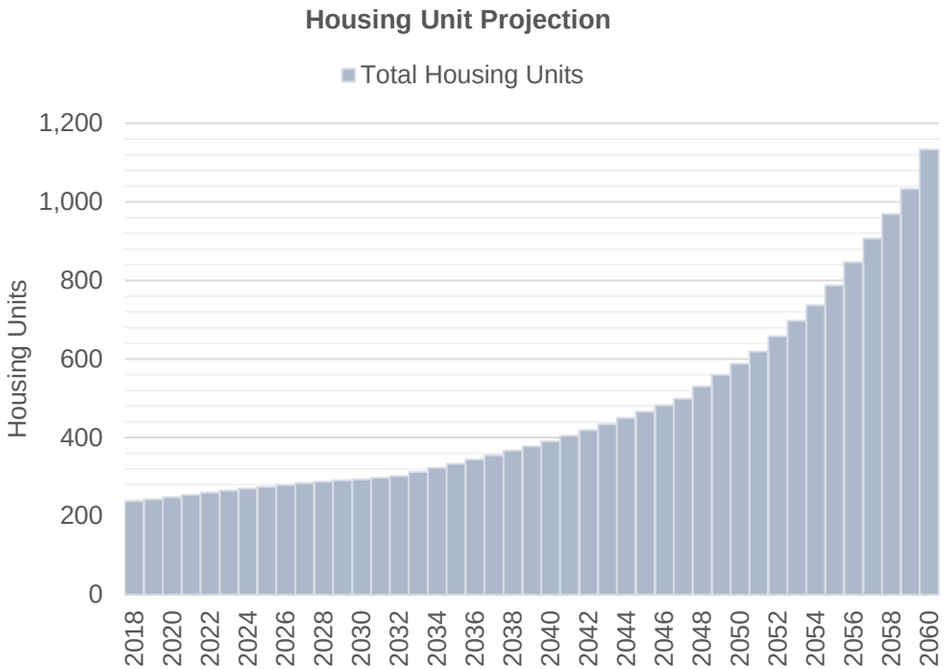
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

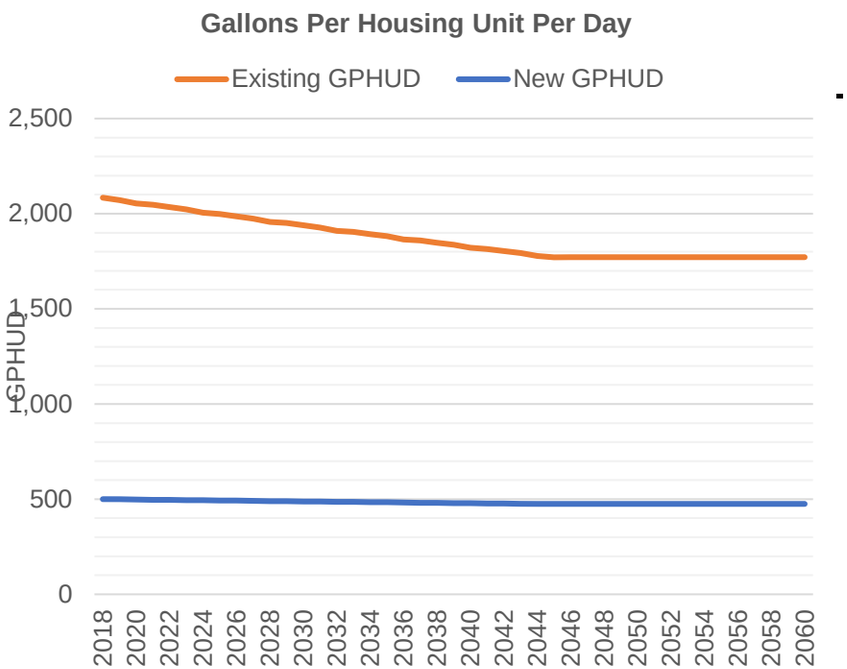
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,219	252	202	0	0	0	0	0	0	0	550	74
2019	2,243	250	201	0	0	0	0	0	0	0	547	76
2020	2,272	248	201	0	0	0	0	0	0	0	543	83
2021	2,301	247	200	0	0	0	0	0	0	0	537	91
2022	2,331	246	200	0	0	0	0	0	0	0	533	99
2023	2,354	244	200	0	0	0	0	0	0	0	528	106
2024	2,362	242	200	0	0	0	0	0	0	0	523	110
2025	2,370	241	200	0	0	0	0	0	0	0	520	112
2026	2,379	240	200	0	0	0	0	0	0	0	517	113
2027	2,388	238	200	0	0	0	0	0	0	0	514	115
2028	2,394	236	200	0	0	0	0	0	0	0	511	116
2029	2,398	235	200	0	0	0	0	0	0	0	507	117
2030	2,403	234	200	0	0	0	0	0	0	0	504	118
2031	2,407	233	200	0	0	0	0	0	0	0	501	119
2032	2,416	231	200	0	0	0	0	0	0	0	498	119
2033	2,447	230	200	0	0	0	0	0	0	0	498	121
2034	2,479	228	200	0	0	0	0	0	0	0	496	126
2035	2,511	227	200	0	0	0	0	0	0	0	495	131
2036	2,545	225	200	0	0	0	0	0	0	0	493	137
2037	2,601	224	200	0	0	0	0	0	0	0	494	142
2038	2,658	223	200	0	0	0	0	0	0	0	494	152
2039	2,717	222	200	0	0	0	0	0	0	0	495	161
2040	2,778	220	200	0	0	0	0	0	0	0	495	171
2041	2,844	219	200	0	0	0	0	0	0	0	496	181
2042	2,912	218	200	0	0	0	0	0	0	0	496	192
2043	2,989	216	200	0	0	0	0	0	0	0	498	204
2044	3,074	214	200	0	0	0	0	0	0	0	501	216
2045	3,161	214	200	0	0	0	0	0	0	0	502	231
2046	3,250	214	200	0	0	0	0	0	0	0	507	245
2047	3,342	214	200	0	0	0	0	0	0	0	513	260
2048	3,496	214	200	0	0	0	0	0	0	0	526	275
2049	3,631	214	200	0	0	0	0	0	0	0	531	301
2050	3,758	214	200	0	0	0	0	0	0	0	538	324
2051	3,887	214	200	0	0	0	0	0	0	0	546	345
2052	4,016	214	200	0	0	0	0	0	0	0	554	366
2053	4,149	214	200	0	0	0	0	0	0	0	561	388
2054	4,284	214	200	0	0	0	0	0	0	0	569	410
2055	4,412	214	200	0	0	0	0	0	0	0	577	431
2056	4,531	214	200	0	0	0	0	0	0	0	538	499
2057	4,653	214	200	0	0	0	0	0	0	0	525	537
2058	4,778	214	200	0	0	0	0	0	0	0	533	557
2059	4,906	214	200	0	0	0	0	0	0	0	542	577
2060	4,994	214	200	0	0	0	0	0	0	0	547	598

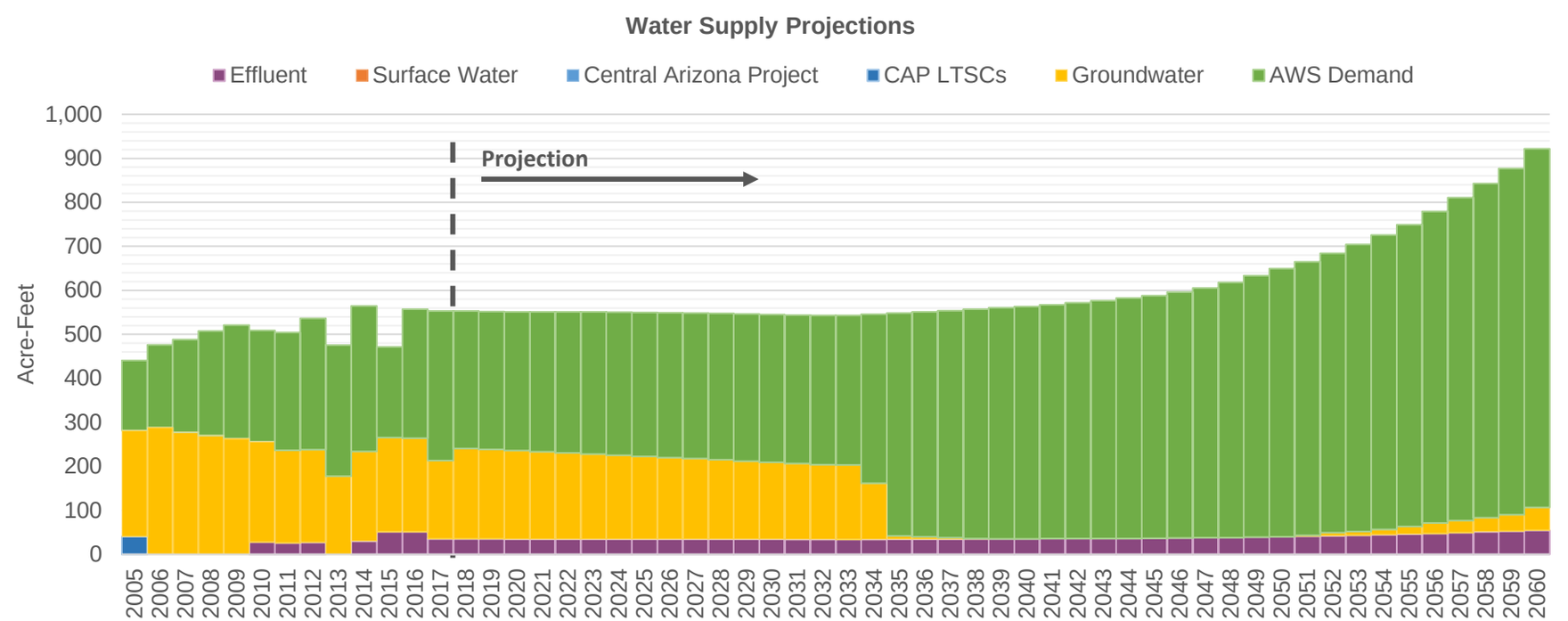
RidgeView

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

RidgeView

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

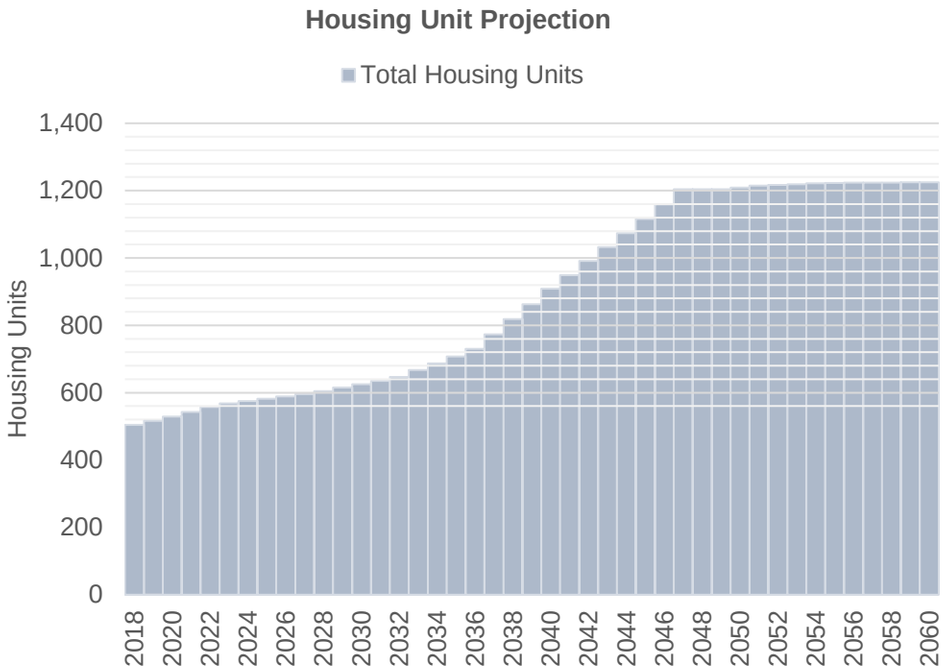
Water Supply Projections (Acre-Feet)

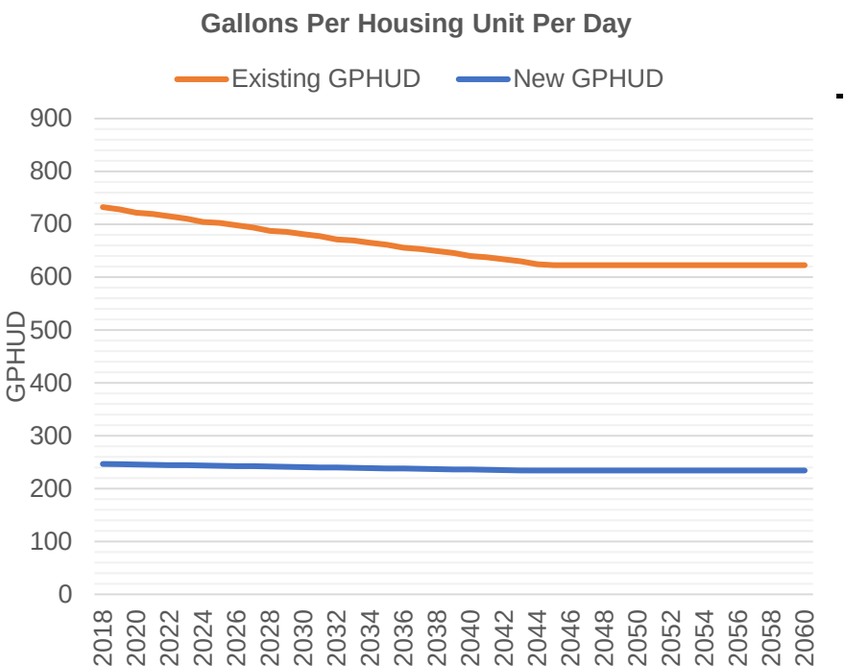
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	238	2,084	500	35	0	0	0	0	0	0	206	313
2019	243	2,072	499	35	0	0	0	0	0	0	204	313
2020	248	2,054	498	35	0	0	0	0	0	0	201	315
2021	254	2,047	497	35	0	0	0	0	0	0	198	318
2022	260	2,035	496	35	0	0	0	0	0	0	196	320
2023	265	2,022	495	35	0	0	0	0	0	0	193	323
2024	270	2,005	494	35	0	0	0	0	0	0	190	325
2025	274	1,998	493	35	0	0	0	0	0	0	188	327
2026	279	1,986	492	35	0	0	0	0	0	0	185	329
2027	284	1,974	491	35	0	0	0	0	0	0	183	331
2028	288	1,957	490	35	0	0	0	0	0	0	180	333
2029	291	1,951	489	35	0	0	0	0	0	0	177	334
2030	294	1,939	488	35	0	0	0	0	0	0	175	336
2031	298	1,927	487	34	0	0	0	0	0	0	173	337
2032	302	1.911	486	34	0	0	0	0	0	0	170	339
2033	312	1,904	485	34	0	0	0	0	0	0	169	340
2034	323	1,893	484	34	0	0	0	0	0	0	128	384
2035	333	1,881	483	35	0	0	0	0	0	0	7	507
2036	344	1,865	482	35	0	0	0	0	0	0	5	511
2037	355	1,859	481	35	0	0	0	0	0	0	3	516
2038	367	1,848	480	35	0	0	0	0	0	0	1	521
2039	378	1,837	479	35	0	0	0	0	0	0	0	525
2040	390	1,821	478	35	0	0	0	0	0	0	0	528
2041	405	1,815	477	36	0	0	0	0	0	0	0	532
2042	419	1,804	477	36	0	0	0	0	0	0	0	536
2043	434	1,793	476	36	0	0	0	0	0	0	0	541
2044	450	1,777	475	36	0	0	0	0	0	0	0	546
2045	466	1,772	475	37	0	0	0	0	0	0	0	551
2046	482	1,772	475	37	0	0	0	0	0	0	0	559
2047	499	1,772	475	38	0	0	0	0	0	0	0	567
2048	530	1,772	475	38	0	0	0	0	0	0	0	580
2049	559	1,772	475	39	0	0	0	0	0	0	0	595
2050	588	1,772	475	40	0	0	0	0	0	0	0	609
2051	619	1,772	475	41	0	0	0	0	0	0	2	622
2052	658	1,772	475	42	0	0	0	0	0	0	7	635
2053	697	1,772	475	43	0	0	0	0	0	0	9	652
2054	737	1,772	475	45	0	0	0	0	0	0	12	669
2055	787	1,772	475	46	0	0	0	0	0	0	18	686
2056	846	1,772	475	47	0	0	0	0	0	0	24	708
2057	907	1,772	475	49	0	0	0	0	0	0	28	733
2058	969	1,772	475	51	0	0	0	0	0	0	32	760
2059	1,033	1,772	475	53	0	0	0	0	0	0	37	786
2060	1,133	1,772	475	55	0	0	0	0	0	0	52	815

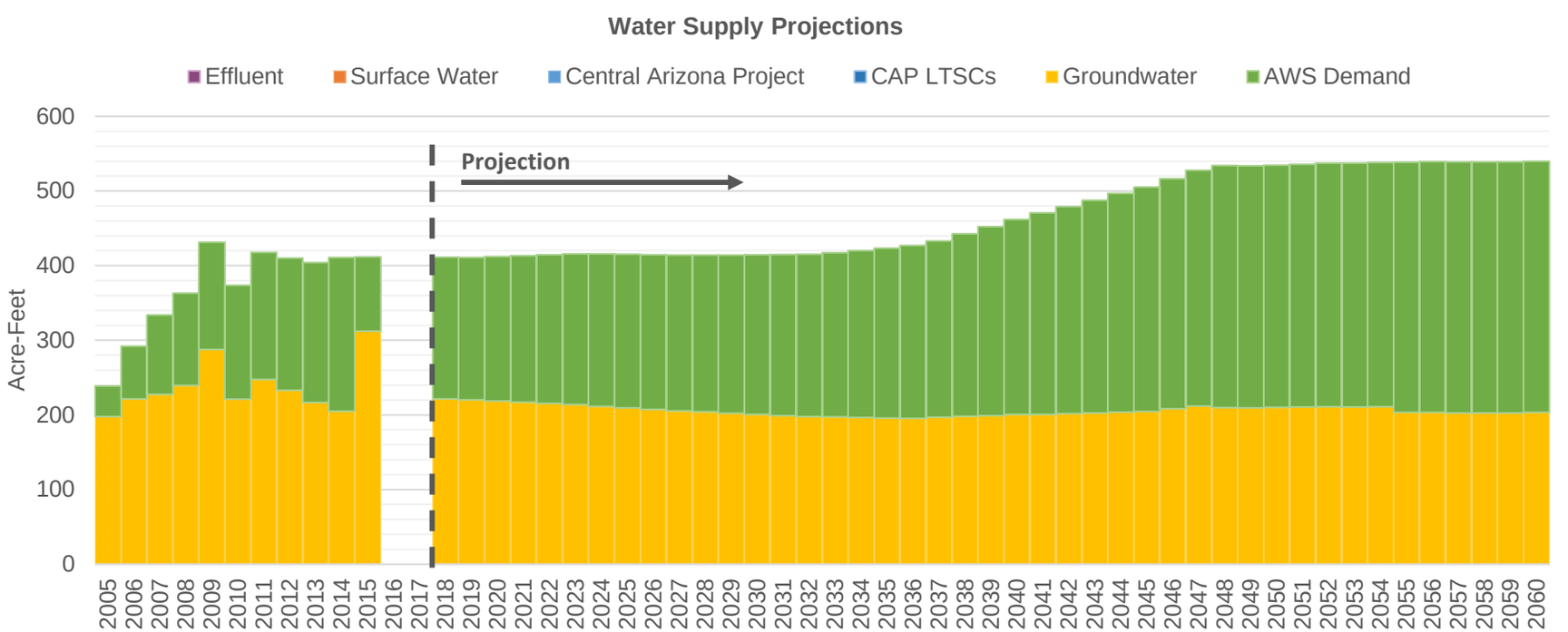
Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]

Saguaro







Central Arizona Project Service Area Model

Saguaro

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

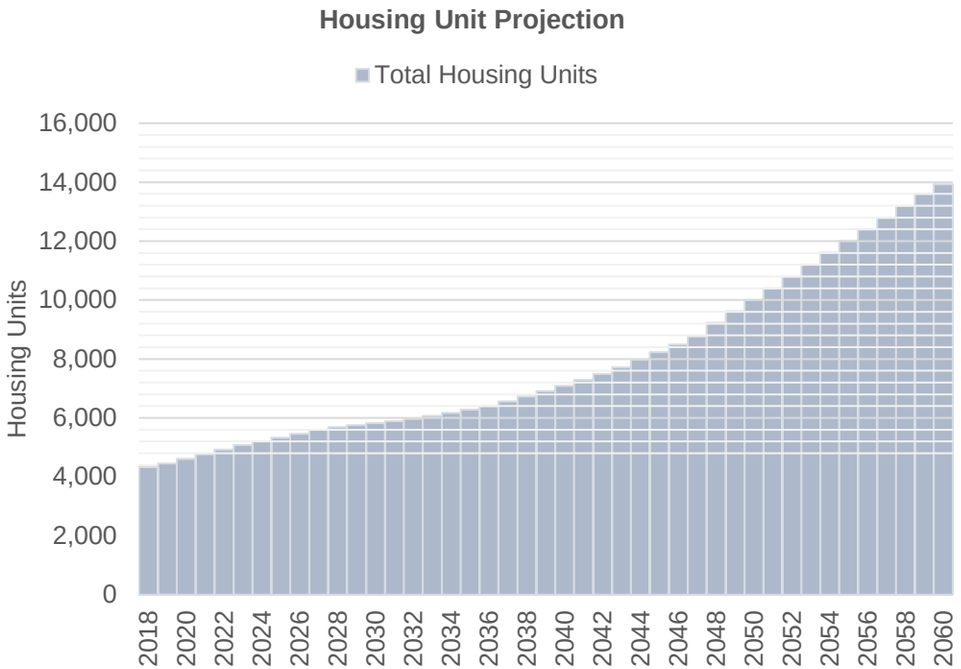
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

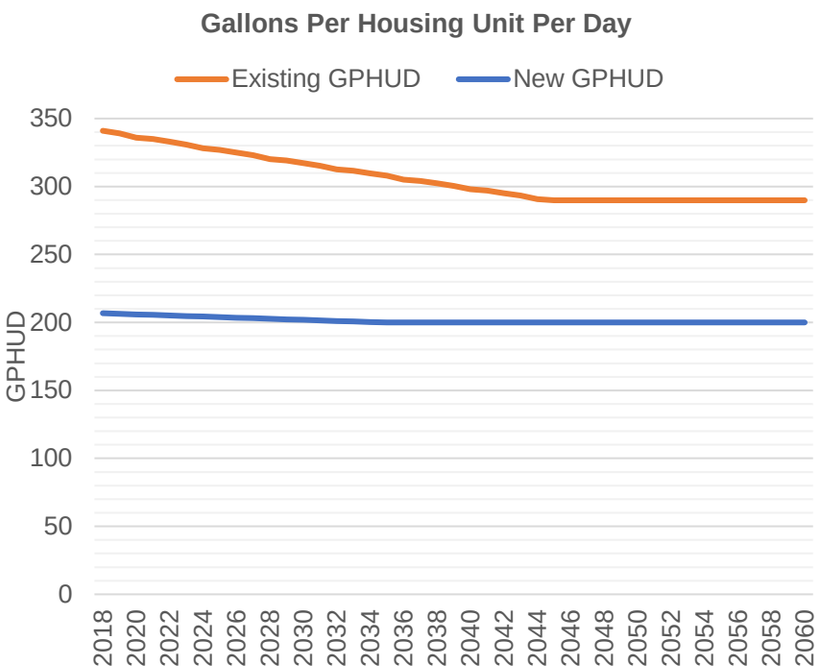
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	504	732	247	0	0	0	0	0	0	0	221	190
2019	516	728	246	0	0	0	0	0	0	0	220	191
2020	529	722	246	0	0	0	0	0	0	0	219	193
2021	543	719	245	0	0	0	0	0	0	0	217	196
2022	557	715	245	0	0	0	0	0	0	0	216	199
2023	568	711	244	0	0	0	0	0	0	0	214	202
2024	575	705	244	0	0	0	0	0	0	0	211	204
2025	582	702	243	0	0	0	0	0	0	0	209	206
2026	589	698	243	0	0	0	0	0	0	0	208	207
2027	596	694	242	0	0	0	0	0	0	0	206	209
2028	605	688	242	0	0	0	0	0	0	0	204	210
2029	615	686	241	0	0	0	0	0	0	0	202	212
2030	625	681	241	0	0	0	0	0	0	0	201	214
2031	635	677	240	0	0	0	0	0	0	0	199	216
2032	647	671	240	0	0	0	0	0	0	0	198	218
2033	667	669	239	0	0	0	0	0	0	0	197	220
2034	687	665	239	0	0	0	0	0	0	0	197	224
2035	708	661	238	0	0	0	0	0	0	0	196	228
2036	730	655	238	0	0	0	0	0	0	0	195	232
2037	773	653	237	0	0	0	0	0	0	0	197	236
2038	818	649	237	0	0	0	0	0	0	0	198	244
2039	863	646	236	0	0	0	0	0	0	0	199	253
2040	909	640	236	0	0	0	0	0	0	0	200	262
2041	949	638	235	0	0	0	0	0	0	0	201	270
2042	991	634	235	0	0	0	0	0	0	0	202	278
2043	1,032	630	235	0	0	0	0	0	0	0	202	285
2044	1,074	625	234	0	0	0	0	0	0	0	204	293
2045	1,116	623	234	0	0	0	0	0	0	0	205	301
2046	1,159	623	234	0	0	0	0	0	0	0	208	308
2047	1,204	623	234	0	0	0	0	0	0	0	212	316
2048	1,204	623	234	0	0	0	0	0	0	0	210	324
2049	1,204	623	234	0	0	0	0	0	0	0	209	324
2050	1,209	623	234	0	0	0	0	0	0	0	210	324
2051	1,215	623	234	0	0	0	0	0	0	0	211	325
2052	1,217	623	234	0	0	0	0	0	0	0	211	326
2053	1,219	623	234	0	0	0	0	0	0	0	211	327
2054	1,222	623	234	0	0	0	0	0	0	0	211	327
2055	1,223	623	234	0	0	0	0	0	0	0	204	335
2056	1,224	623	234	0	0	0	0	0	0	0	203	336
2057	1,224	623	234	0	0	0	0	0	0	0	203	336
2058	1,224	623	234	0	0	0	0	0	0	0	203	336
2059	1,225	623	234	0	0	0	0	0	0	0	203	336
2060	1,225	623	234	0	0	0	0	0	0	0	203	337

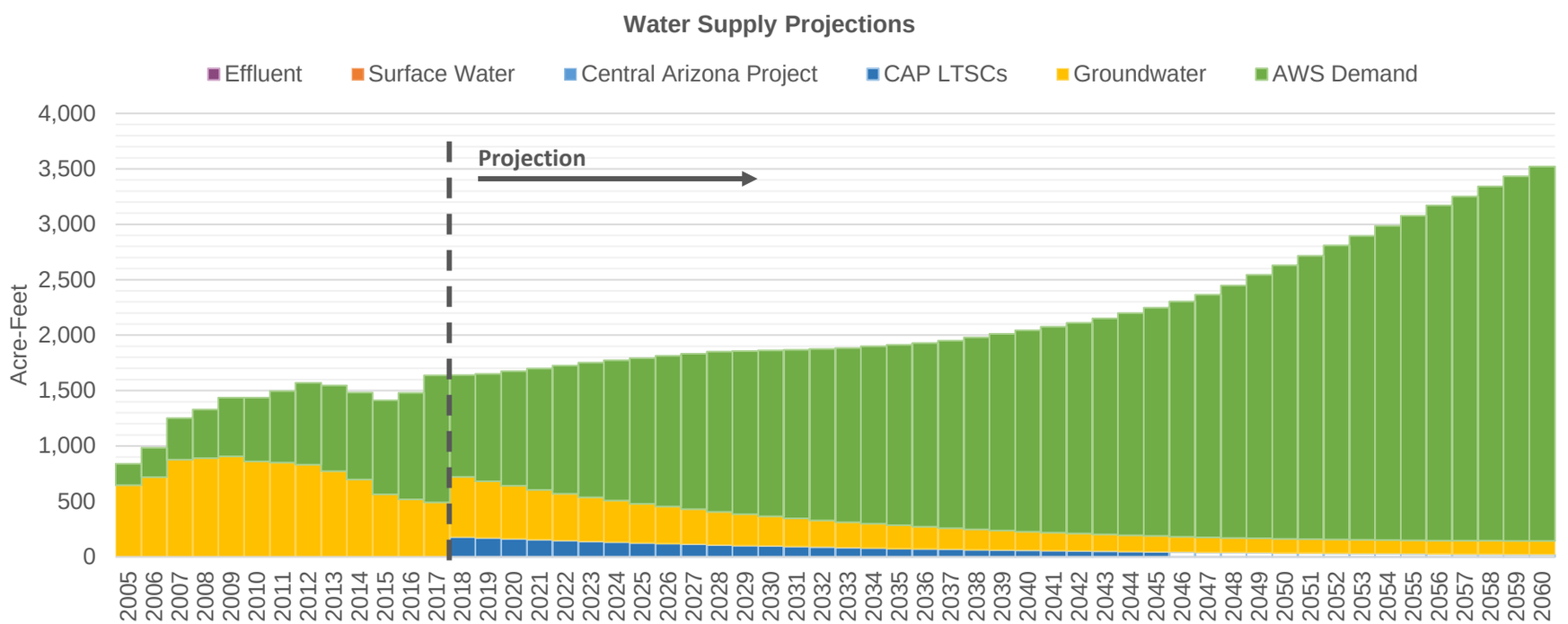
Central Arizona Project Service Area Model

Sahuarita

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Sahuarita

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

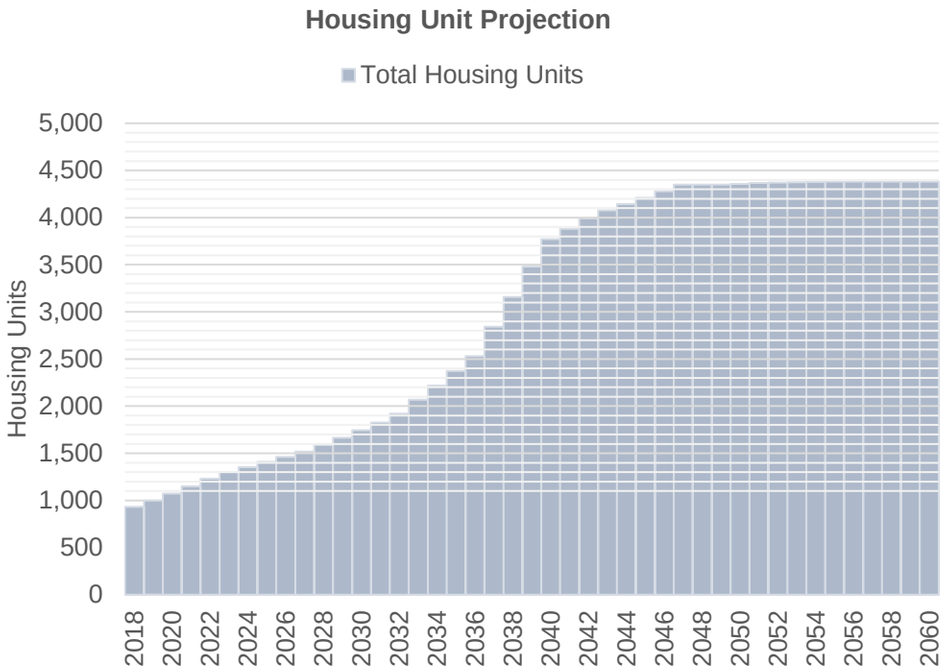
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

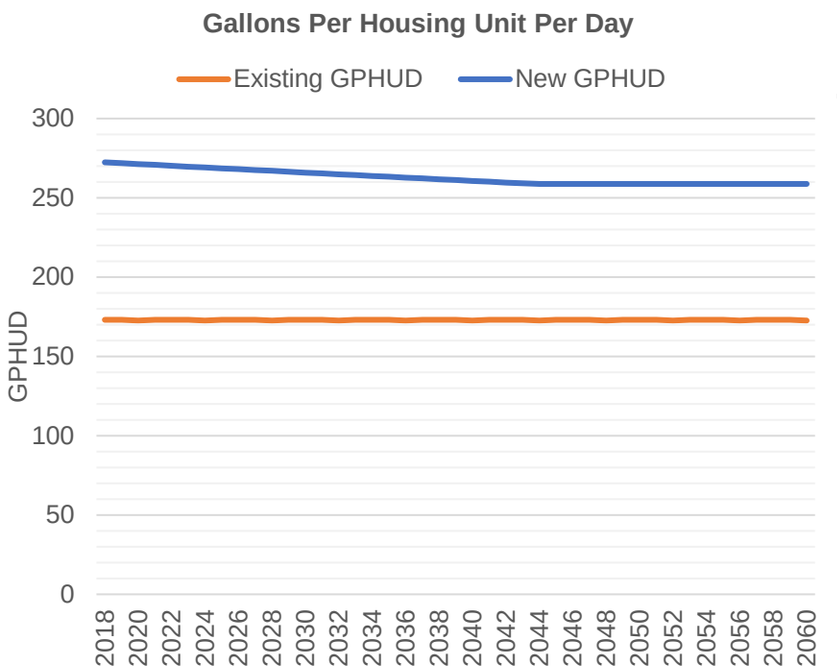
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,324	341	207	0	0	0	0	0	0	179	544	918
2019	4,455	339	206	0	0	0	0	0	0	171	510	970
2020	4,607	336	206	0	0	0	0	0	0	162	479	1,033
2021	4,766	335	206	0	0	0	0	0	0	154	450	1,096
2022	4,927	333	205	0	0	0	0	0	0	146	423	1,157
2023	5,077	331	205	0	0	0	0	0	0	139	398	1,215
2024	5,203	328	204	0	0	0	0	0	0	132	375	1,267
2025	5,331	327	204	0	0	0	0	0	0	125	354	1,314
2026	5,462	325	204	0	0	0	0	0	0	119	334	1,360
2027	5,595	323	203	0	0	0	0	0	0	113	316	1,404
2028	5,689	320	203	0	0	0	0	0	0	107	299	1,444
2029	5,754	319	202	0	0	0	0	0	0	102	283	1,472
2030	5,821	317	202	0	0	0	0	0	0	97	268	1,497
2031	5,889	315	201	0	0	0	0	0	0	92	255	1,521
2032	5.963	313	201	0	0	0	0	0	0	88	242	1.545
2033	6,067	312	201	0	0	0	0	0	0	83	230	1,571
2034	6,174	310	200	0	0	0	0	0	0	79	220	1,600
2035	6,282	308	200	0	0	0	0	0	0	75	209	1,628
2036	6,394	305	200	0	0	0	0	0	0	71	200	1,658
2037	6,562	304	200	0	0	0	0	0	0	68	191	1,692
2038	6,734	302	200	0	0	0	0	0	0	64	183	1,733
2039	6,910	301	200	0	0	0	0	0	0	61	176	1,773
2040	7,093	298	200	0	0	0	0	0	0	58	169	1,816
2041	7,289	297	200	0	0	0	0	0	0	55	163	1,858
2042	7,491	295	200	0	0	0	0	0	0	52	157	1,902
2043	7,721	293	200	0	0	0	0	0	0	50	152	1,950
2044	7,972	291	200	0	0	0	0	0	0	47	147	2,005
2045	8,230	290	200	0	0	0	0	0	0	45	143	2,058
2046	8,494	290	200	0	0	0	0	0	0	43	139	2,122
2047	8,765	290	200	0	0	0	0	0	0	41	136	2,188
2048	9,226	290	200	0	0	0	0	0	0	39	133	2,278
2049	9,628	290	200	0	0	0	0	0	0	37	130	2,376
2050	10,008	290	200	0	0	0	0	0	0	35	128	2,468
2051	10,398	290	200	0	0	0	0	0	0	33	126	2,558
2052	10,792	290	200	0	0	0	0	0	0	31	125	2,653
2053	11,196	290	200	0	0	0	0	0	0	30	123	2,741
2054	11,611	290	200	0	0	0	0	0	0	28	123	2,835
2055	12,012	290	200	0	0	0	0	0	0	27	122	2,928
2056	12,394	290	200	0	0	0	0	0	0	26	122	3,022
2057	12,787	290	200	0	0	0	0	0	0	24	122	3,105
2058	13,190	290	200	0	0	0	0	0	0	23	122	3,195
2059	13,604	290	200	0	0	0	0	0	0	22	123	3,288
2060	13,930	290	200	0	0	0	0	0	0	21	124	3,377

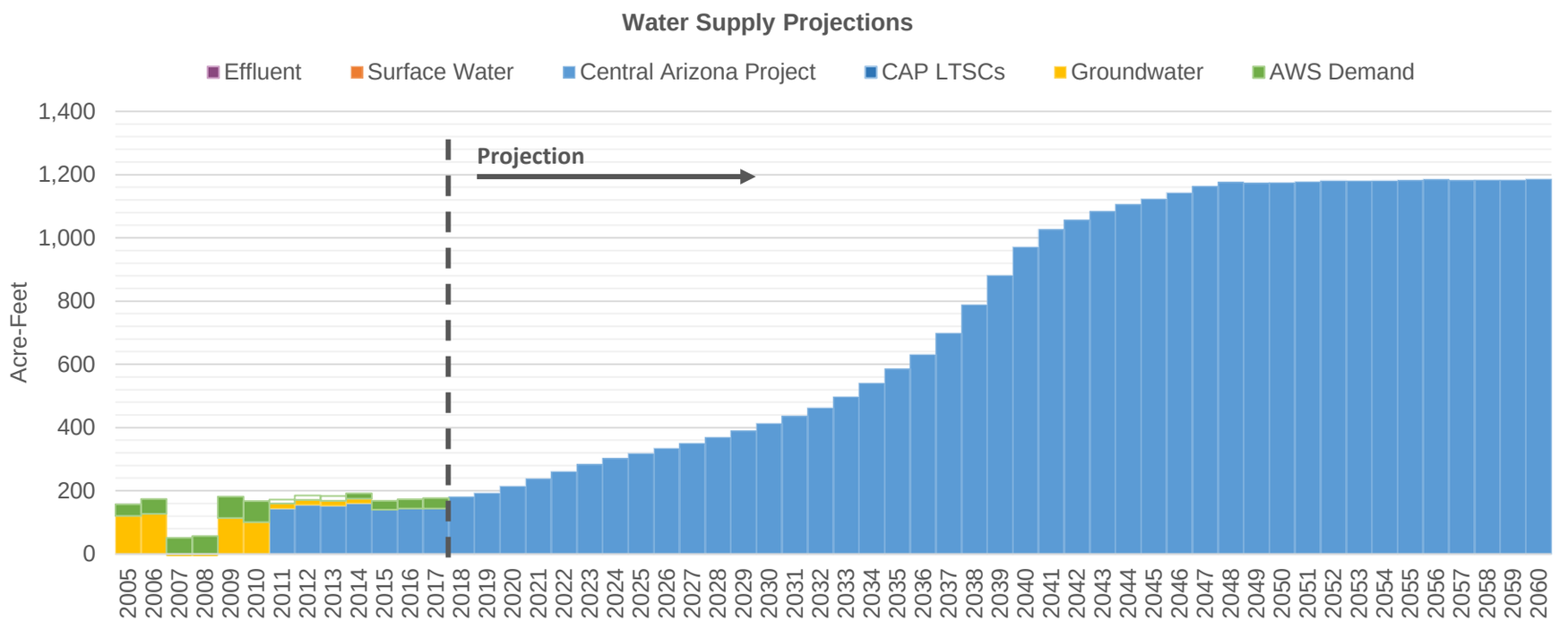
Central Arizona Project Service Area Model

SpanishTrailWC

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

SpanishTrailWC

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

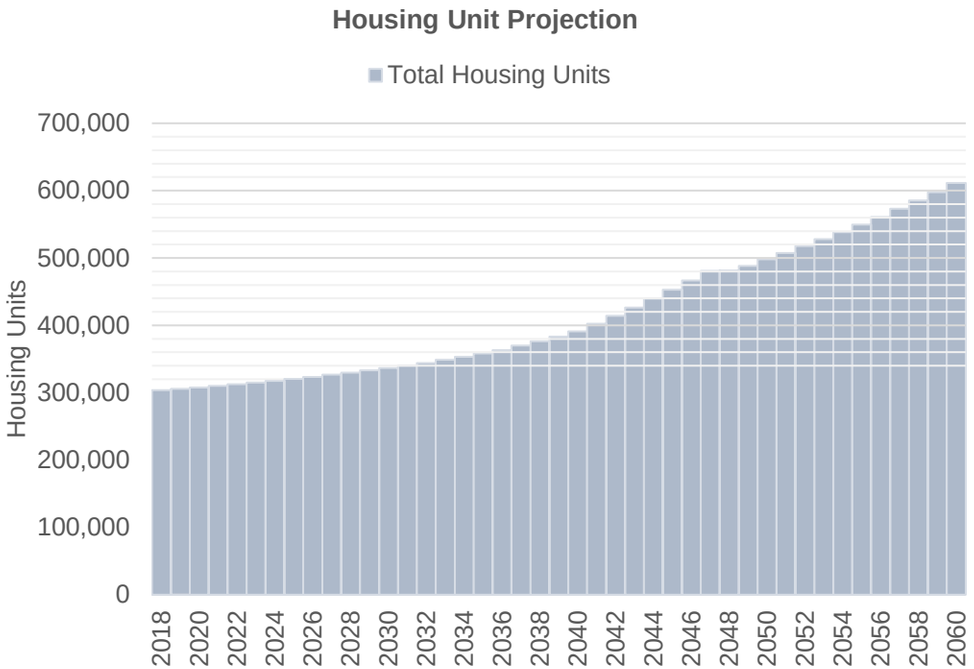
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

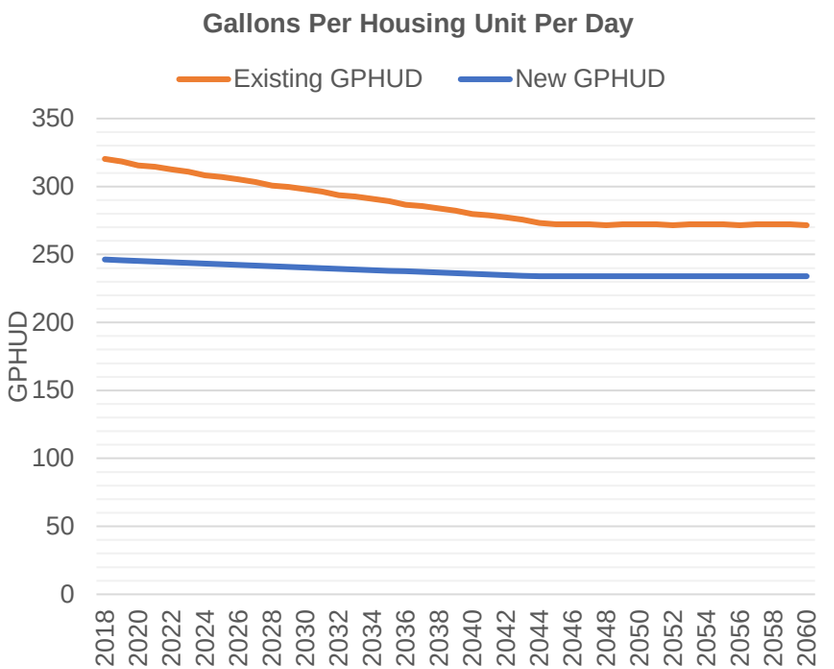
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	933	173	272	0	0	0	0	180	2,857	0	0	0
2019	998	173	272	0	0	0	0	193	2,844	0	0	0
2020	1,073	173	271	0	0	0	0	214	2,823	0	0	0
2021	1,151	173	271	0	0	0	0	237	2,800	0	0	0
2022	1,231	173	270	0	0	0	0	261	2,776	0	0	0
2023	1,302	173	270	0	0	0	0	284	2,753	0	0	0
2024	1,354	173	269	0	0	0	0	303	2,734	0	0	0
2025	1,408	173	269	0	0	0	0	318	2,719	0	0	0
2026	1,462	173	268	0	0	0	0	334	2,703	0	0	0
2027	1,518	173	268	0	0	0	0	350	2,687	0	0	0
2028	1,587	173	267	0	0	0	0	369	2,668	0	0	0
2029	1,665	173	266	0	0	0	0	390	2,647	0	0	0
2030	1,744	173	266	0	0	0	0	413	2,624	0	0	0
2031	1,826	173	265	0	0	0	0	436	2,601	0	0	0
2032	1.919	173	265	0	0	0	0	462	2.575	0	0	0
2033	2,067	173	264	0	0	0	0	497	2,540	0	0	0
2034	2,218	173	264	0	0	0	0	540	2,497	0	0	0
2035	2,373	173	263	0	0	0	0	585	2,452	0	0	0
2036	2,532	173	263	0	0	0	0	631	2,406	0	0	0
2037	2,842	173	262	0	0	0	0	698	2,339	0	0	0
2038	3,158	173	262	0	0	0	0	789	2,248	0	0	0
2039	3,482	173	261	0	0	0	0	881	1,620	0	0	0
2040	3,771	173	261	0	0	0	0	971	2,046	0	0	0
2041	3,881	173	260	0	0	0	0	1,026	2,011	0	0	0
2042	3,993	173	260	0	0	0	0	1,056	1,981	0	0	0
2043	4,077	173	259	0	0	0	0	1,083	1,954	0	0	0
2044	4,142	173	259	0	0	0	0	1,106	1,931	0	0	0
2045	4,210	173	259	0	0	0	0	1,123	1,914	0	0	0
2046	4,278	173	259	0	0	0	0	1,143	1,894	0	0	0
2047	4,349	173	259	0	0	0	0	1,163	1,874	0	0	0
2048	4,349	173	259	0	0	0	0	1,176	1,861	0	0	0
2049	4,349	173	259	0	0	0	0	1,173	1,864	0	0	0
2050	4,358	173	259	0	0	0	0	1,174	1,863	0	0	0
2051	4,366	173	259	0	0	0	0	1,177	1,860	0	0	0
2052	4,370	173	259	0	0	0	0	1,181	1,758	0	0	0
2053	4,373	173	259	0	0	0	0	1,180	1,759	0	0	0
2054	4,377	173	259	0	0	0	0	1,181	1,548	0	0	0
2055	4,380	173	259	0	0	0	0	1,182	1,073	0	0	0
2056	4,380	173	259	0	0	0	0	1,185	806	0	0	0
2057	4,381	173	259	0	0	0	0	1,182	1,546	0	0	0
2058	4,381	173	259	0	0	0	0	1,182	1,546	0	0	0
2059	4,382	173	259	0	0	0	0	1,182	1,546	0	0	0
2060	4,382	173	259	0	0	0	0	1,185	1,543	0	0	0

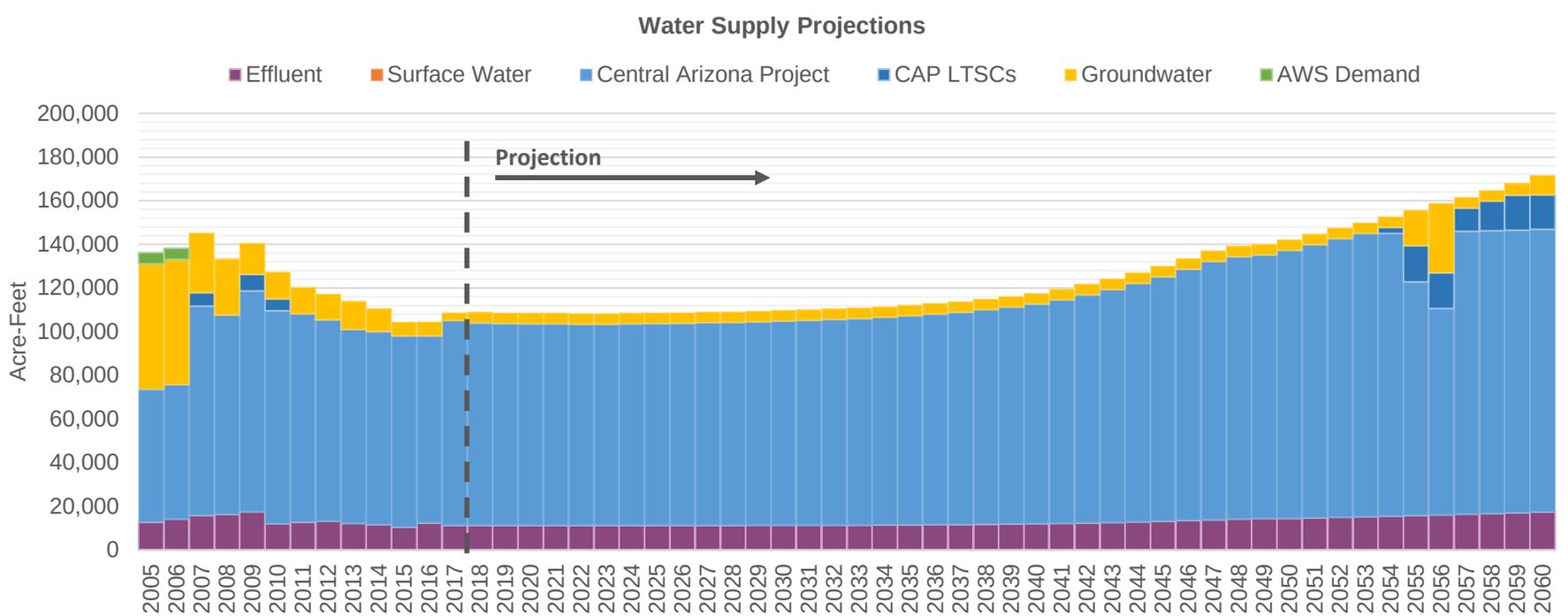
Tucson

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Tucson

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

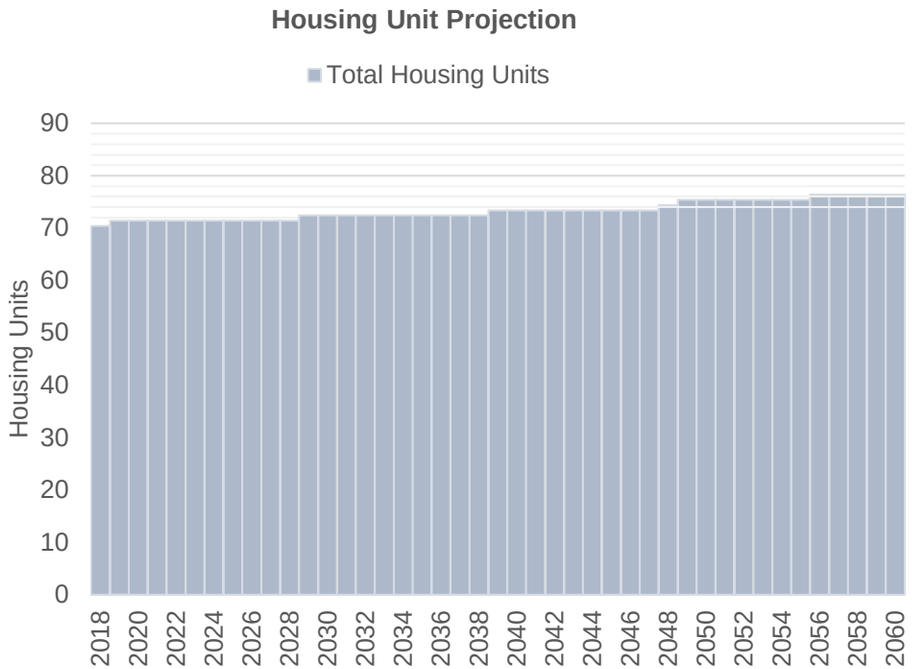
Water Supply Projections (Acre-Feet)

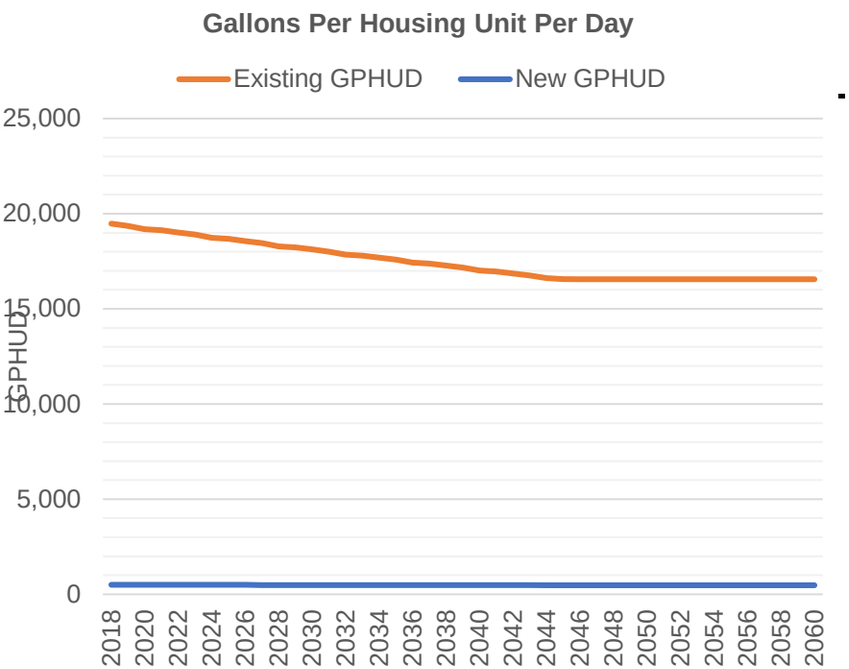
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	303,802	320	246	11,236	0	0	0	92,687	51,485	0	4,951	0
2019	305,670	318	246	11,236	0	0	0	92,371	51,801	0	4,951	0
2020	307,830	316	245	11,203	0	0	0	92,311	51,861	0	4,951	0
2021	310,088	315	245	11,194	0	0	0	92,276	51,896	0	4,951	0
2022	312,375	313	244	11,189	0	0	0	92,259	51,913	0	4,951	0
2023	314,846	311	244	11,187	0	0	0	92,269	51,903	0	4,951	0
2024	317,694	308	243	11,188	0	0	0	92,364	51,808	0	4,951	0
2025	320,599	307	243	11,198	0	0	0	92,490	51,682	0	4,951	0
2026	323,563	305	242	11,212	0	0	0	92,639	51,534	0	4,951	0
2027	326,589	303	242	11,228	0	0	0	92,802	51,371	0	4,951	0
2028	329,821	301	241	11,247	0	0	0	93,017	51,155	0	4,951	0
2029	333,224	300	241	11,271	0	0	0	93,242	50,930	0	4,951	0
2030	336,698	298	240	11,297	0	0	0	93,516	50,656	0	4,951	0
2031	340,247	296	240	11,328	0	0	0	93,805	50,367	0	4,951	0
2032	344,022	294	240	11,361	0	0	0	94,160	50,012	0	4,951	0
2033	348,673	293	239	11,401	0	0	0	94,598	49,574	0	4,951	0
2034	353,426	291	239	11,450	0	0	0	95,186	48,986	0	4,951	0
2035	358,283	289	238	11,516	0	0	0	95,783	48,389	0	4,951	0
2036	363,263	287	238	11,584	0	0	0	96,449	47,723	0	4,951	0
2037	369,842	286	237	11,660	0	0	0	97,250	46,922	0	4,951	0
2038	376,569	284	237	11,751	0	0	0	98,307	45,865	0	4,951	0
2039	383,450	282	236	11,869	0	0	0	99,373	19,372	0	4,951	0
2040	391,218	280	236	11,991	0	0	0	100,629	42,601	0	4,951	0
2041	402,457	279	235	12,134	0	0	0	102,314	41,858	0	4,951	0
2042	413,959	277	235	12,322	0	0	0	104,498	39,674	0	4,951	0
2043	426,369	276	234	12,567	0	0	0	106,771	37,402	0	4,951	0
2044	439,516	273	234	12,827	0	0	0	109,354	34,818	0	4,951	0
2045	452,973	272	234	13,120	0	0	0	111,896	32,276	0	4,951	0
2046	466,737	272	234	13,413	0	0	0	115,168	29,004	0	4,951	0
2047	480,835	272	234	13,781	0	0	0	118,451	25,721	0	4,951	0
2048	481,573	272	234	14,158	0	0	0	120,147	24,025	0	4,951	0
2049	488,319	272	234	14,371	0	0	0	120,786	23,386	0	4,951	0
2050	497,810	272	234	14,459	0	0	0	122,826	21,346	0	4,951	0
2051	507,551	272	234	14,679	0	0	0	125,127	19,045	0	4,951	0
2052	517,595	272	234	14,939	0	0	0	127,610	11,904	0	4,951	0
2053	527,894	272	234	15,222	0	0	0	129,843	9,671	0	4,951	0
2054	538,457	272	234	15,482	0	0	0	129,512	0	2,805	4,951	0
2055	549,507	272	234	15,764	0	0	0	107,007	0	16,601	16,211	0
2056	561,091	272	234	16,056	0	0	0	94,505	0	16,435	31,735	0
2057	572,978	272	234	16,381	0	0	0	129,512	0	10,781	4,951	0
2058	585,178	272	234	16,680	0	0	0	129,512	0	13,639	4,951	0
2059	597,701	272	234	17,006	0	0	0	129,512	0	16,026	5,479	0
2060	611,536	272	234	17,340	0	0	0	129,512	0	15,866	8,976	0

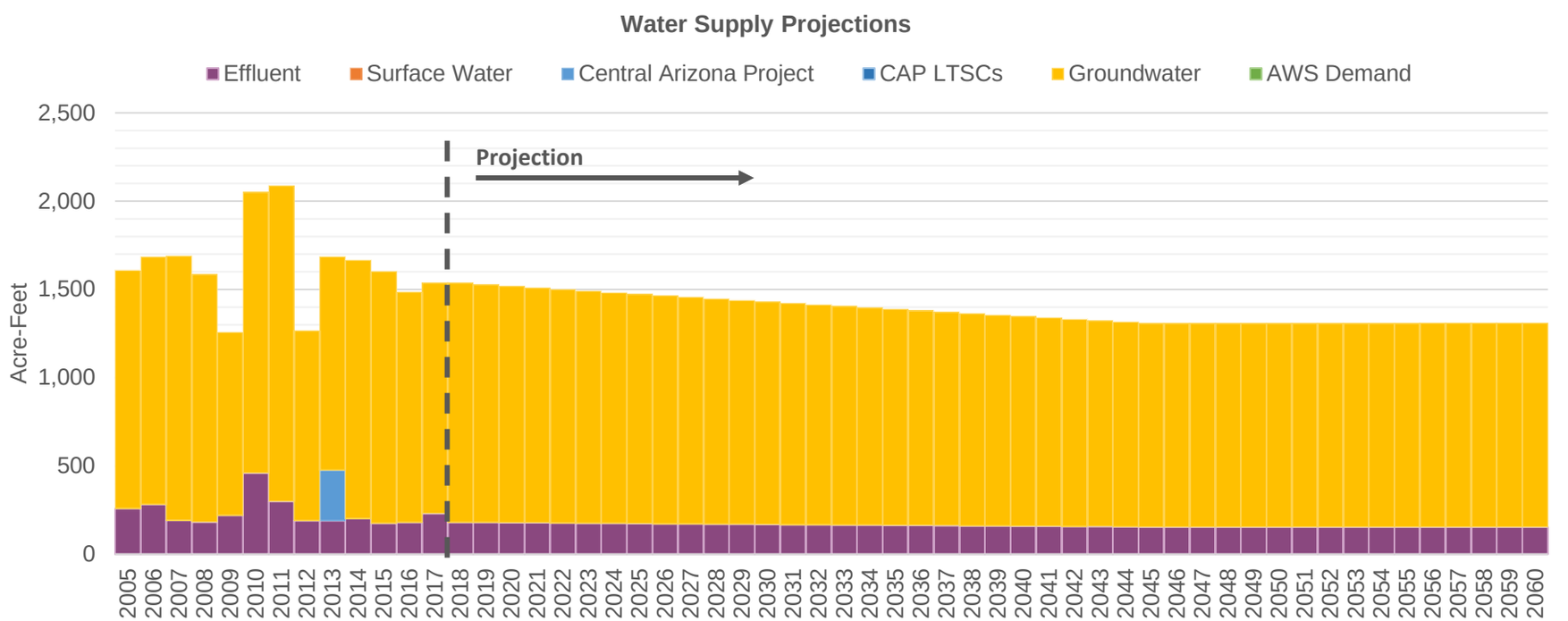
UniversityofAZ

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

UniversityofAZ

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions

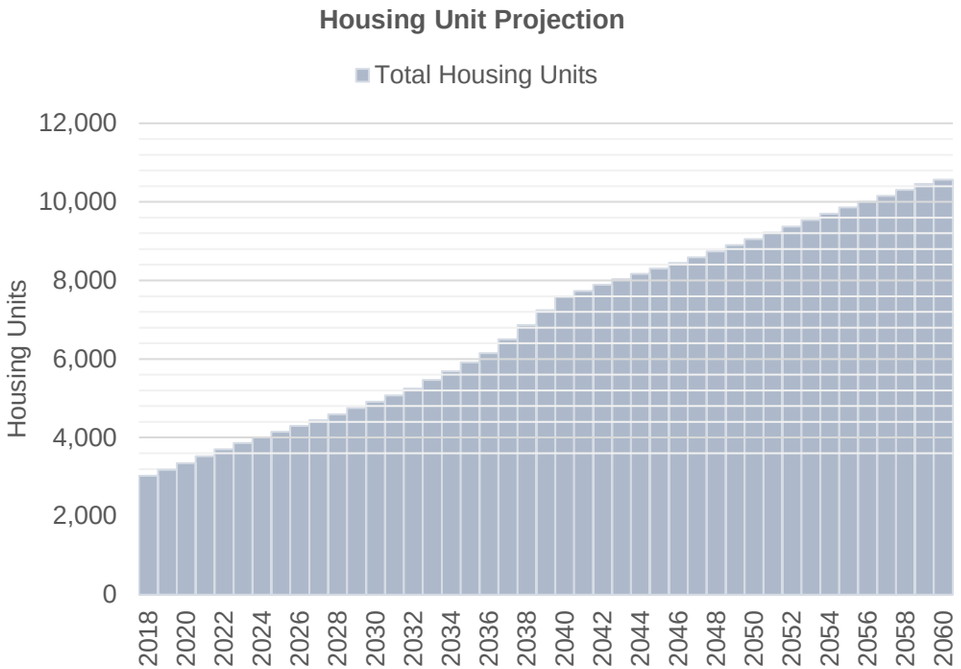
Water Supply Projections (Acre-Feet)

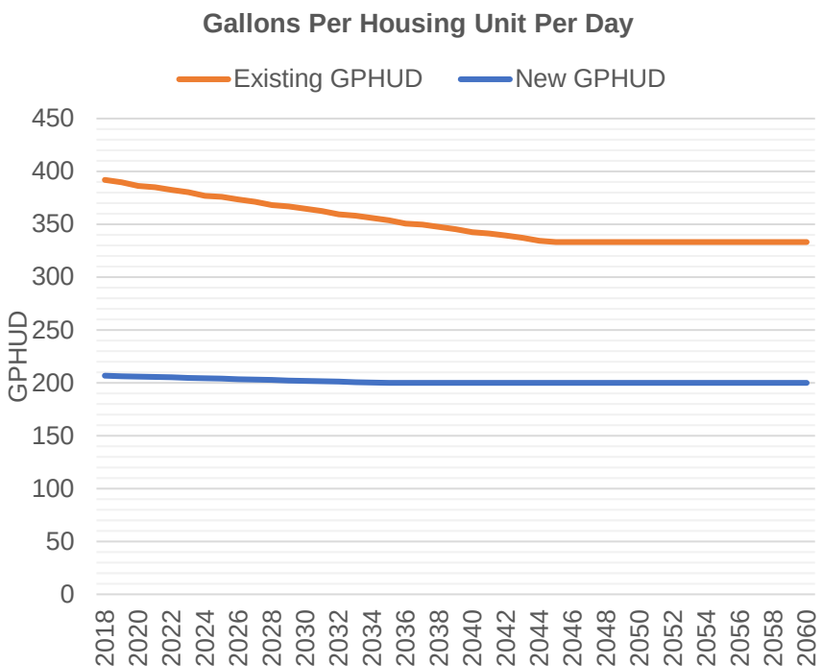
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	70	19,478	500	180	0	0	0	0	0	0	1,356	0
2019	71	19,361	499	180	0	0	0	0	0	0	1,347	0
2020	71	19,192	498	179	0	0	0	0	0	0	1,339	0
2021	71	19,129	497	178	0	0	0	0	0	0	1,331	0
2022	71	19,015	496	177	0	0	0	0	0	0	1,323	0
2023	71	18,901	495	176	0	0	0	0	0	0	1,315	0
2024	71	18,736	494	175	0	0	0	0	0	0	1,307	0
2025	71	18,674	493	174	0	0	0	0	0	0	1,300	0
2026	71	18,562	492	173	0	0	0	0	0	0	1,292	0
2027	71	18,451	491	172	0	0	0	0	0	0	1,284	0
2028	71	18,290	490	171	0	0	0	0	0	0	1,276	0
2029	72	18,230	489	170	0	0	0	0	0	0	1,269	0
2030	72	18,121	488	169	0	0	0	0	0	0	1,262	0
2031	72	18,012	487	168	0	0	0	0	0	0	1,254	0
2032	72	17,855	486	167	0	0	0	0	0	0	1,246	0
2033	72	17,797	485	166	0	0	0	0	0	0	1,239	0
2034	72	17,690	484	165	0	0	0	0	0	0	1,231	0
2035	72	17,584	483	164	0	0	0	0	0	0	1,224	0
2036	72	17,431	482	163	0	0	0	0	0	0	1,217	0
2037	72	17,373	481	162	0	0	0	0	0	0	1,209	0
2038	72	17,269	480	161	0	0	0	0	0	0	1,202	0
2039	73	17,166	479	160	0	0	0	0	0	0	1,195	0
2040	73	17,016	478	159	0	0	0	0	0	0	1,188	0
2041	73	16,960	477	158	0	0	0	0	0	0	1,181	0
2042	73	16,858	477	157	0	0	0	0	0	0	1,174	0
2043	73	16,757	476	156	0	0	0	0	0	0	1,167	0
2044	73	16,611	475	155	0	0	0	0	0	0	1,160	0
2045	73	16,557	475	154	0	0	0	0	0	0	1,153	0
2046	73	16,556	475	153	0	0	0	0	0	0	1,154	0
2047	73	16,556	475	153	0	0	0	0	0	0	1,154	0
2048	74	16,556	475	153	0	0	0	0	0	0	1,154	0
2049	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2050	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2051	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2052	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2053	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2054	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2055	75	16,556	475	153	0	0	0	0	0	0	1,155	0
2056	76	16,556	475	153	0	0	0	0	0	0	1,156	0
2057	76	16,556	475	153	0	0	0	0	0	0	1,156	0
2058	76	16,556	475	153	0	0	0	0	0	0	1,156	0
2059	76	16,556	475	153	0	0	0	0	0	0	1,156	0
2060	76	16,556	475	153	0	0	0	0	0	0	1,156	0

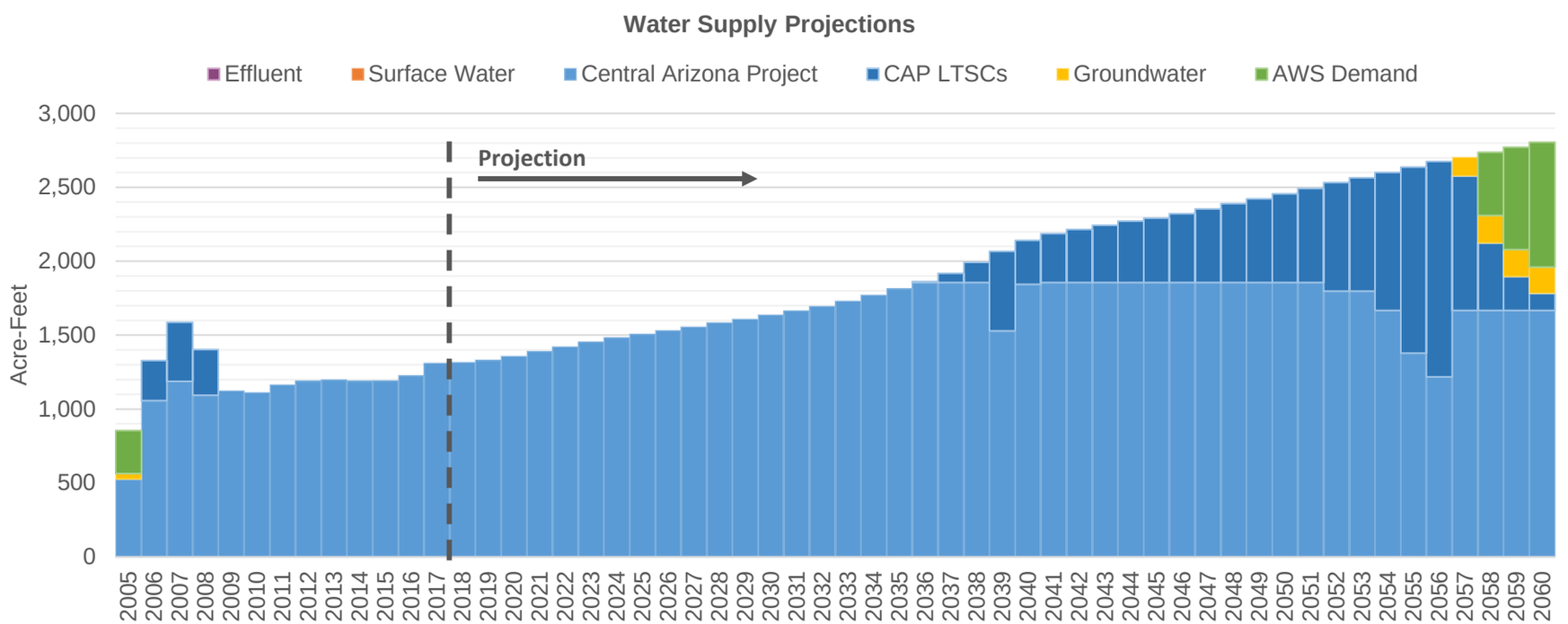
VailWC

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

VailWC

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

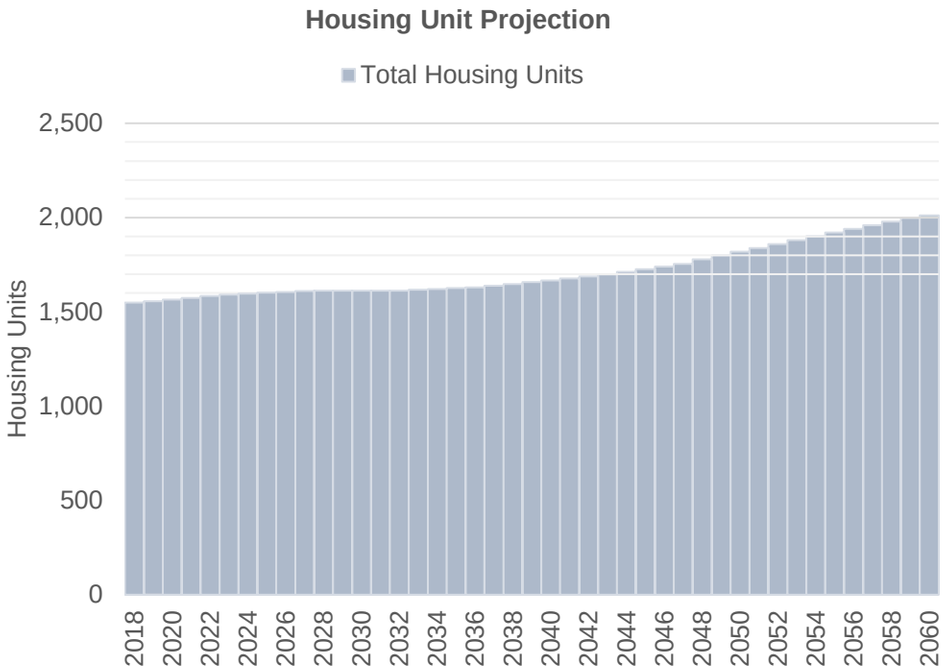
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

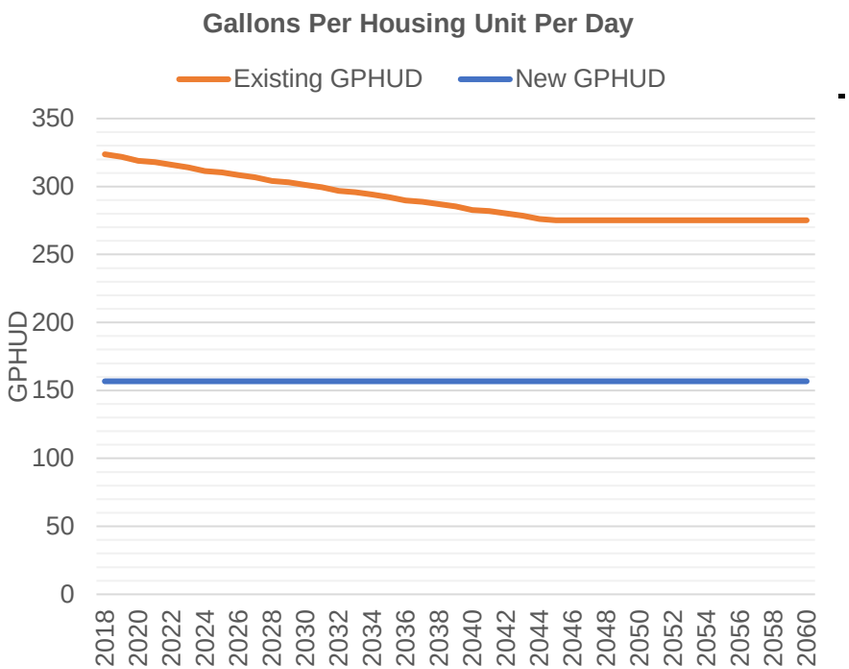
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,032	392	207	0	0	0	0	1,317	540	0	0	0
2019	3,177	390	206	0	0	0	0	1,331	526	0	0	0
2020	3,345	386	206	0	0	0	0	1,359	498	0	0	0
2021	3,521	385	206	0	0	0	0	1,391	466	0	0	0
2022	3,698	383	205	0	0	0	0	1,423	434	0	0	0
2023	3,864	380	205	0	0	0	0	1,455	402	0	0	0
2024	4,005	377	204	0	0	0	0	1,483	374	0	0	0
2025	4,149	376	204	0	0	0	0	1,506	351	0	0	0
2026	4,295	374	204	0	0	0	0	1,531	326	0	0	0
2027	4,445	371	203	0	0	0	0	1,557	300	0	0	0
2028	4,597	368	203	0	0	0	0	1,584	273	0	0	0
2029	4,753	367	202	0	0	0	0	1,610	247	0	0	0
2030	4,912	365	202	0	0	0	0	1,638	219	0	0	0
2031	5,074	362	201	0	0	0	0	1,666	191	0	0	0
2032	5.247	359	201	0	0	0	0	1.696	161	0	0	0
2033	5,466	358	201	0	0	0	0	1,731	126	0	0	0
2034	5,689	356	200	0	0	0	0	1,772	85	0	0	0
2035	5,917	354	200	0	0	0	0	1,815	42	0	0	0
2036	6,151	351	200	0	0	0	0	1,857	0	4	0	0
2037	6,506	350	200	0	0	0	0	1,857	0	61	0	0
2038	6,868	348	200	0	0	0	0	1,857	0	135	0	0
2039	7,239	345	200	0	0	0	0	1,529	0	537	0	0
2040	7,576	342	200	0	0	0	0	1,845	0	297	0	0
2041	7,733	341	200	0	0	0	0	1,857	0	331	0	0
2042	7,893	339	200	0	0	0	0	1,857	0	359	0	0
2043	8,037	337	200	0	0	0	0	1,857	0	387	0	0
2044	8,169	334	200	0	0	0	0	1,857	0	414	0	0
2045	8,305	333	200	0	0	0	0	1,857	0	434	0	0
2046	8,445	333	200	0	0	0	0	1,857	0	465	0	0
2047	8,587	333	200	0	0	0	0	1,857	0	496	0	0
2048	8,742	333	200	0	0	0	0	1,857	0	533	0	0
2049	8,897	333	200	0	0	0	0	1,857	0	564	0	0
2050	9,055	333	200	0	0	0	0	1,857	0	600	0	0
2051	9,216	333	200	0	0	0	0	1,857	0	635	0	0
2052	9,374	333	200	0	0	0	0	1,797	0	735	0	0
2053	9,536	333	200	0	0	0	0	1,797	0	767	0	0
2054	9,702	333	200	0	0	0	0	1,668	0	932	0	0
2055	9,858	333	200	0	0	0	0	1,378	0	1,258	0	0
2056	10,003	333	200	0	0	0	0	1,217	0	1,457	0	0
2057	10,151	333	200	0	0	0	0	1,668	0	909	126	0
2058	10,303	333	200	0	0	0	0	1,668	0	455	187	427
2059	10,459	333	200	0	0	0	0	1,668	0	227	183	693
2060	10,565	333	200	0	0	0	0	1,668	0	114	179	844

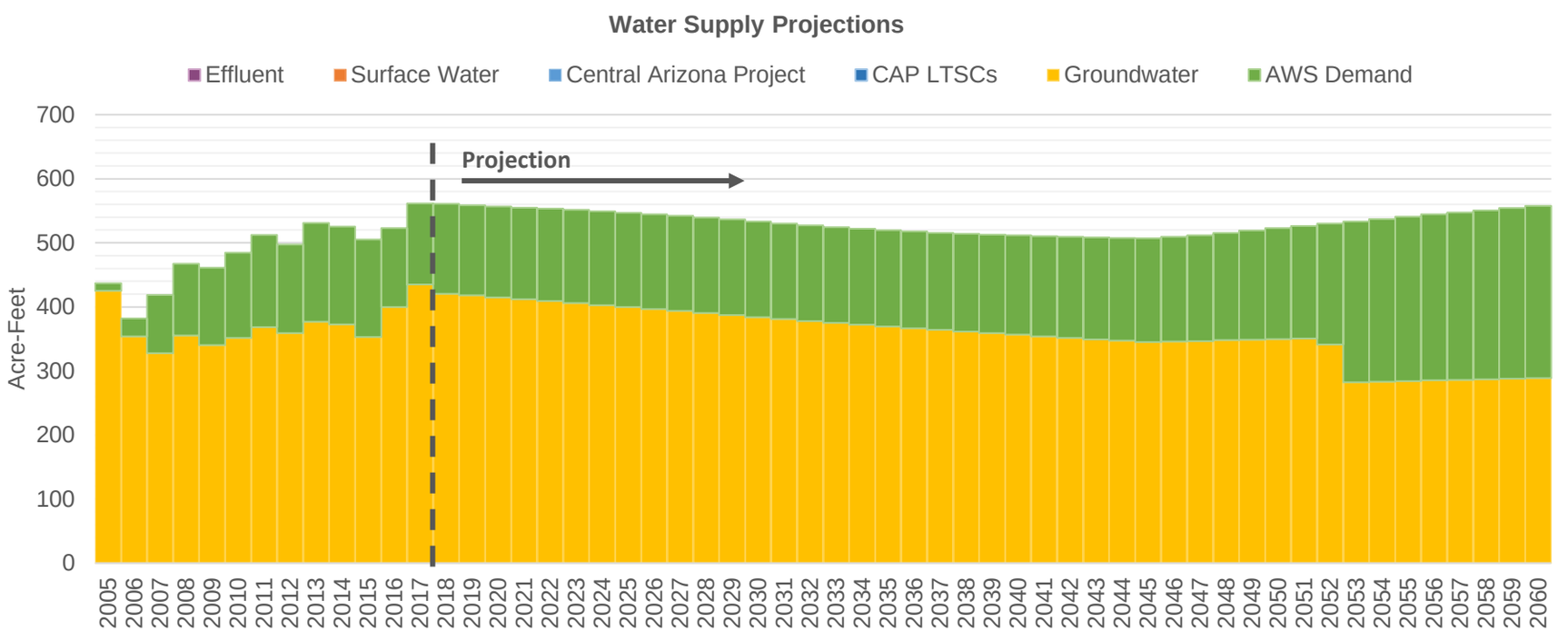
VoyagerWC

Central Arizona Project Service Area Model

C. Rapid, Outward, Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

VoyagerWC

C. Rapid, Outward, Dry Climate [LSCRBS]

7/7/20 6:54 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,549	324	157	0	0	0	0	0	0	0	421	141
2019	1,557	322	157	0	0	0	0	0	0	0	418	141
2020	1,565	319	157	0	0	0	0	0	0	0	415	142
2021	1,574	318	157	0	0	0	0	0	0	0	412	143
2022	1,584	316	157	0	0	0	0	0	0	0	409	144
2023	1,591	314	157	0	0	0	0	0	0	0	406	146
2024	1,596	311	157	0	0	0	0	0	0	0	403	146
2025	1,601	310	157	0	0	0	0	0	0	0	400	147
2026	1,606	309	157	0	0	0	0	0	0	0	397	148
2027	1,610	307	157	0	0	0	0	0	0	0	394	148
2028	1,612	304	157	0	0	0	0	0	0	0	391	149
2029	1,612	303	157	0	0	0	0	0	0	0	387	149
2030	1,612	301	157	0	0	0	0	0	0	0	384	149
2031	1,612	299	157	0	0	0	0	0	0	0	381	149
2032	1,612	297	157	0	0	0	0	0	0	0	378	149
2033	1,617	296	157	0	0	0	0	0	0	0	375	149
2034	1,621	294	157	0	0	0	0	0	0	0	372	150
2035	1,626	292	157	0	0	0	0	0	0	0	369	150
2036	1,630	290	157	0	0	0	0	0	0	0	367	151
2037	1,639	289	157	0	0	0	0	0	0	0	364	152
2038	1,648	287	157	0	0	0	0	0	0	0	362	153
2039	1,657	285	157	0	0	0	0	0	0	0	359	154
2040	1,667	283	157	0	0	0	0	0	0	0	357	155
2041	1,677	282	157	0	0	0	0	0	0	0	354	156
2042	1,687	280	157	0	0	0	0	0	0	0	352	158
2043	1,699	279	157	0	0	0	0	0	0	0	349	159
2044	1,713	276	157	0	0	0	0	0	0	0	347	160
2045	1,726	275	157	0	0	0	0	0	0	0	345	162
2046	1,740	275	157	0	0	0	0	0	0	0	346	164
2047	1,754	275	157	0	0	0	0	0	0	0	346	166
2048	1,779	275	157	0	0	0	0	0	0	0	348	167
2049	1,799	275	157	0	0	0	0	0	0	0	349	170
2050	1,819	275	157	0	0	0	0	0	0	0	350	173
2051	1,839	275	157	0	0	0	0	0	0	0	351	176
2052	1,859	275	157	0	0	0	0	0	0	0	341	189
2053	1,880	275	157	0	0	0	0	0	0	0	282	251
2054	1,901	275	157	0	0	0	0	0	0	0	283	254
2055	1,921	275	157	0	0	0	0	0	0	0	284	256
2056	1,940	275	157	0	0	0	0	0	0	0	285	259
2057	1,959	275	157	0	0	0	0	0	0	0	286	261
2058	1,978	275	157	0	0	0	0	0	0	0	287	264
2059	1,998	275	157	0	0	0	0	0	0	0	288	266
2060	2,012	275	157	0	0	0	0	0	0	0	289	269

CAP:SAM Supply and Demand Projections by Water Provider

Scenario D

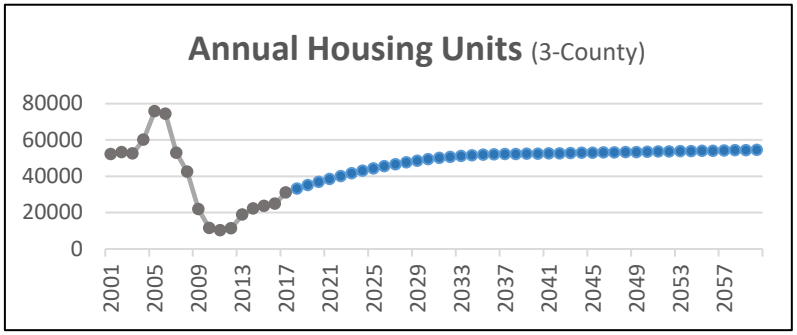
Climate: Worse Case
Growth Rate: Slow
Growth Pattern: Compact
Relative Risk: Low

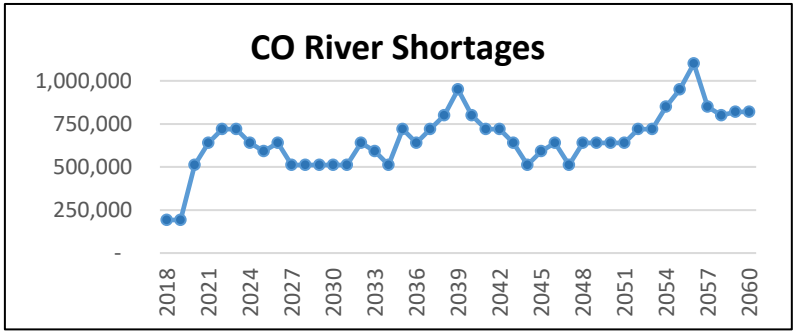
D. Slow, Compact, Very Dry Climate

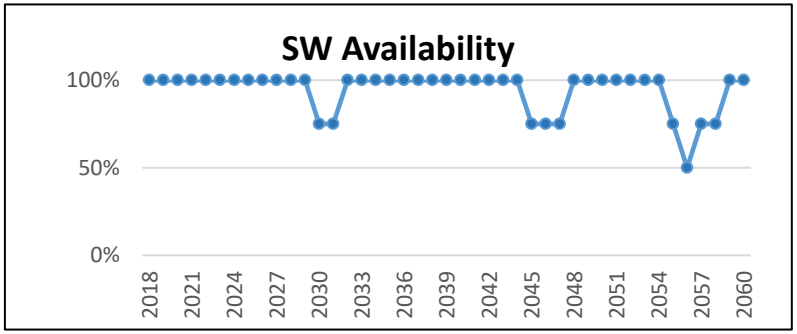
Run Date: 7/13/2020 **Filename:** CAPServiceArea_v3.50_LSCRBS_A(

Growth rate based on Low growth series form AZ Dept. of Administration, and compact growth pattern. "Very Dry" =

Allow Shortages	Yes	
Select CRSS Array	3	*3=Synthetic*
Use Specific Trace	Yes	
Selected Trace	3	*1=Moderate; 2=Deep; 3=Slight*
AWBA Max M&I	20%	
Surface Water Scenario	3	*1=No Reduction; 2=Occational; 3=Frequent*
Use CAP Buildup	Yes	
CAP Buildup Scenario	2	*1=2035; 2=2045*
HU Growth Pattern	5	*1=Baseline*
HU Forecast	2	*1=Use Curve; 2=Eller Forecast*
HU Curve	3	
HU Growth Start Rate	-1%	
HU Ordinary Level	34,000	
HU Rate @ 50 yrs	-3%	
GPHUD Change Existing	-0.4%	*per year*
GPHUD Max Change Existing	-10%	
GPHUD Min Existing	200	
GPHUD Scenario New	1	
GPHUD Change New	0.0%	*per year*
Ag Climate Adjustment	0.2	
Ag Efficiency Increase	0.1%	*per year*
Ag Efficiency Goal	80%	
Ag Replace Crop CU	2.66	
Ag Intensity Scenario	2	
Ag Develop on Crops	50%	*Perecent of max on active Ag*
Ag Acres Replace Percent	0%	
Ag Replace Crop Year	2025	



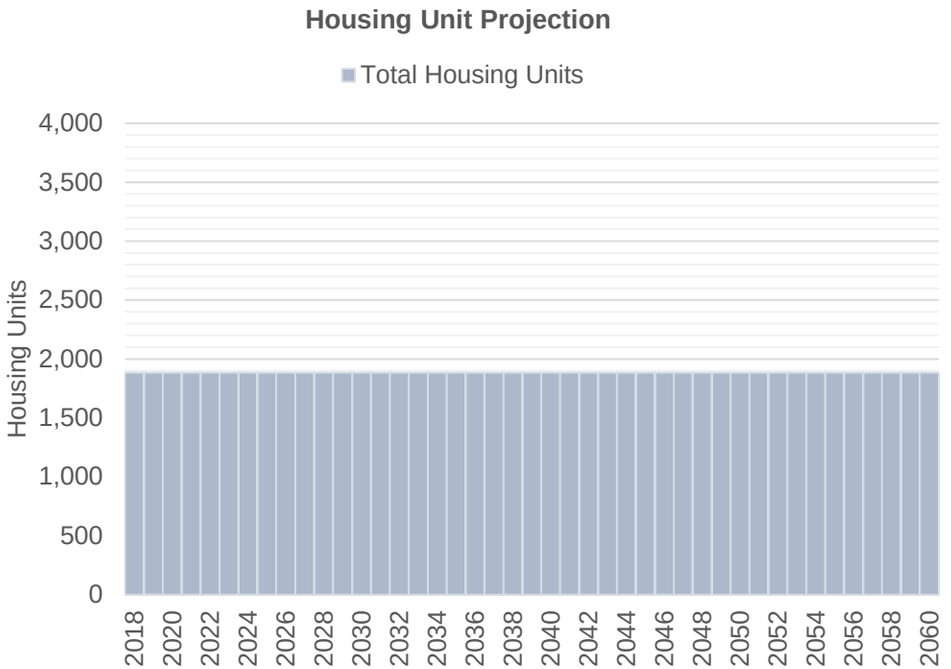


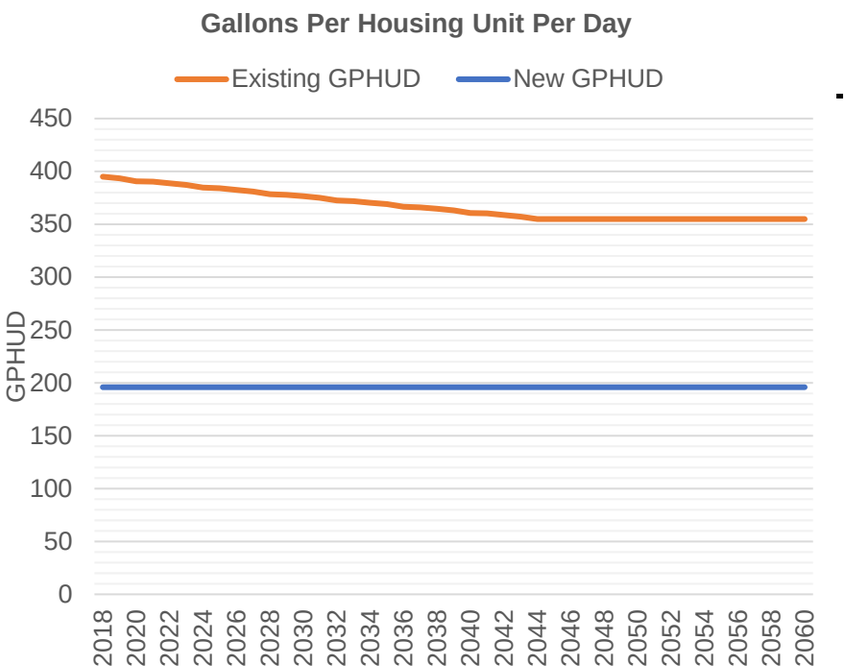


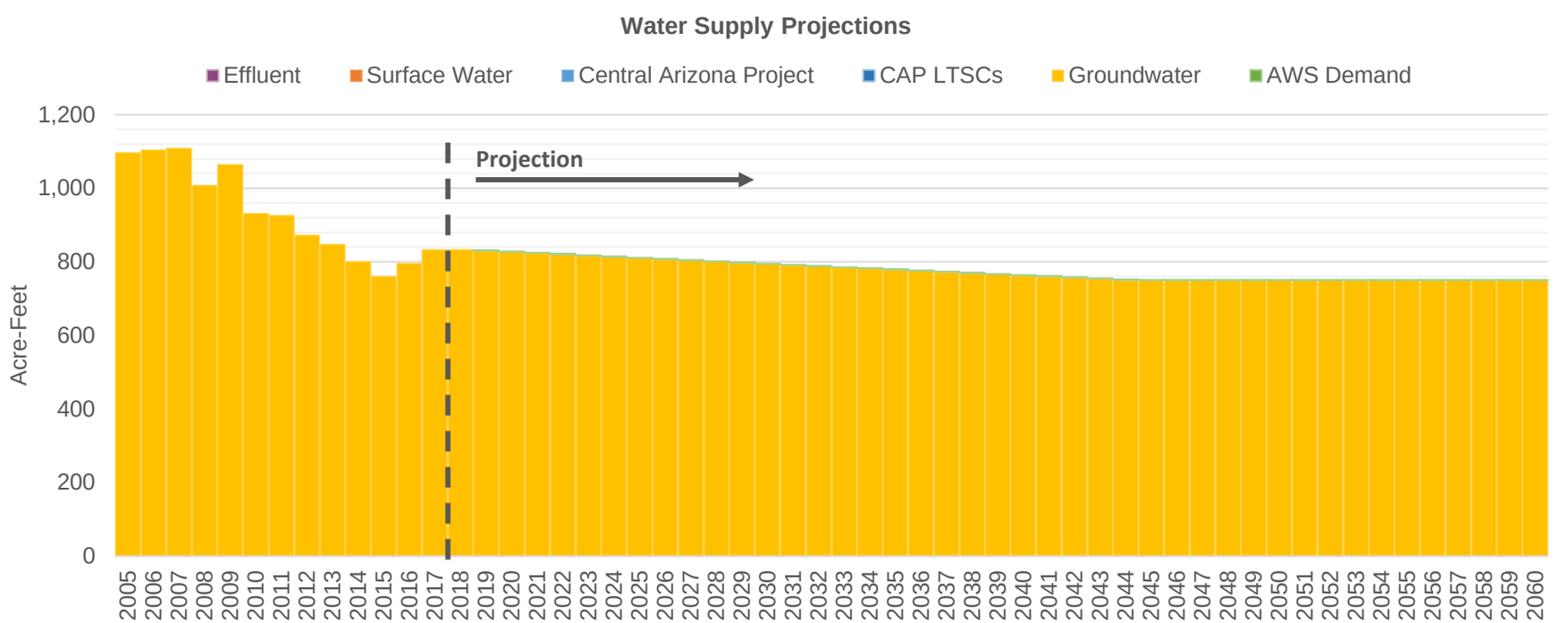
Central Arizona Project Service Area Model

AvraWaterCoop

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

AvraWaterCoop

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

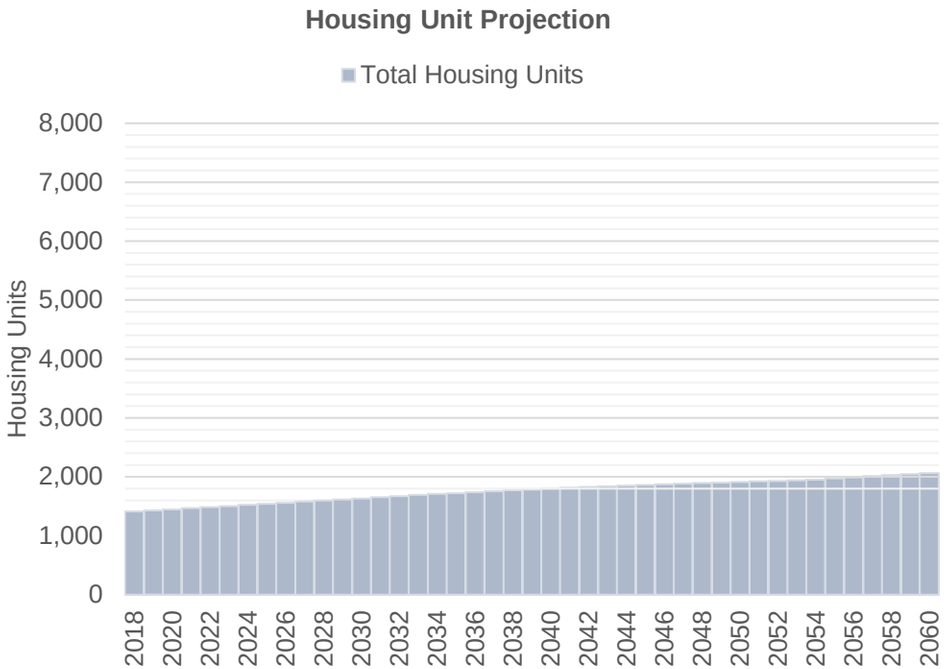
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

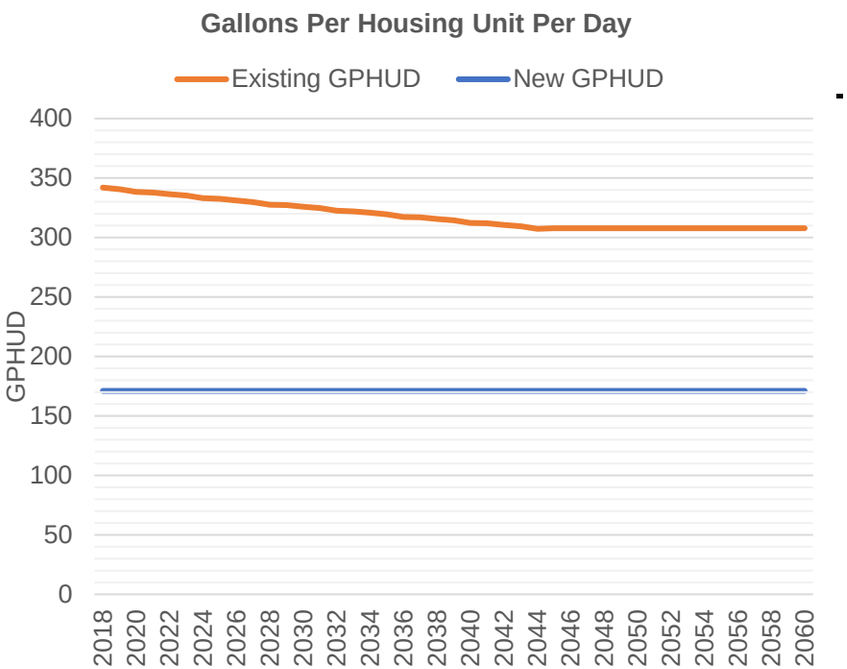
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,885	395	196	0	0	0	0	0	0	0	834	0
2019	1,885	393	196	0	0	0	0	0	0	0	831	0
2020	1,885	391	196	0	0	0	0	0	0	0	827	0
2021	1,885	390	196	0	0	0	0	0	0	0	824	0
2022	1,885	389	196	0	0	0	0	0	0	0	821	0
2023	1,885	387	196	0	0	0	0	0	0	0	817	0
2024	1,885	385	196	0	0	0	0	0	0	0	814	0
2025	1,885	384	196	0	0	0	0	0	0	0	811	0
2026	1,885	383	196	0	0	0	0	0	0	0	808	0
2027	1,885	381	196	0	0	0	0	0	0	0	804	0
2028	1,885	378	196	0	0	0	0	0	0	0	801	0
2029	1,885	378	196	0	0	0	0	0	0	0	798	0
2030	1,885	376	196	0	0	0	0	0	0	0	795	0
2031	1,885	375	196	0	0	0	0	0	0	0	792	0
2032	1,885	372	196	0	0	0	0	0	0	0	789	0
2033	1,885	372	196	0	0	0	0	0	0	0	785	0
2034	1,885	370	196	0	0	0	0	0	0	0	782	0
2035	1,885	369	196	0	0	0	0	0	0	0	779	0
2036	1,885	367	196	0	0	0	0	0	0	0	776	0
2037	1,885	366	196	0	0	0	0	0	0	0	773	0
2038	1,885	365	196	0	0	0	0	0	0	0	770	0
2039	1,885	363	196	0	0	0	0	0	0	0	767	0
2040	1,885	361	196	0	0	0	0	0	0	0	764	0
2041	1,885	360	196	0	0	0	0	0	0	0	761	0
2042	1,885	359	196	0	0	0	0	0	0	0	758	0
2043	1,885	357	196	0	0	0	0	0	0	0	754	0
2044	1,885	355	196	0	0	0	0	0	0	0	751	0
2045	1,885	355	196	0	0	0	0	0	0	0	751	0
2046	1,885	355	196	0	0	0	0	0	0	0	751	0
2047	1,885	355	196	0	0	0	0	0	0	0	751	0
2048	1,885	355	196	0	0	0	0	0	0	0	751	0
2049	1,885	355	196	0	0	0	0	0	0	0	751	0
2050	1,885	355	196	0	0	0	0	0	0	0	751	0
2051	1,885	355	196	0	0	0	0	0	0	0	751	0
2052	1,885	355	196	0	0	0	0	0	0	0	751	0
2053	1,885	355	196	0	0	0	0	0	0	0	751	0
2054	1,885	355	196	0	0	0	0	0	0	0	751	0
2055	1,885	355	196	0	0	0	0	0	0	0	751	0
2056	1,885	355	196	0	0	0	0	0	0	0	751	0
2057	1,885	355	196	0	0	0	0	0	0	0	751	0
2058	1,885	355	196	0	0	0	0	0	0	0	751	0
2059	1,885	355	196	0	0	0	0	0	0	0	751	0
2060	1,885	355	196	0	0	0	0	0	0	0	751	0

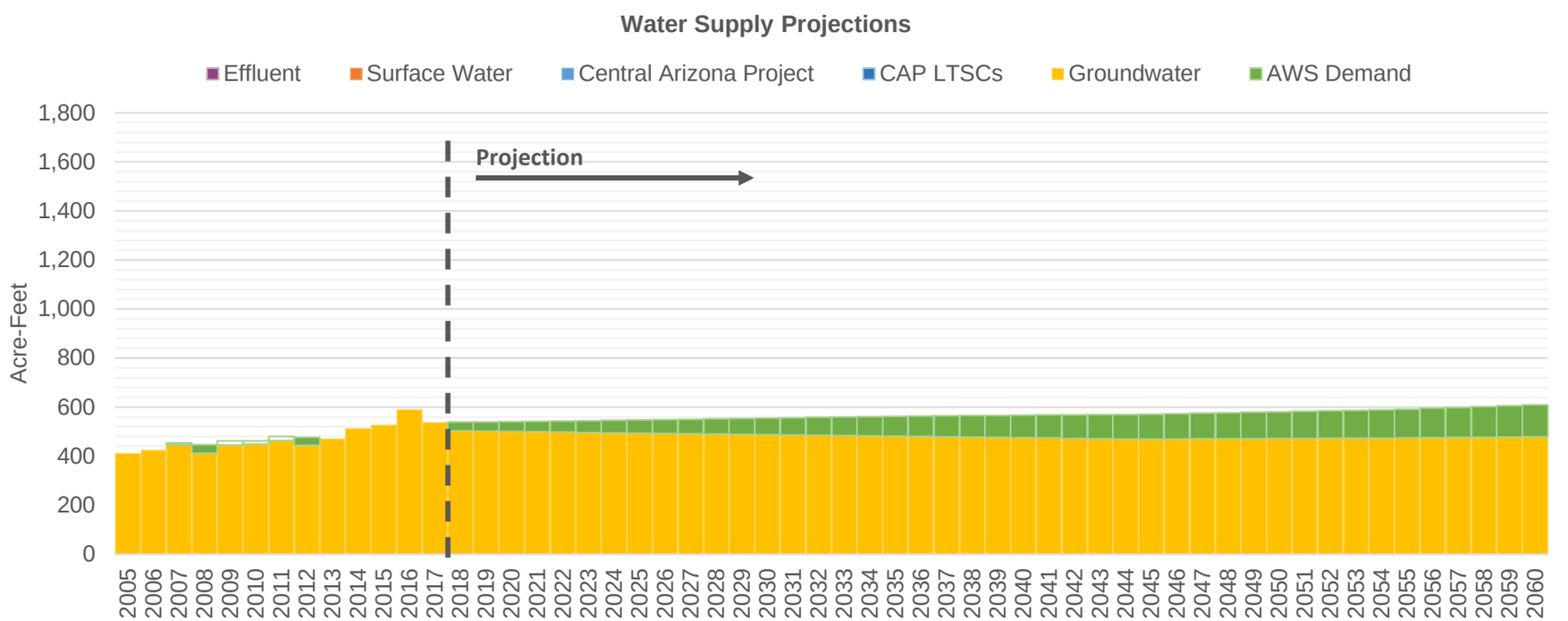
AZWCOracle

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

AZWCOracle

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

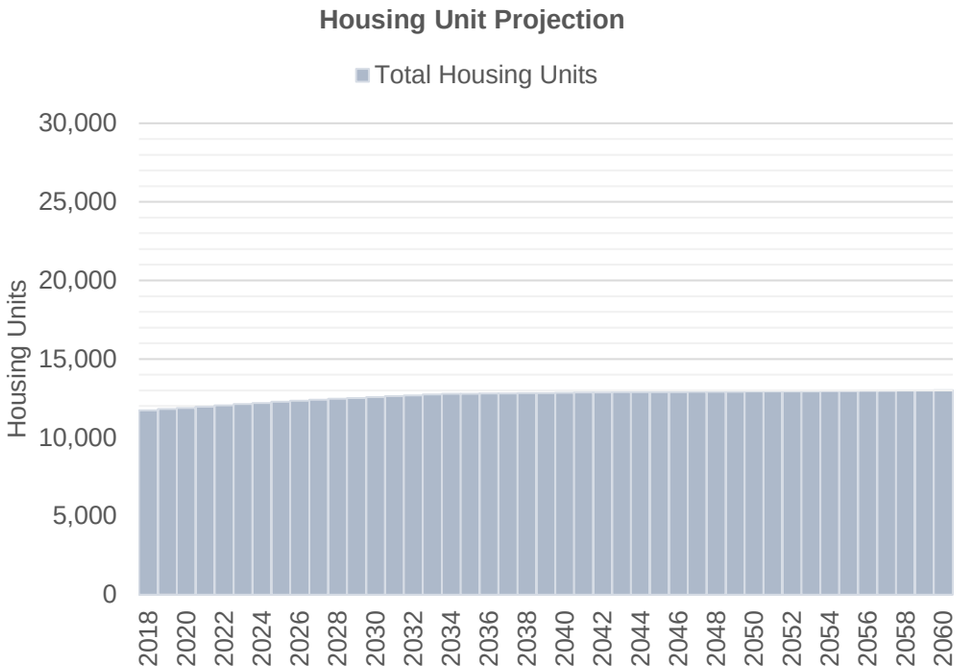
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

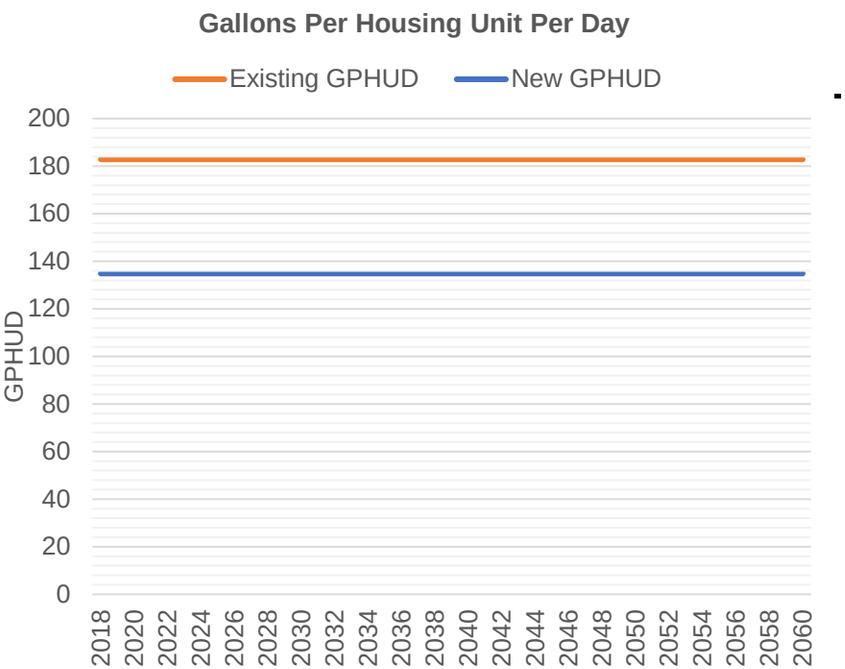
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,412	342	171	0	0	0	0	0	0	0	503	36
2019	1,430	341	171	0	0	0	0	0	0	0	502	37
2020	1,449	338	171	0	0	0	0	0	0	0	501	40
2021	1,467	338	171	0	0	0	0	0	0	0	499	43
2022	1,485	337	171	0	0	0	0	0	0	0	498	45
2023	1,504	335	171	0	0	0	0	0	0	0	496	48
2024	1,523	333	171	0	0	0	0	0	0	0	495	51
2025	1,541	333	171	0	0	0	0	0	0	0	494	54
2026	1,560	331	171	0	0	0	0	0	0	0	493	56
2027	1,579	330	171	0	0	0	0	0	0	0	491	59
2028	1,598	328	171	0	0	0	0	0	0	0	490	62
2029	1,616	327	171	0	0	0	0	0	0	0	489	65
2030	1,634	326	171	0	0	0	0	0	0	0	488	67
2031	1,654	325	171	0	0	0	0	0	0	0	487	70
2032	1,673	322	171	0	0	0	0	0	0	0	485	73
2033	1,691	322	171	0	0	0	0	0	0	0	484	76
2034	1,709	321	171	0	0	0	0	0	0	0	483	78
2035	1,724	319	171	0	0	0	0	0	0	0	481	81
2036	1,740	317	171	0	0	0	0	0	0	0	480	83
2037	1,755	317	171	0	0	0	0	0	0	0	479	85
2038	1,771	316	171	0	0	0	0	0	0	0	478	88
2039	1,786	314	171	0	0	0	0	0	0	0	476	90
2040	1,800	312	171	0	0	0	0	0	0	0	475	92
2041	1,815	312	171	0	0	0	0	0	0	0	474	94
2042	1,829	311	171	0	0	0	0	0	0	0	472	96
2043	1,842	309	171	0	0	0	0	0	0	0	471	98
2044	1,853	307	171	0	0	0	0	0	0	0	469	100
2045	1,863	308	171	0	0	0	0	0	0	0	469	102
2046	1,873	308	171	0	0	0	0	0	0	0	470	103
2047	1,883	308	171	0	0	0	0	0	0	0	470	105
2048	1,893	308	171	0	0	0	0	0	0	0	471	106
2049	1,903	308	171	0	0	0	0	0	0	0	471	108
2050	1,912	308	171	0	0	0	0	0	0	0	471	109
2051	1,922	308	171	0	0	0	0	0	0	0	472	111
2052	1,931	308	171	0	0	0	0	0	0	0	472	112
2053	1,940	308	171	0	0	0	0	0	0	0	473	113
2054	1,953	308	171	0	0	0	0	0	0	0	473	115
2055	1,973	308	171	0	0	0	0	0	0	0	475	117
2056	1,992	308	171	0	0	0	0	0	0	0	476	119
2057	2,011	308	171	0	0	0	0	0	0	0	476	122
2058	2,029	308	171	0	0	0	0	0	0	0	477	125
2059	2,047	308	171	0	0	0	0	0	0	0	478	128
2060	2,064	308	171	0	0	0	0	0	0	0	479	130

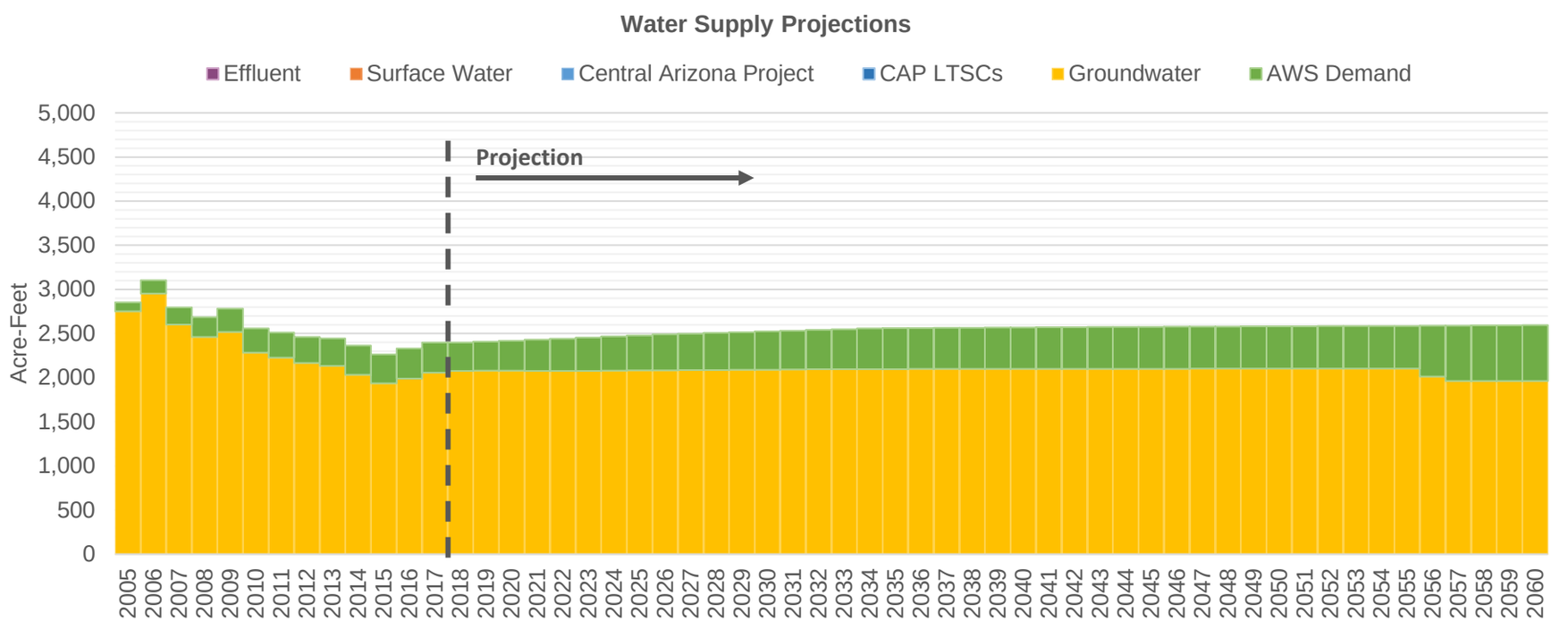
Central Arizona Project Service Area Model

CommWaterGreenVly

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

CommWaterGre

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

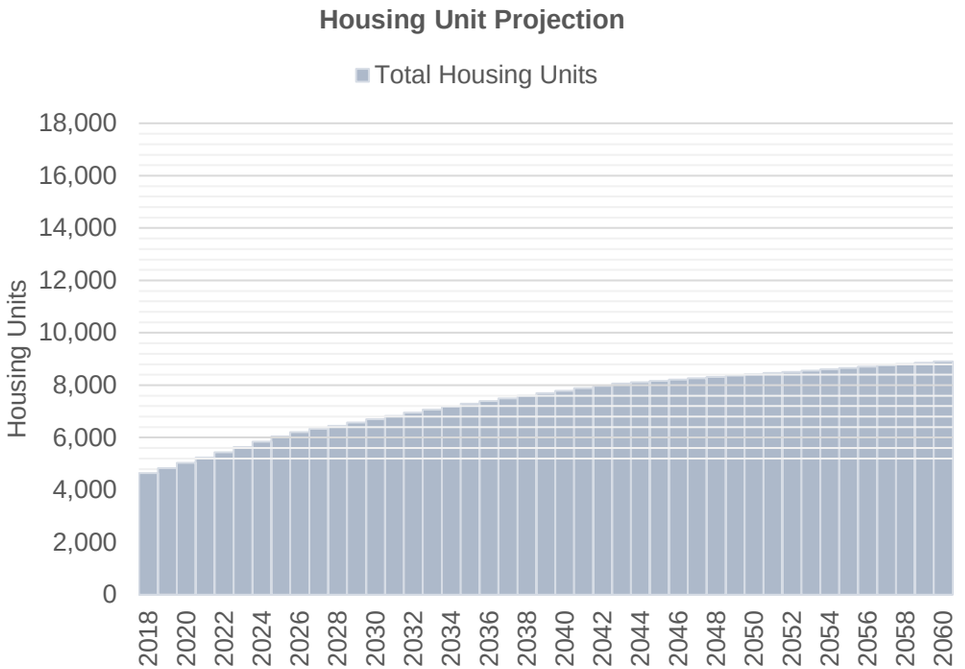
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

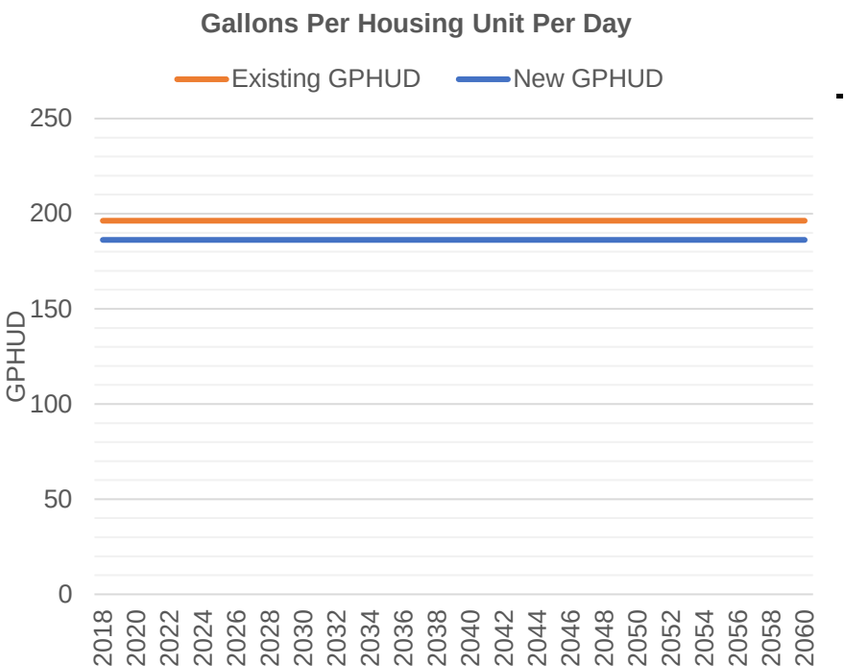
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	11,731	183	135	0	0	0	0	0	0	0	2,077	322
2019	11,809	183	135	0	0	0	0	0	0	0	2,079	328
2020	11,887	183	135	0	0	0	0	0	0	0	2,079	340
2021	11,967	183	135	0	0	0	0	0	0	0	2,078	353
2022	12,046	183	135	0	0	0	0	0	0	0	2,077	366
2023	12,126	183	135	0	0	0	0	0	0	0	2,077	378
2024	12,207	183	135	0	0	0	0	0	0	0	2,080	387
2025	12,287	183	135	0	0	0	0	0	0	0	2,082	397
2026	12,352	183	135	0	0	0	0	0	0	0	2,083	407
2027	12,409	183	135	0	0	0	0	0	0	0	2,085	414
2028	12,464	183	135	0	0	0	0	0	0	0	2,087	421
2029	12,519	183	135	0	0	0	0	0	0	0	2,089	427
2030	12,573	183	135	0	0	0	0	0	0	0	2,091	433
2031	12,630	183	135	0	0	0	0	0	0	0	2,093	439
2032	12,686	183	135	0	0	0	0	0	0	0	2,096	446
2033	12,741	183	135	0	0	0	0	0	0	0	2,097	452
2034	12,779	183	135	0	0	0	0	0	0	0	2,098	459
2035	12,791	183	135	0	0	0	0	0	0	0	2,098	463
2036	12,803	183	135	0	0	0	0	0	0	0	2,098	464
2037	12,815	183	135	0	0	0	0	0	0	0	2,098	466
2038	12,827	183	135	0	0	0	0	0	0	0	2,099	467
2039	12,838	183	135	0	0	0	0	0	0	0	2,099	468
2040	12,850	183	135	0	0	0	0	0	0	0	2,100	470
2041	12,861	183	135	0	0	0	0	0	0	0	2,100	471
2042	12,872	183	135	0	0	0	0	0	0	0	2,101	472
2043	12,882	183	135	0	0	0	0	0	0	0	2,101	473
2044	12,888	183	135	0	0	0	0	0	0	0	2,101	475
2045	12,895	183	135	0	0	0	0	0	0	0	2,101	475
2046	12,901	183	135	0	0	0	0	0	0	0	2,101	476
2047	12,908	183	135	0	0	0	0	0	0	0	2,102	477
2048	12,914	183	135	0	0	0	0	0	0	0	2,102	477
2049	12,920	183	135	0	0	0	0	0	0	0	2,102	478
2050	12,926	183	135	0	0	0	0	0	0	0	2,102	479
2051	12,932	183	135	0	0	0	0	0	0	0	2,103	480
2052	12,938	183	135	0	0	0	0	0	0	0	2,103	480
2053	12,943	183	135	0	0	0	0	0	0	0	2,103	481
2054	12,951	183	135	0	0	0	0	0	0	0	2,103	481
2055	12,962	183	135	0	0	0	0	0	0	0	2,104	482
2056	12,973	183	135	0	0	0	0	0	0	0	2,013	575
2057	12,984	183	135	0	0	0	0	0	0	0	1,962	628
2058	12,994	183	135	0	0	0	0	0	0	0	1,962	629
2059	13,004	183	135	0	0	0	0	0	0	0	1,963	630
2060	13,014	183	135	0	0	0	0	0	0	0	1,963	631

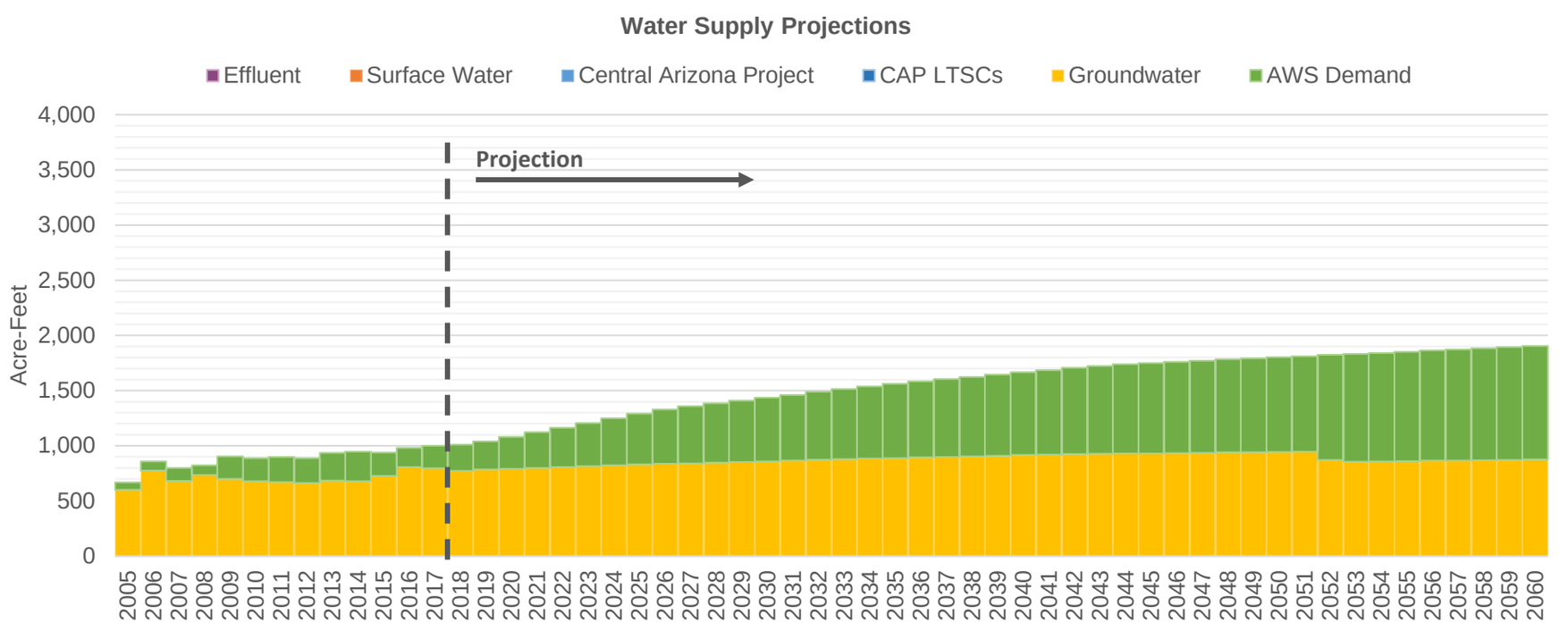
FarmersWC

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

FarmersWC

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

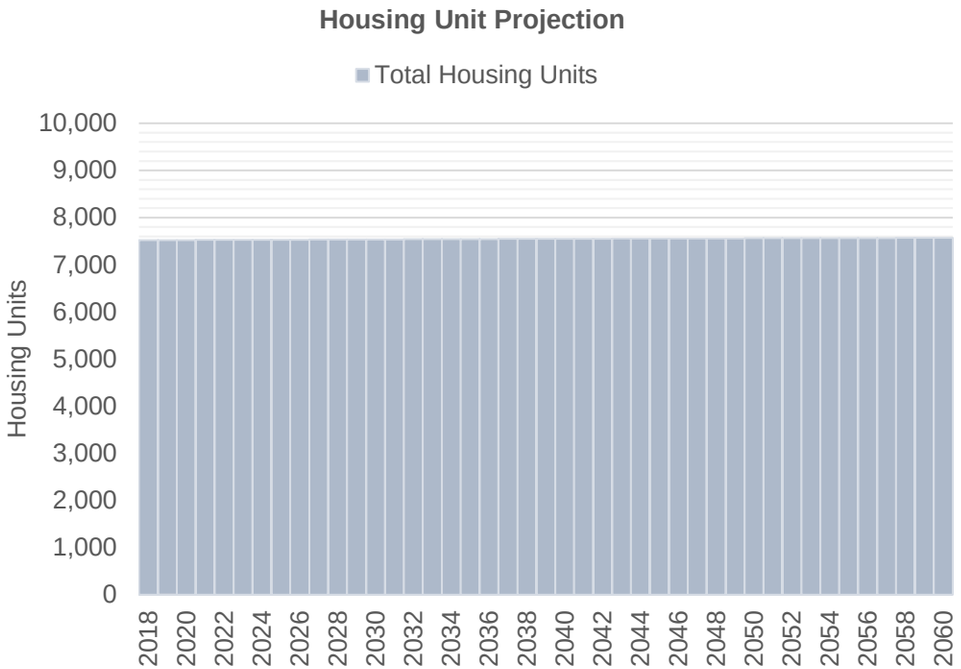
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

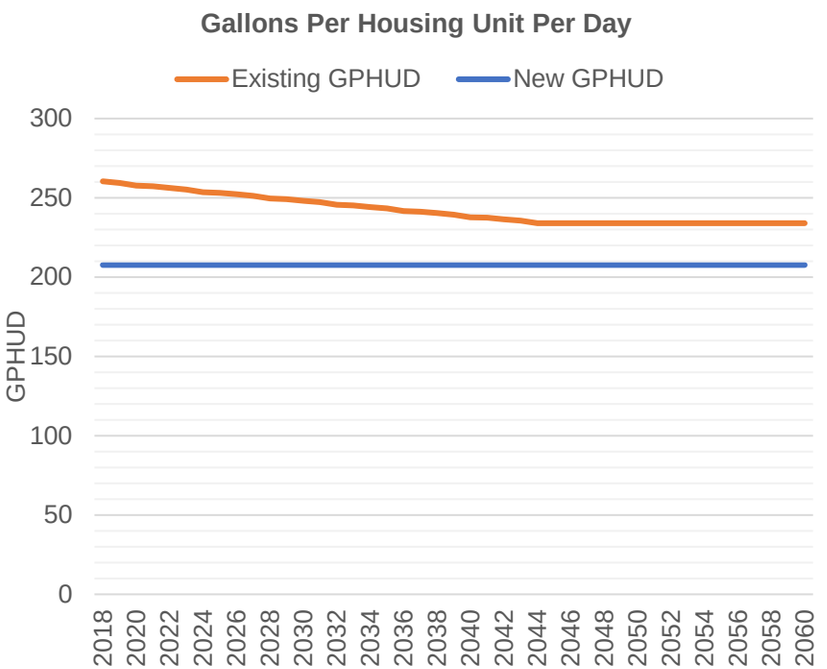
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,639	196	186	0	0	0	0	0	0	0	772	238
2019	4,836	196	186	0	0	0	0	0	0	0	786	254
2020	5,035	196	186	0	0	0	0	0	0	0	792	289
2021	5,236	196	186	0	0	0	0	0	0	0	799	324
2022	5,438	196	186	0	0	0	0	0	0	0	807	358
2023	5,641	196	186	0	0	0	0	0	0	0	815	392
2024	5,844	196	186	0	0	0	0	0	0	0	824	426
2025	6,049	196	186	0	0	0	0	0	0	0	832	460
2026	6,203	196	186	0	0	0	0	0	0	0	836	493
2027	6,329	196	186	0	0	0	0	0	0	0	841	518
2028	6,453	196	186	0	0	0	0	0	0	0	848	538
2029	6,575	196	186	0	0	0	0	0	0	0	853	557
2030	6,696	196	186	0	0	0	0	0	0	0	859	577
2031	6,822	196	186	0	0	0	0	0	0	0	866	595
2032	6.947	196	186	0	0	0	0	0	0	0	874	615
2033	7,070	196	186	0	0	0	0	0	0	0	879	635
2034	7,185	196	186	0	0	0	0	0	0	0	884	654
2035	7,289	196	186	0	0	0	0	0	0	0	889	672
2036	7,392	196	186	0	0	0	0	0	0	0	896	688
2037	7,493	196	186	0	0	0	0	0	0	0	899	705
2038	7,592	196	186	0	0	0	0	0	0	0	904	720
2039	7,691	196	186	0	0	0	0	0	0	0	909	736
2040	7,788	196	186	0	0	0	0	0	0	0	916	752
2041	7,884	196	186	0	0	0	0	0	0	0	919	767
2042	7,978	196	186	0	0	0	0	0	0	0	924	782
2043	8,058	196	186	0	0	0	0	0	0	0	927	797
2044	8,112	196	186	0	0	0	0	0	0	0	931	809
2045	8,165	196	186	0	0	0	0	0	0	0	931	818
2046	8,217	196	186	0	0	0	0	0	0	0	934	826
2047	8,268	196	186	0	0	0	0	0	0	0	937	834
2048	8,318	196	186	0	0	0	0	0	0	0	941	842
2049	8,367	196	186	0	0	0	0	0	0	0	942	850
2050	8,416	196	186	0	0	0	0	0	0	0	944	858
2051	8,463	196	186	0	0	0	0	0	0	0	947	865
2052	8,510	196	186	0	0	0	0	0	0	0	871	953
2053	8,555	196	186	0	0	0	0	0	0	0	855	976
2054	8,603	196	186	0	0	0	0	0	0	0	858	983
2055	8,656	196	186	0	0	0	0	0	0	0	861	991
2056	8,707	196	186	0	0	0	0	0	0	0	866	999
2057	8,758	196	186	0	0	0	0	0	0	0	867	1,006
2058	8,807	196	186	0	0	0	0	0	0	0	870	1,014
2059	8,855	196	186	0	0	0	0	0	0	0	872	1,021
2060	8,902	196	186	0	0	0	0	0	0	0	878	1,029

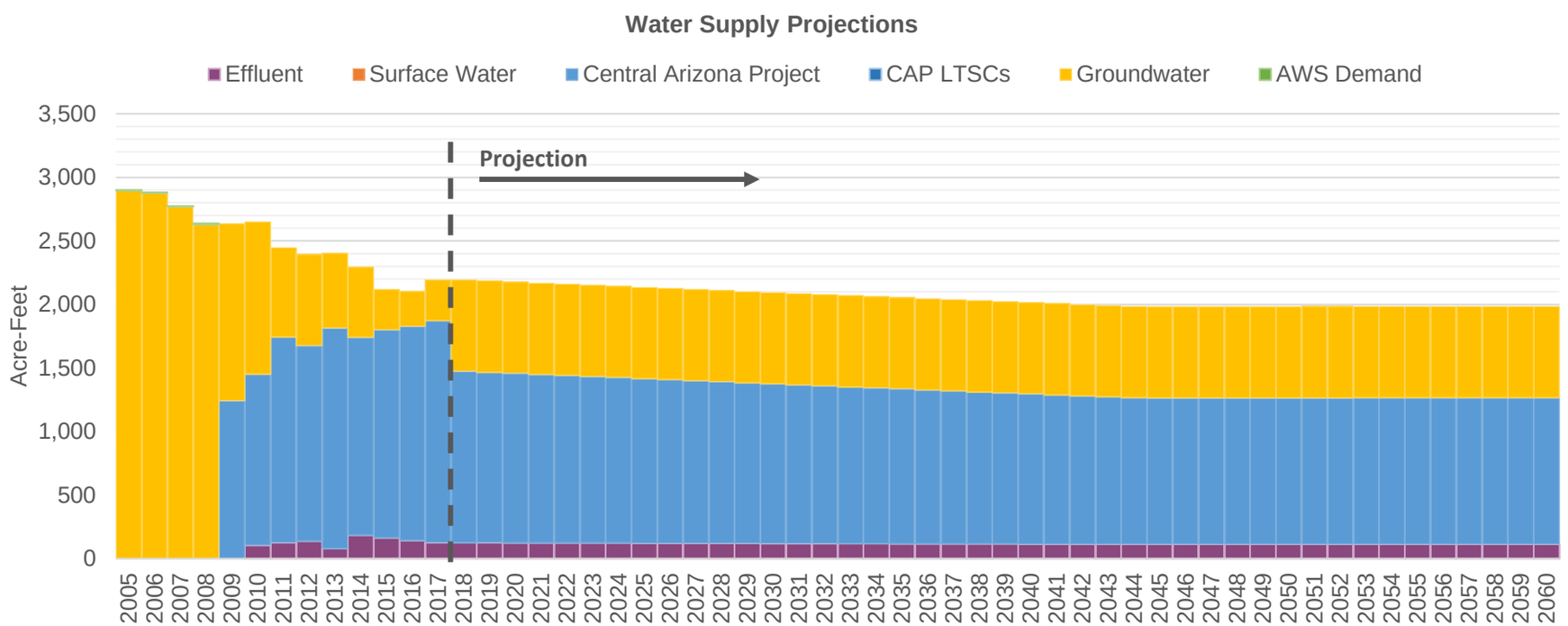
Central Arizona Project Service Area Model

FWID

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

FWID

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

Demand Assumptions

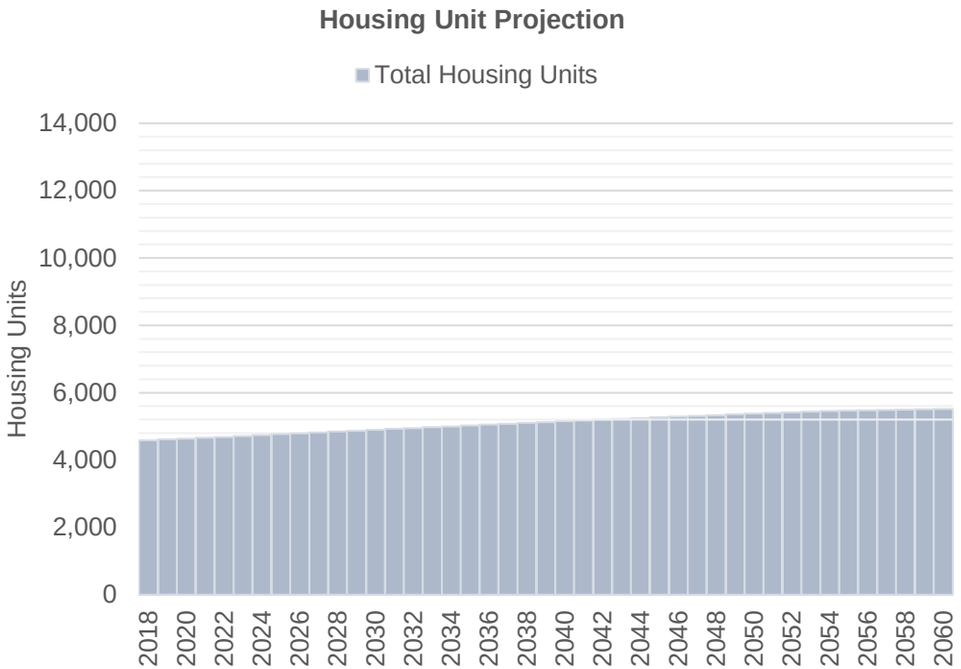
Water Supply Projections (Acre-Feet)

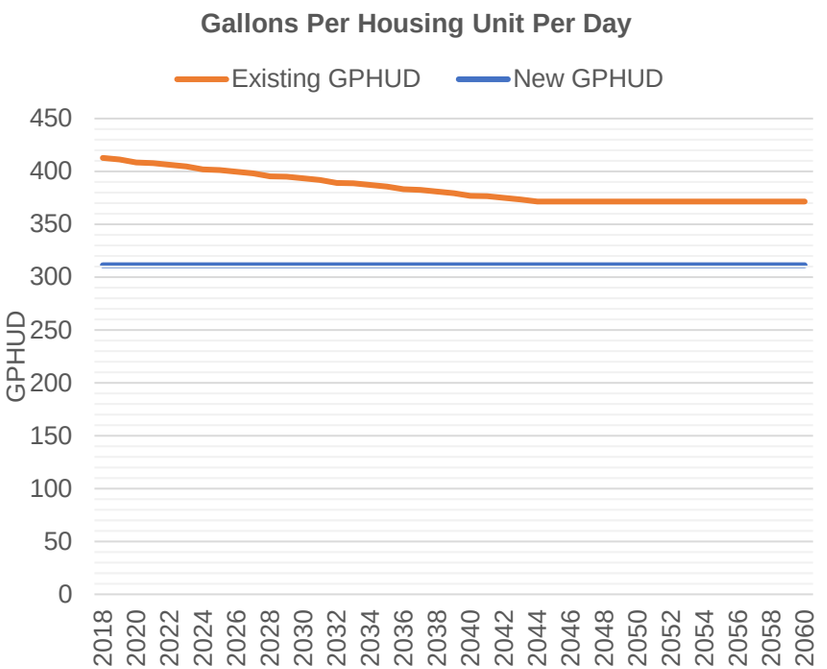
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	7,522	260	208	125	0	0	0	1,350	1,523	0	719	0
2019	7,523	259	208	125	0	0	0	1,341	1,532	0	719	0
2020	7,524	258	208	125	0	0	0	1,333	1,540	0	719	0
2021	7,526	257	208	124	0	0	0	1,325	1,548	0	719	0
2022	7,527	256	208	124	0	0	0	1,318	1,555	0	719	0
2023	7,528	255	208	123	0	0	0	1,310	1,563	0	719	0
2024	7,530	254	208	123	0	0	0	1,302	1,571	0	719	0
2025	7,531	253	208	122	0	0	0	1,294	1,579	0	719	0
2026	7,532	252	208	122	0	0	0	1,286	1,587	0	719	0
2027	7,534	251	208	121	0	0	0	1,279	1,594	0	719	0
2028	7,535	250	208	121	0	0	0	1,271	1,602	0	719	0
2029	7,536	249	208	120	0	0	0	1,263	1,610	0	719	0
2030	7,537	248	208	120	0	0	0	1,255	1,618	0	719	0
2031	7,539	247	208	119	0	0	0	1,248	1,625	0	719	0
2032	7,540	246	208	119	0	0	0	1,240	1,633	0	719	0
2033	7,542	245	208	118	0	0	0	1,233	1,640	0	719	0
2034	7,543	244	208	118	0	0	0	1,225	1,648	0	719	0
2035	7,544	243	208	118	0	0	0	1,218	1,655	0	719	0
2036	7,545	242	208	117	0	0	0	1,210	1,663	0	719	0
2037	7,547	241	208	117	0	0	0	1,203	1,670	0	719	0
2038	7,548	240	208	116	0	0	0	1,196	1,481	0	719	0
2039	7,549	239	208	116	0	0	0	1,188	1,035	0	719	0
2040	7,550	238	208	115	0	0	0	1,181	1,447	0	719	0
2041	7,551	237	208	115	0	0	0	1,174	1,655	0	719	0
2042	7,552	237	208	114	0	0	0	1,167	1,636	0	719	0
2043	7,554	236	208	114	0	0	0	1,159	1,714	0	719	0
2044	7,555	234	208	113	0	0	0	1,152	1,721	0	719	0
2045	7,556	234	208	113	0	0	0	1,150	1,723	0	719	0
2046	7,557	234	208	113	0	0	0	1,151	1,630	0	719	0
2047	7,558	234	208	113	0	0	0	1,151	1,722	0	719	0
2048	7,559	234	208	113	0	0	0	1,151	1,629	0	719	0
2049	7,560	234	208	113	0	0	0	1,151	1,629	0	719	0
2050	7,561	234	208	113	0	0	0	1,151	1,629	0	719	0
2051	7,562	234	208	113	0	0	0	1,152	1,628	0	719	0
2052	7,563	234	208	113	0	0	0	1,152	1,429	0	719	0
2053	7,564	234	208	113	0	0	0	1,152	1,429	0	719	0
2054	7,564	234	208	113	0	0	0	1,152	1,105	0	719	0
2055	7,565	234	208	113	0	0	0	1,152	855	0	719	0
2056	7,566	234	208	113	0	0	0	1,153	481	0	719	0
2057	7,567	234	208	113	0	0	0	1,153	1,104	0	719	0
2058	7,568	234	208	113	0	0	0	1,153	1,228	0	719	0
2059	7,569	234	208	113	0	0	0	1,153	1,178	0	719	0
2060	7,569	234	208	113	0	0	0	1,153	1,178	0	719	0

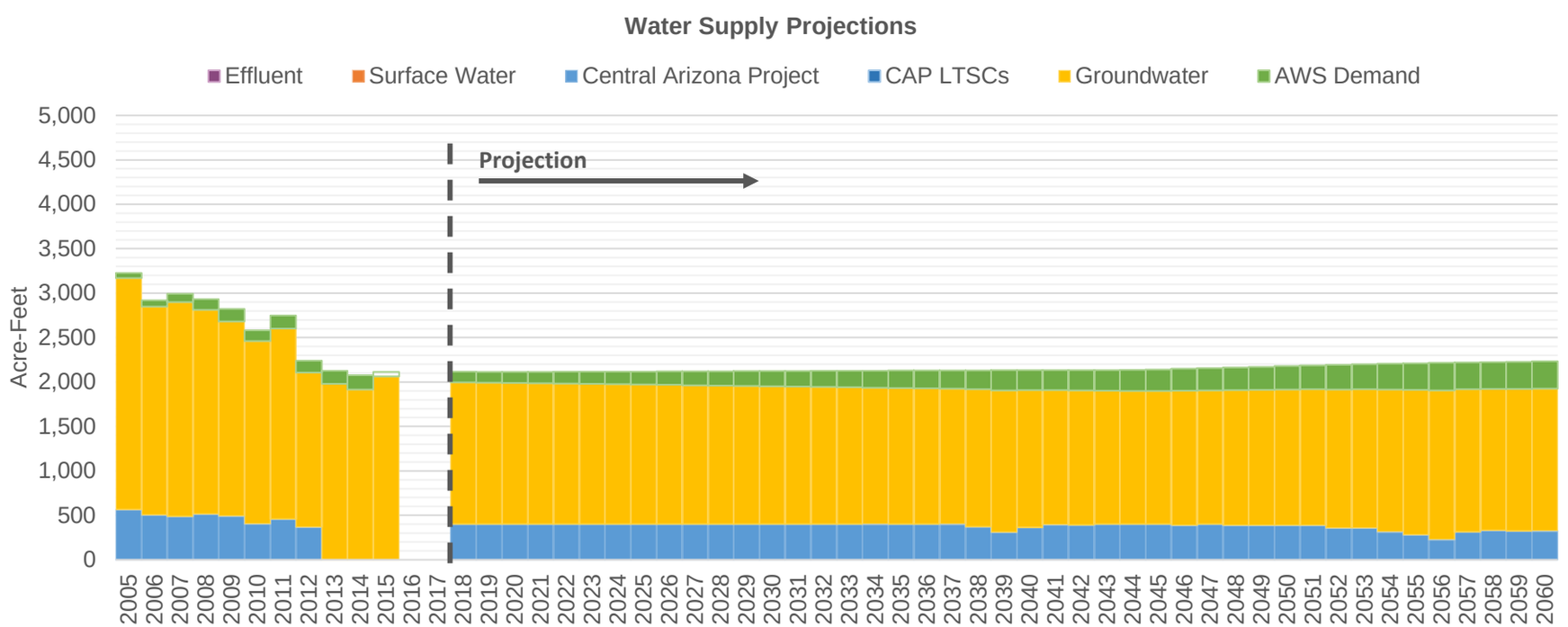
Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

GVDWID







Central Arizona Project Service Area Model

GVDWID

D. Slow, Compact, Very Dry Climate

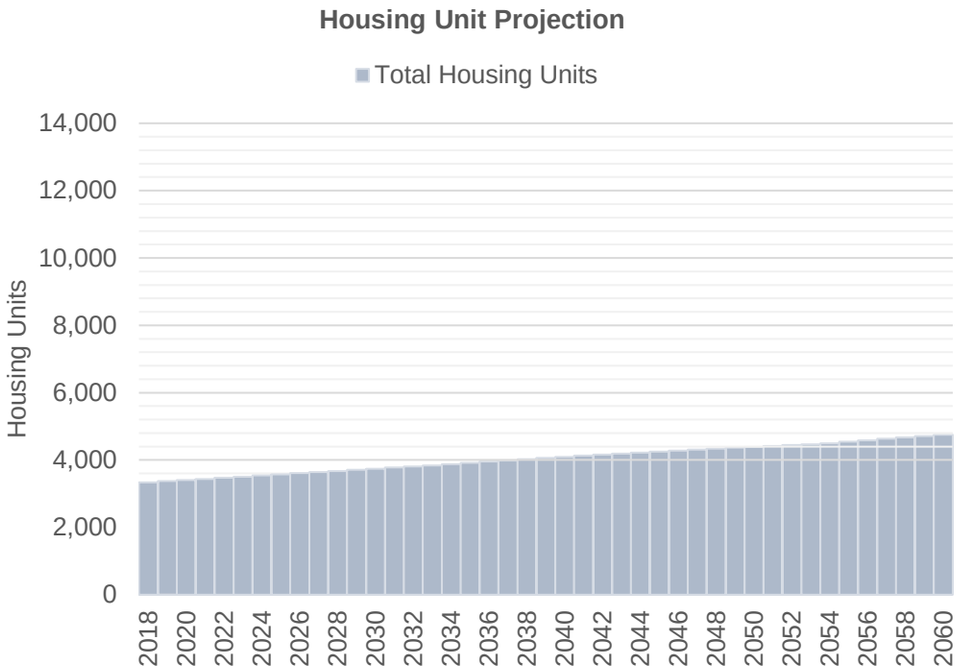
7/13/20 12:06 PM

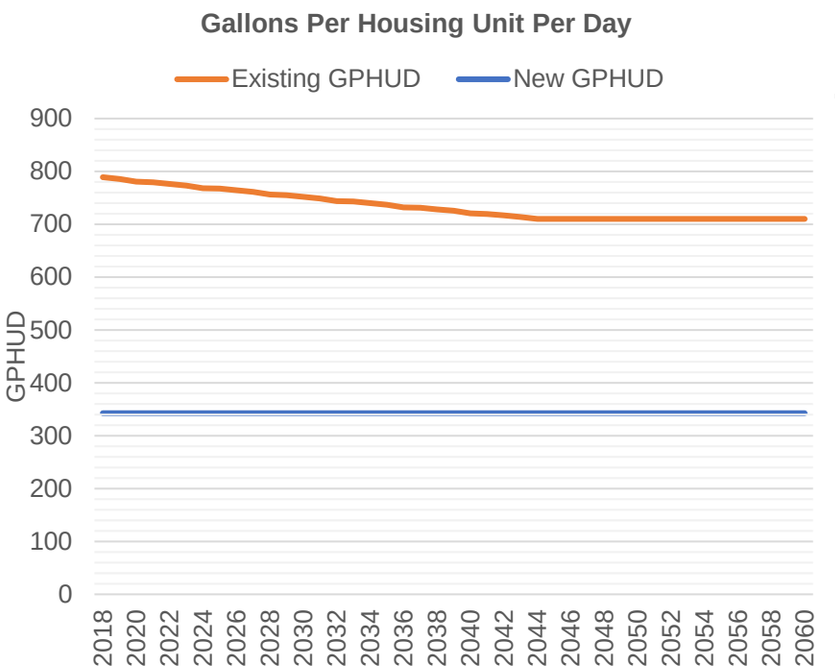
Date	Demand Assumptions: Housing Units	GPHUD		Water Supply Projections (Acre-Feet): Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,583	413	311	0	0	0	399	0	0	0	1,598	119
2019	4,609	411	311	0	0	0	399	0	0	0	1,594	121
2020	4,634	408	311	0	0	0	399	0	0	0	1,590	125
2021	4,660	408	311	0	0	0	399	0	0	0	1,587	129
2022	4,686	406	311	0	0	0	399	0	0	0	1,583	133
2023	4,712	405	311	0	0	0	399	0	0	0	1,580	137
2024	4,739	402	311	0	0	0	399	0	0	0	1,577	142
2025	4,765	401	311	0	0	0	399	0	0	0	1,573	147
2026	4,791	400	311	0	0	0	399	0	0	0	1,569	151
2027	4,818	398	311	0	0	0	399	0	0	0	1,565	156
2028	4,844	395	311	0	0	0	399	0	0	0	1,562	161
2029	4,870	395	311	0	0	0	399	0	0	0	1,557	166
2030	4,895	393	311	0	0	0	399	0	0	0	1,553	171
2031	4,922	392	311	0	0	0	399	0	0	0	1,550	175
2032	4.948	389	311	0	0	0	399	0	0	0	1.546	180
2033	4,974	389	311	0	0	0	399	0	0	0	1,542	185
2034	5,000	387	311	0	0	0	399	0	0	0	1,538	190
2035	5,026	386	311	0	0	0	399	0	0	0	1,535	195
2036	5,051	383	311	0	0	0	399	0	0	0	1,531	200
2037	5,076	383	311	0	0	0	399	0	0	0	1,527	204
2038	5,101	381	311	0	0	0	372	0	0	0	1,547	212
2039	5,126	379	311	0	0	0	309	0	0	0	1,599	225
2040	5,150	377	311	0	0	0	365	0	0	0	1,546	223
2041	5,173	376	311	0	0	0	393	0	0	0	1,517	224
2042	5,197	375	311	0	0	0	389	0	0	0	1,516	228
2043	5,220	373	311	0	0	0	399	0	0	0	1,504	232
2044	5,243	372	311	0	0	0	399	0	0	0	1,501	236
2045	5,266	372	311	0	0	0	399	0	0	0	1,501	240
2046	5,289	372	311	0	0	0	386	0	0	0	1,516	247
2047	5,311	372	311	0	0	0	399	0	0	0	1,508	249
2048	5,333	372	311	0	0	0	386	0	0	0	1,523	255
2049	5,354	372	311	0	0	0	386	0	0	0	1,526	260
2050	5,376	372	311	0	0	0	386	0	0	0	1,529	264
2051	5,396	372	311	0	0	0	386	0	0	0	1,532	268
2052	5,416	372	311	0	0	0	358	0	0	0	1,559	277
2053	5,436	372	311	0	0	0	358	0	0	0	1,561	281
2054	5,453	372	311	0	0	0	313	0	0	0	1,601	292
2055	5,465	372	311	0	0	0	279	0	0	0	1,632	301
2056	5,476	372	311	0	0	0	227	0	0	0	1,678	312
2057	5,487	372	311	0	0	0	313	0	0	0	1,606	300
2058	5,499	372	311	0	0	0	331	0	0	0	1,593	300
2059	5,509	372	311	0	0	0	324	0	0	0	1,600	304
2060	5,520	372	311	0	0	0	324	0	0	0	1,602	306

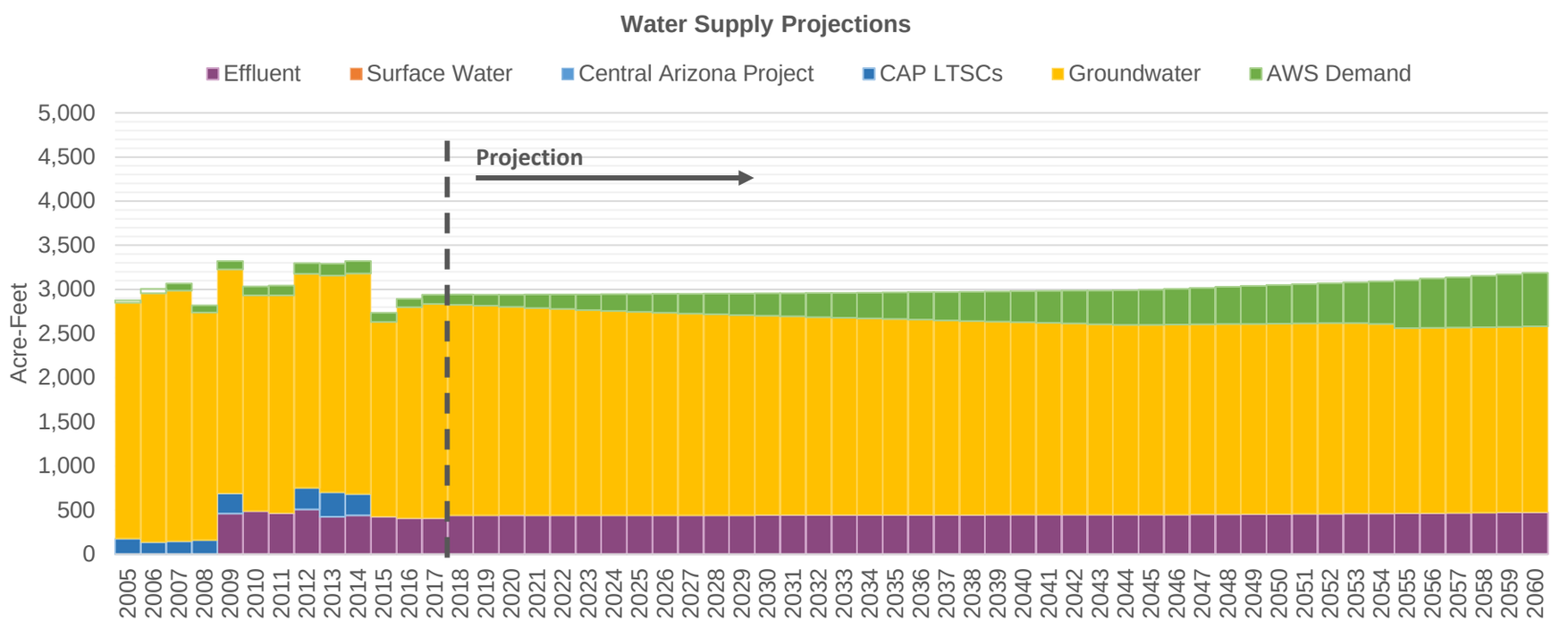
LagoDelOro

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

LagoDelOro

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

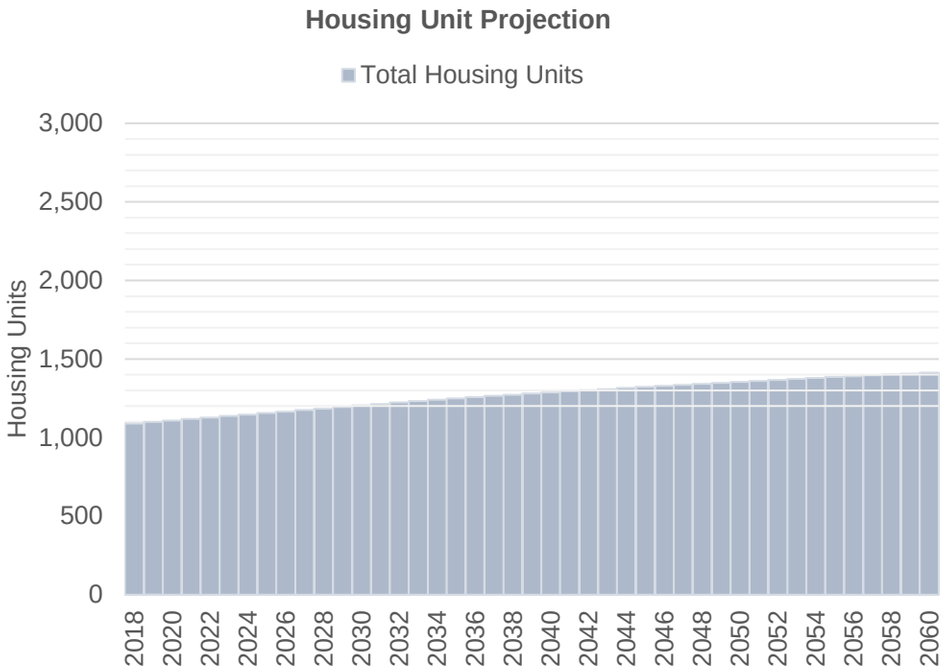
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

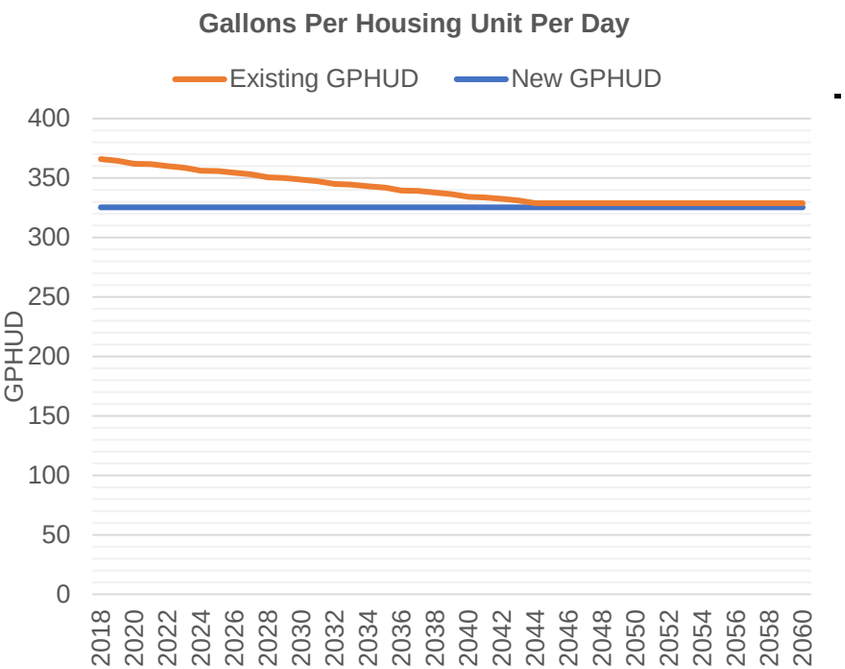
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,341	789	343	441	0	0	0	0	0	0	2,386	116
2019	3,373	786	343	441	0	0	0	0	0	0	2,376	123
2020	3,406	781	343	441	0	0	0	0	0	0	2,363	137
2021	3,439	780	343	441	0	0	0	0	0	0	2,349	152
2022	3,473	777	343	441	0	0	0	0	0	0	2,337	165
2023	3,506	773	343	441	0	0	0	0	0	0	2,325	178
2024	3,540	768	343	441	0	0	0	0	0	0	2,314	190
2025	3,574	767	343	441	0	0	0	0	0	0	2,303	203
2026	3,607	764	343	442	0	0	0	0	0	0	2,293	214
2027	3,641	761	343	442	0	0	0	0	0	0	2,284	224
2028	3,675	756	343	442	0	0	0	0	0	0	2,276	234
2029	3,708	755	343	442	0	0	0	0	0	0	2,267	244
2030	3,741	752	343	443	0	0	0	0	0	0	2,259	253
2031	3,775	749	343	443	0	0	0	0	0	0	2,251	263
2032	3,808	744	343	443	0	0	0	0	0	0	2,244	272
2033	3,842	743	343	443	0	0	0	0	0	0	2,236	281
2034	3,877	740	343	444	0	0	0	0	0	0	2,228	291
2035	3,914	737	343	444	0	0	0	0	0	0	2,220	301
2036	3,951	732	343	444	0	0	0	0	0	0	2,214	311
2037	3,988	731	343	445	0	0	0	0	0	0	2,205	321
2038	4,024	728	343	445	0	0	0	0	0	0	2,198	332
2039	4,059	725	343	446	0	0	0	0	0	0	2,190	342
2040	4,094	721	343	446	0	0	0	0	0	0	2,183	352
2041	4,129	720	343	447	0	0	0	0	0	0	2,174	361
2042	4,163	717	343	447	0	0	0	0	0	0	2,167	371
2043	4,195	714	343	447	0	0	0	0	0	0	2,159	381
2044	4,224	710	343	448	0	0	0	0	0	0	2,152	390
2045	4,253	710	343	448	0	0	0	0	0	0	2,150	398
2046	4,282	710	343	449	0	0	0	0	0	0	2,152	406
2047	4,309	710	343	451	0	0	0	0	0	0	2,153	414
2048	4,337	710	343	452	0	0	0	0	0	0	2,156	422
2049	4,364	710	343	454	0	0	0	0	0	0	2,155	430
2050	4,390	710	343	455	0	0	0	0	0	0	2,157	437
2051	4,416	710	343	457	0	0	0	0	0	0	2,158	445
2052	4,441	710	343	458	0	0	0	0	0	0	2,160	452
2053	4,466	710	343	460	0	0	0	0	0	0	2,160	459
2054	4,499	710	343	461	0	0	0	0	0	0	2,148	481
2055	4,543	710	343	463	0	0	0	0	0	0	2,098	544
2056	4,586	710	343	465	0	0	0	0	0	0	2,101	556
2057	4,629	710	343	468	0	0	0	0	0	0	2,101	569
2058	4,670	710	343	470	0	0	0	0	0	0	2,103	581
2059	4,711	710	343	473	0	0	0	0	0	0	2,104	593
2060	4,751	710	343	475	0	0	0	0	0	0	2,107	605

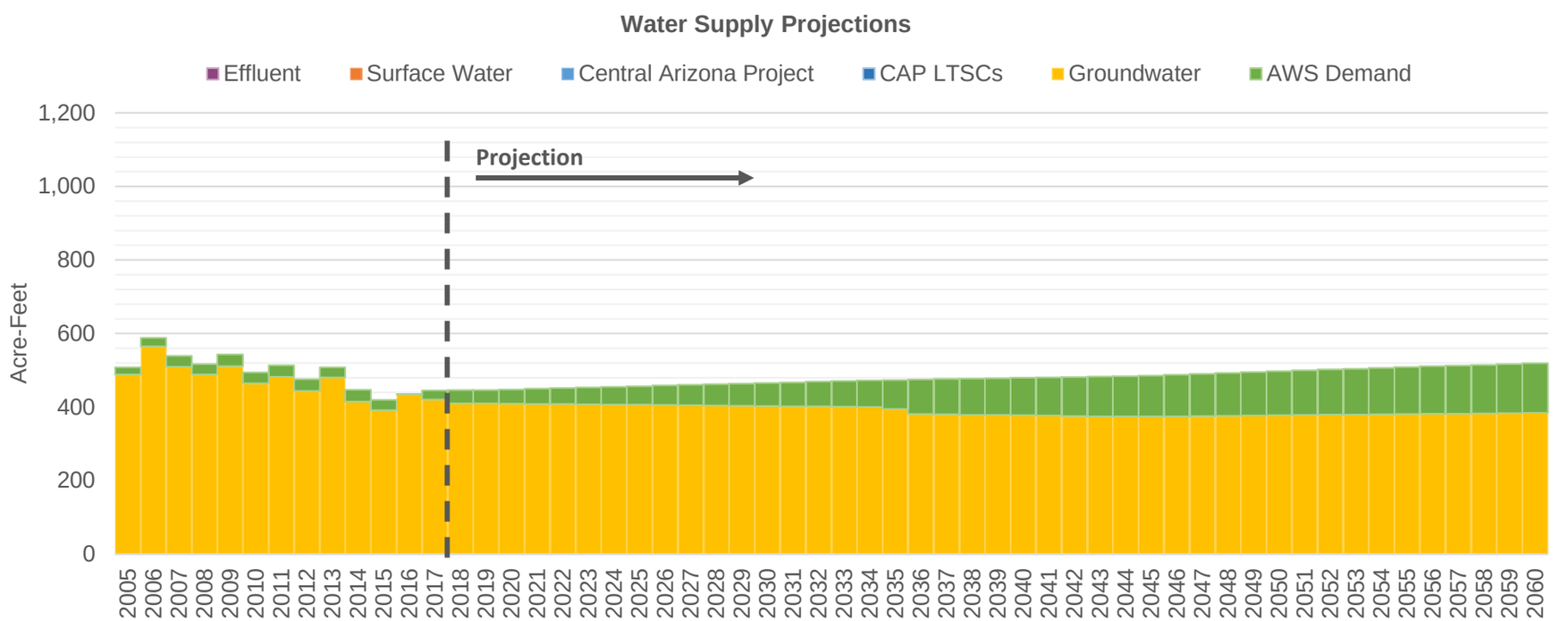
LasQuintas

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

LasQuintas

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

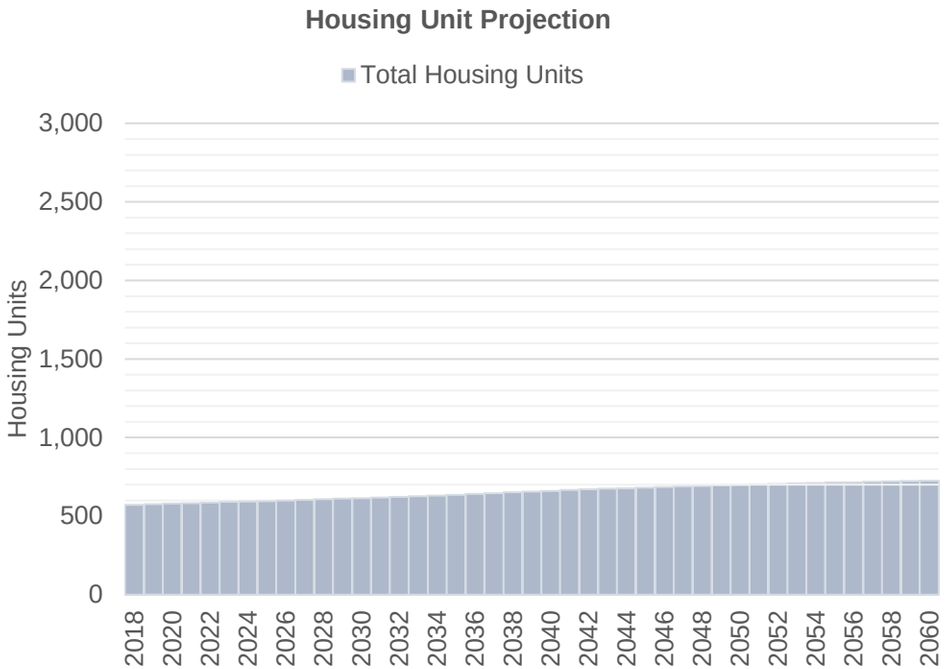
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

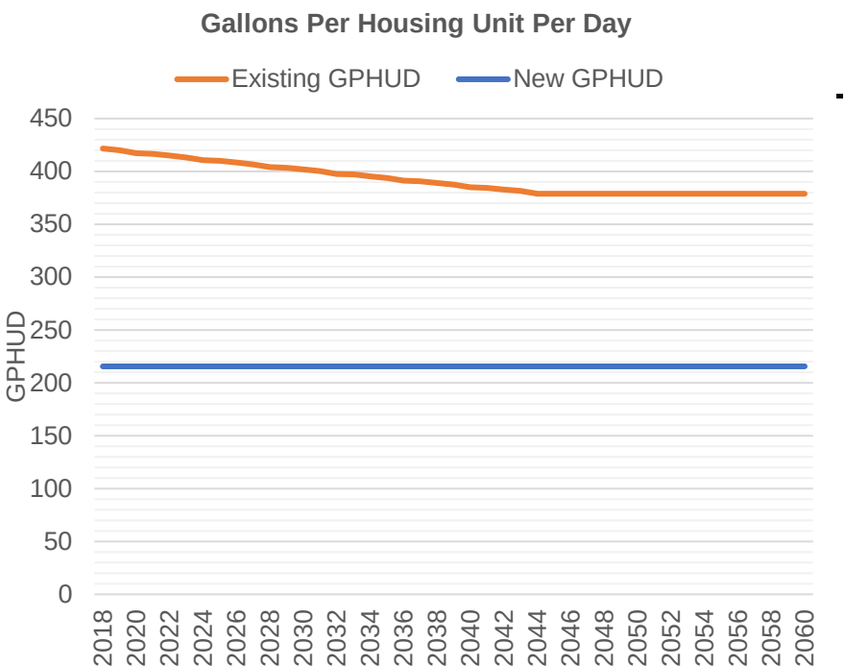
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,090	366	325	0	0	0	0	0	0	0	410	36
2019	1,099	364	325	0	0	0	0	0	0	0	410	37
2020	1,109	362	325	0	0	0	0	0	0	0	409	39
2021	1,118	362	325	0	0	0	0	0	0	0	409	41
2022	1,128	360	325	0	0	0	0	0	0	0	408	43
2023	1,137	359	325	0	0	0	0	0	0	0	408	46
2024	1,147	356	325	0	0	0	0	0	0	0	407	48
2025	1,157	356	325	0	0	0	0	0	0	0	406	50
2026	1,166	354	325	0	0	0	0	0	0	0	406	53
2027	1,176	353	325	0	0	0	0	0	0	0	405	55
2028	1,185	351	325	0	0	0	0	0	0	0	404	58
2029	1,195	350	325	0	0	0	0	0	0	0	404	60
2030	1,204	349	325	0	0	0	0	0	0	0	403	63
2031	1,213	347	325	0	0	0	0	0	0	0	402	65
2032	1,223	345	325	0	0	0	0	0	0	0	402	67
2033	1,232	345	325	0	0	0	0	0	0	0	401	70
2034	1,241	343	325	0	0	0	0	0	0	0	400	72
2035	1,249	342	325	0	0	0	0	0	0	0	395	79
2036	1,257	340	325	0	0	0	0	0	0	0	381	94
2037	1,265	339	325	0	0	0	0	0	0	0	380	96
2038	1,272	338	325	0	0	0	0	0	0	0	379	98
2039	1,280	336	325	0	0	0	0	0	0	0	378	100
2040	1,287	334	325	0	0	0	0	0	0	0	378	102
2041	1,295	334	325	0	0	0	0	0	0	0	377	104
2042	1,302	332	325	0	0	0	0	0	0	0	376	106
2043	1,309	331	325	0	0	0	0	0	0	0	375	108
2044	1,316	329	325	0	0	0	0	0	0	0	374	110
2045	1,323	329	325	0	0	0	0	0	0	0	374	111
2046	1,329	329	325	0	0	0	0	0	0	0	375	113
2047	1,336	329	325	0	0	0	0	0	0	0	376	115
2048	1,342	329	325	0	0	0	0	0	0	0	377	116
2049	1,349	329	325	0	0	0	0	0	0	0	377	118
2050	1,355	329	325	0	0	0	0	0	0	0	378	120
2051	1,361	329	325	0	0	0	0	0	0	0	378	121
2052	1,367	329	325	0	0	0	0	0	0	0	379	123
2053	1,373	329	325	0	0	0	0	0	0	0	380	124
2054	1,379	329	325	0	0	0	0	0	0	0	380	126
2055	1,385	329	325	0	0	0	0	0	0	0	381	128
2056	1,391	329	325	0	0	0	0	0	0	0	382	129
2057	1,396	329	325	0	0	0	0	0	0	0	382	131
2058	1,402	329	325	0	0	0	0	0	0	0	383	132
2059	1,407	329	325	0	0	0	0	0	0	0	383	133
2060	1,413	329	325	0	0	0	0	0	0	0	384	135

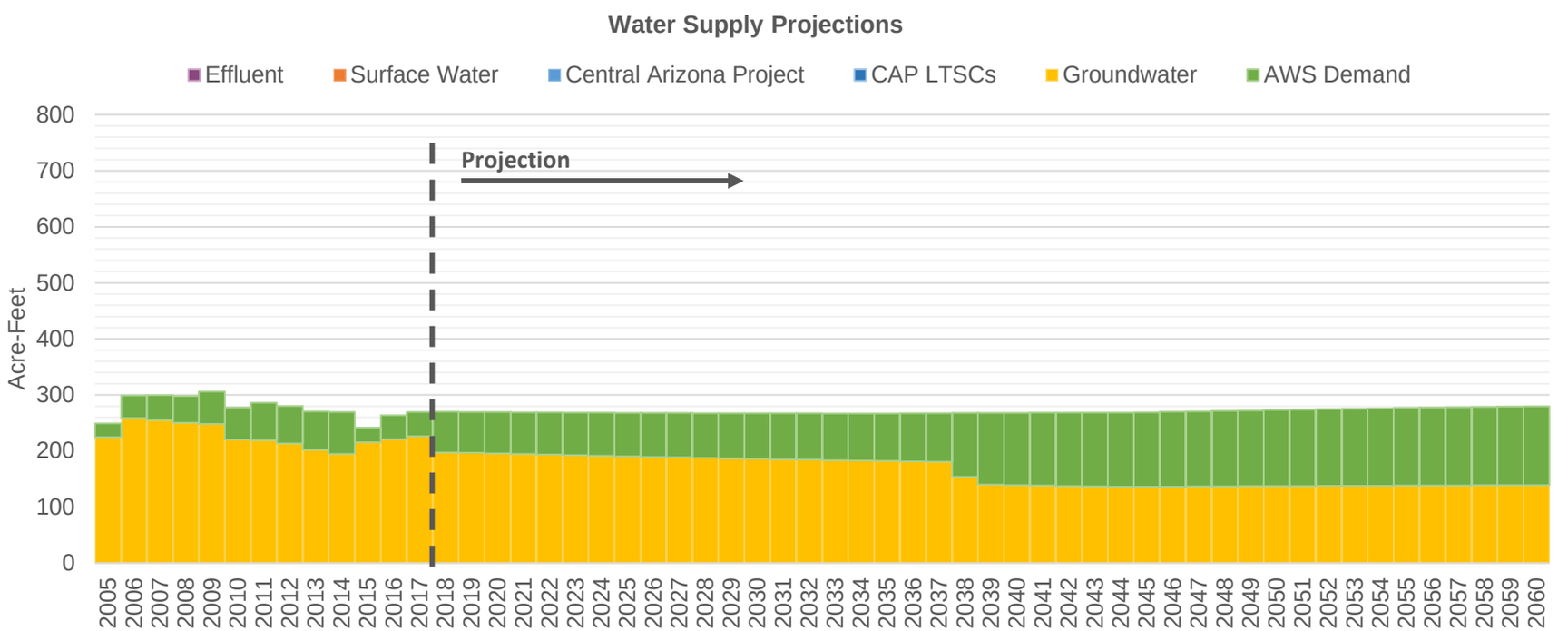
LosCerros

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

LosCerros

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

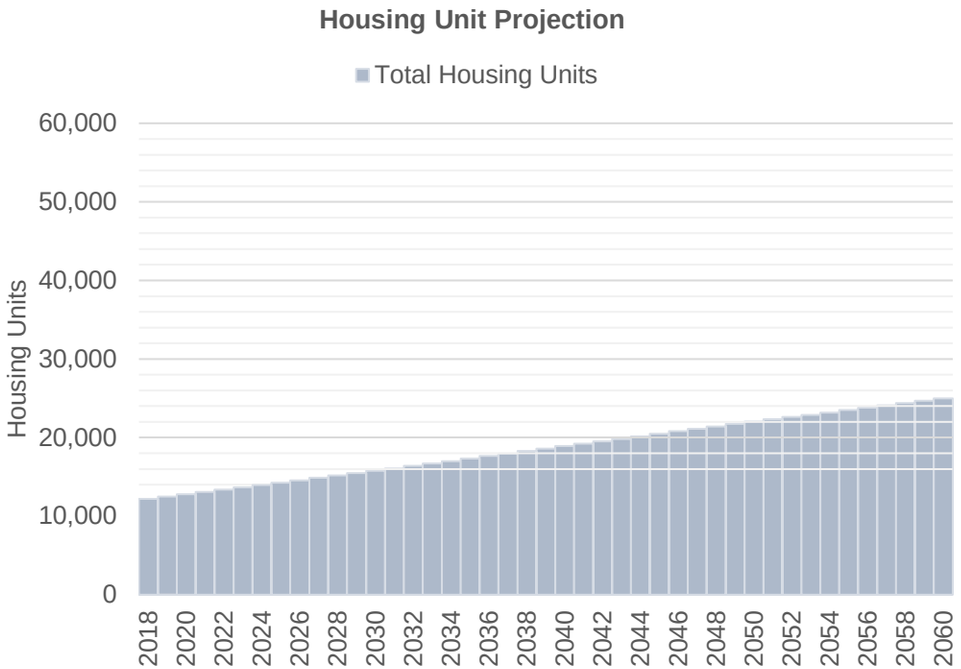
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

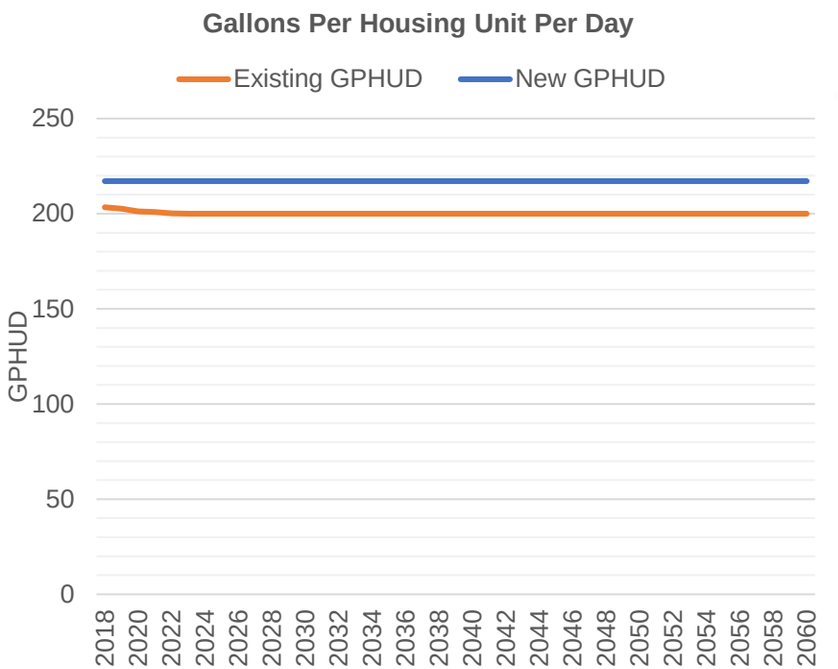
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	573	422	216	0	0	0	0	0	0	0	198	73
2019	576	420	216	0	0	0	0	0	0	0	197	73
2020	580	417	216	0	0	0	0	0	0	0	196	74
2021	583	417	216	0	0	0	0	0	0	0	194	75
2022	586	415	216	0	0	0	0	0	0	0	193	75
2023	590	413	216	0	0	0	0	0	0	0	192	76
2024	593	411	216	0	0	0	0	0	0	0	191	77
2025	596	410	216	0	0	0	0	0	0	0	190	78
2026	600	408	216	0	0	0	0	0	0	0	190	78
2027	604	407	216	0	0	0	0	0	0	0	189	79
2028	608	404	216	0	0	0	0	0	0	0	188	80
2029	612	403	216	0	0	0	0	0	0	0	187	81
2030	615	402	216	0	0	0	0	0	0	0	186	81
2031	619	400	216	0	0	0	0	0	0	0	185	82
2032	623	398	216	0	0	0	0	0	0	0	184	83
2033	627	397	216	0	0	0	0	0	0	0	184	84
2034	631	395	216	0	0	0	0	0	0	0	183	84
2035	636	394	216	0	0	0	0	0	0	0	182	85
2036	641	391	216	0	0	0	0	0	0	0	181	86
2037	646	391	216	0	0	0	0	0	0	0	181	87
2038	651	389	216	0	0	0	0	0	0	0	154	114
2039	656	388	216	0	0	0	0	0	0	0	140	128
2040	661	385	216	0	0	0	0	0	0	0	139	129
2041	666	385	216	0	0	0	0	0	0	0	138	130
2042	670	383	216	0	0	0	0	0	0	0	138	131
2043	675	381	216	0	0	0	0	0	0	0	137	132
2044	678	379	216	0	0	0	0	0	0	0	136	132
2045	682	379	216	0	0	0	0	0	0	0	136	133
2046	685	379	216	0	0	0	0	0	0	0	136	134
2047	689	379	216	0	0	0	0	0	0	0	137	134
2048	692	379	216	0	0	0	0	0	0	0	137	135
2049	696	379	216	0	0	0	0	0	0	0	137	135
2050	699	379	216	0	0	0	0	0	0	0	137	136
2051	702	379	216	0	0	0	0	0	0	0	138	137
2052	705	379	216	0	0	0	0	0	0	0	138	137
2053	708	379	216	0	0	0	0	0	0	0	138	138
2054	711	379	216	0	0	0	0	0	0	0	138	138
2055	714	379	216	0	0	0	0	0	0	0	138	139
2056	716	379	216	0	0	0	0	0	0	0	139	139
2057	719	379	216	0	0	0	0	0	0	0	139	140
2058	721	379	216	0	0	0	0	0	0	0	139	140
2059	723	379	216	0	0	0	0	0	0	0	139	140
2060	726	379	216	0	0	0	0	0	0	0	139	141

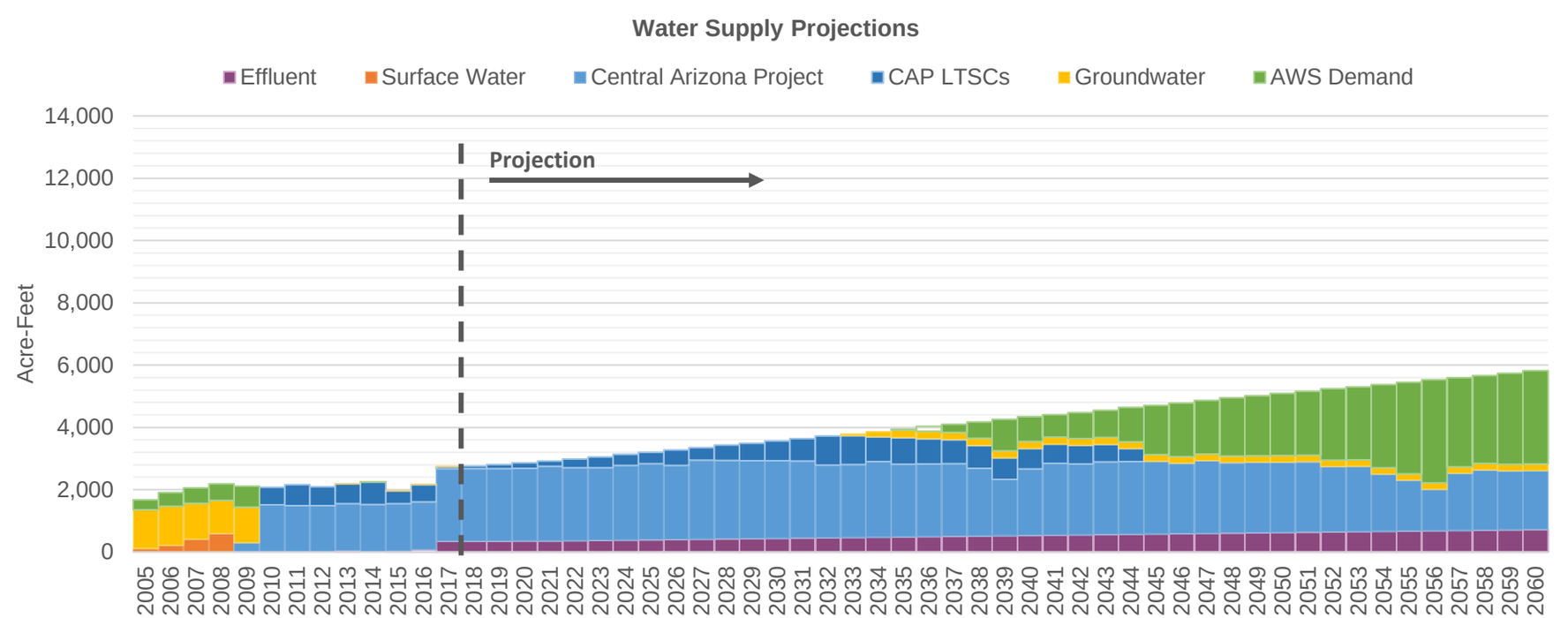
Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

Marana







Central Arizona Project Service Area Model

Marana

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

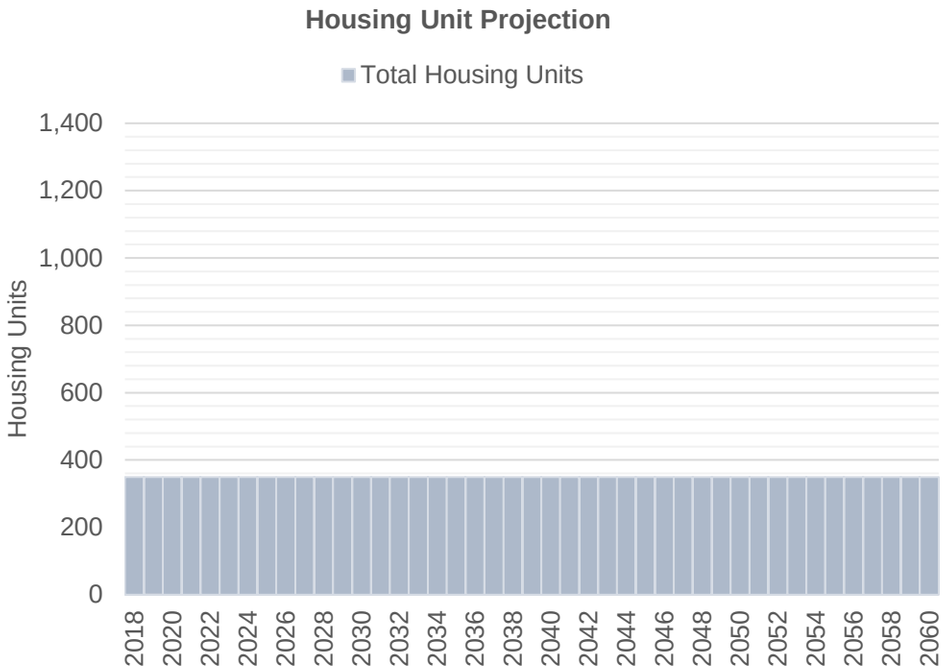
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

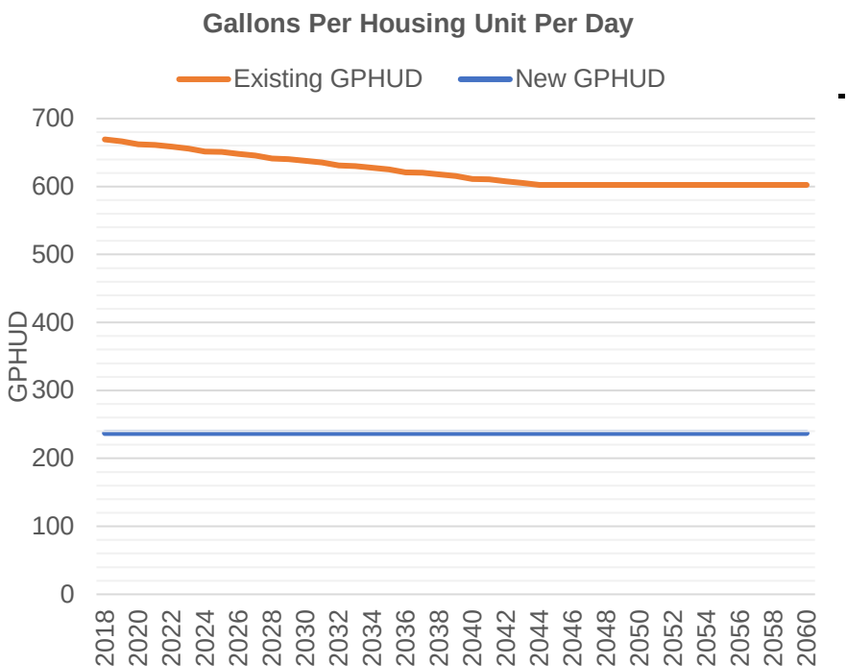
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	12,194	203	217	345	0	0	0	2,336	0	84	0	0
2019	12,483	203	217	345	0	0	0	2,336	0	123	0	0
2020	12,774	201	217	350	0	0	0	2,336	0	178	0	0
2021	13,068	201	217	357	0	0	0	2,393	0	174	0	0
2022	13,364	200	217	365	0	0	0	2,338	0	283	0	0
2023	13,662	200	217	372	0	0	0	2,336	0	347	0	0
2024	13,960	200	217	381	0	0	0	2,395	0	360	0	0
2025	14,259	200	217	391	0	0	0	2,446	0	363	0	0
2026	14,560	200	217	399	0	0	0	2,376	0	498	0	0
2027	14,870	200	217	408	0	0	0	2,536	0	403	0	0
2028	15,175	200	217	417	0	0	0	2,520	0	494	0	0
2029	15,476	200	217	428	0	0	0	2,505	0	563	0	0
2030	15,773	200	217	436	0	0	0	2,489	0	643	0	0
2031	16,083	200	217	445	0	0	0	2,474	0	723	0	0
2032	16,390	200	217	454	0	0	0	2,336	0	938	0	0
2033	16,694	200	217	465	0	0	0	2,342	0	930	54	0
2034	17,007	200	217	473	0	0	0	2,431	0	795	168	0
2035	17,335	200	217	482	0	0	0	2,336	0	850	243	34
2036	17,659	200	217	492	0	0	0	2,336	0	808	238	161
2037	17,979	200	217	503	0	0	0	2,336	0	767	234	262
2038	18,295	200	217	512	0	0	0	2,177	0	729	231	532
2039	18,606	200	217	521	0	0	0	1,808	0	692	227	1,007
2040	18,913	200	217	531	0	0	0	2,137	0	658	224	793
2041	19,216	200	217	542	0	0	0	2,300	0	625	222	718
2042	19,514	200	217	549	0	0	0	2,279	0	594	219	838
2043	19,822	200	217	558	0	0	0	2,336	0	564	217	877
2044	20,153	200	217	568	0	0	0	2,336	0	416	215	1,108
2045	20,479	200	217	579	0	0	0	2,336	0	0	214	1,581
2046	20,800	200	217	587	0	0	0	2,261	0	0	212	1,729
2047	21,115	200	217	597	0	0	0	2,336	0	0	211	1,722
2048	21,425	200	217	607	0	0	0	2,261	0	0	210	1,878
2049	21,729	200	217	618	0	0	0	2,261	0	0	209	1,929
2050	22,028	200	217	626	0	0	0	2,261	0	0	209	1,995
2051	22,320	200	217	635	0	0	0	2,261	0	0	208	2,058
2052	22,608	200	217	644	0	0	0	2,098	0	0	208	2,296
2053	22,889	200	217	654	0	0	0	2,098	0	0	208	2,341
2054	23,183	200	217	661	0	0	0	1,835	0	0	208	2,667
2055	23,497	200	217	670	0	0	0	1,633	0	0	208	2,934
2056	23,805	200	217	679	0	0	0	1,329	0	0	209	3,320
2057	24,107	200	217	690	0	0	0	1,835	0	0	209	2,861
2058	24,401	200	217	698	0	0	0	1,936	0	0	210	2,824
2059	24,690	200	217	707	0	0	0	1,896	0	0	210	2,925
2060	24,971	200	217	716	0	0	0	1,896	0	0	211	3,001

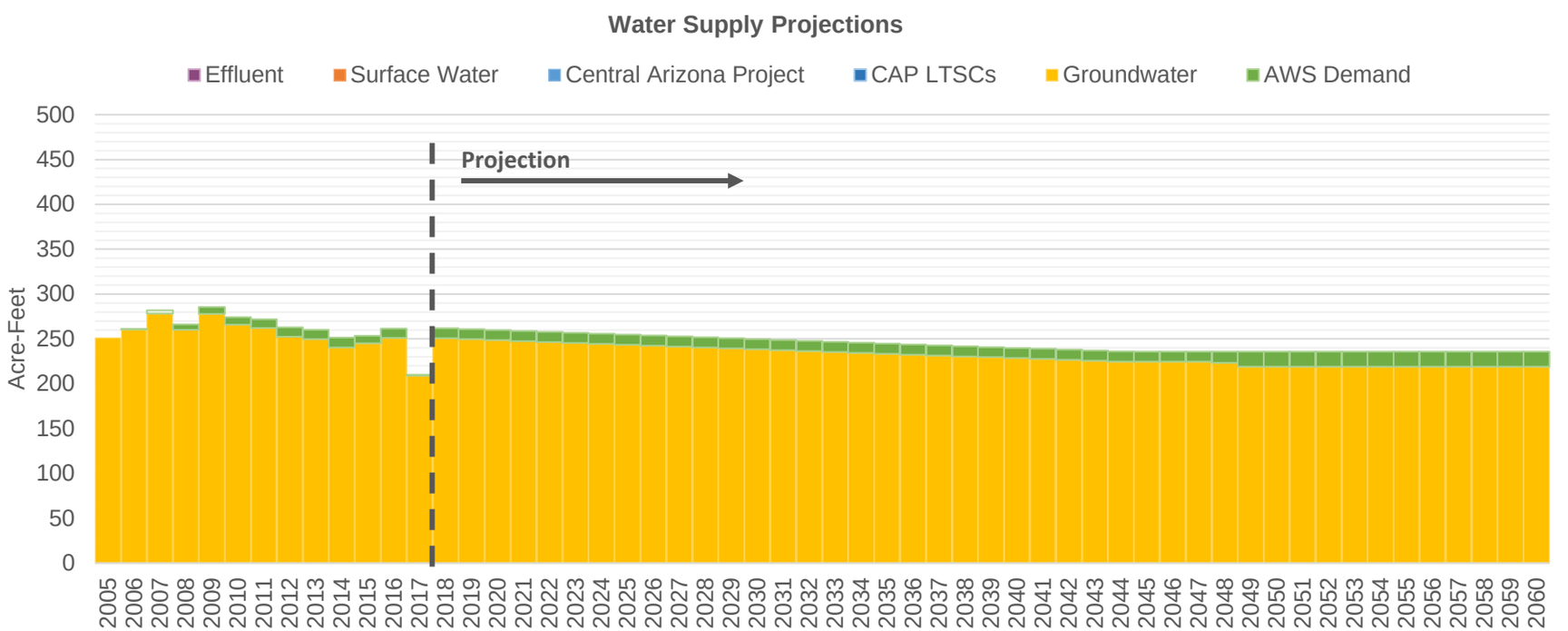
Central Arizona Project Service Area Model

MaranaDomestic

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

MaranaDomesti

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

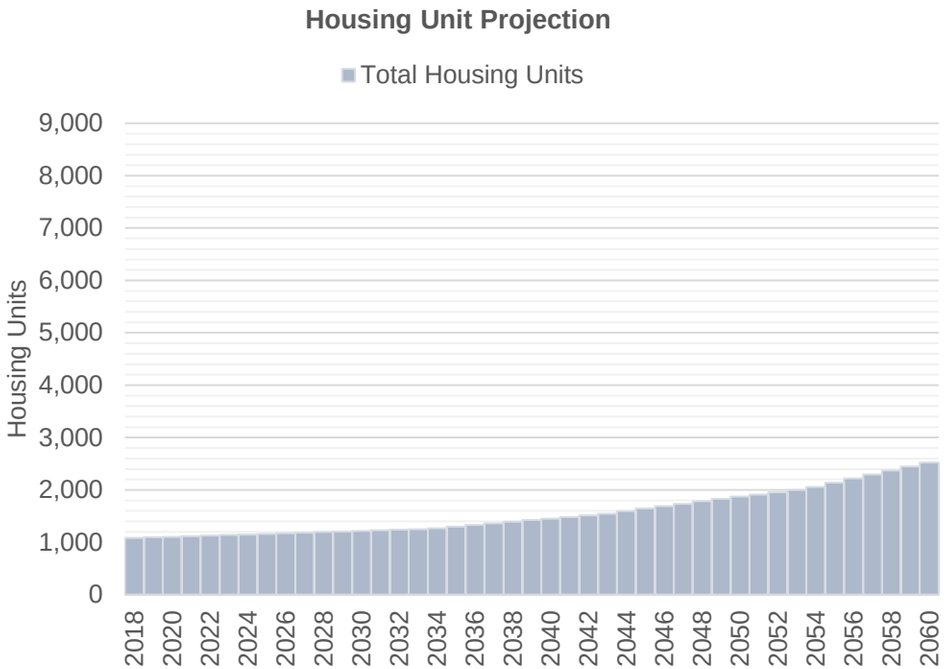
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

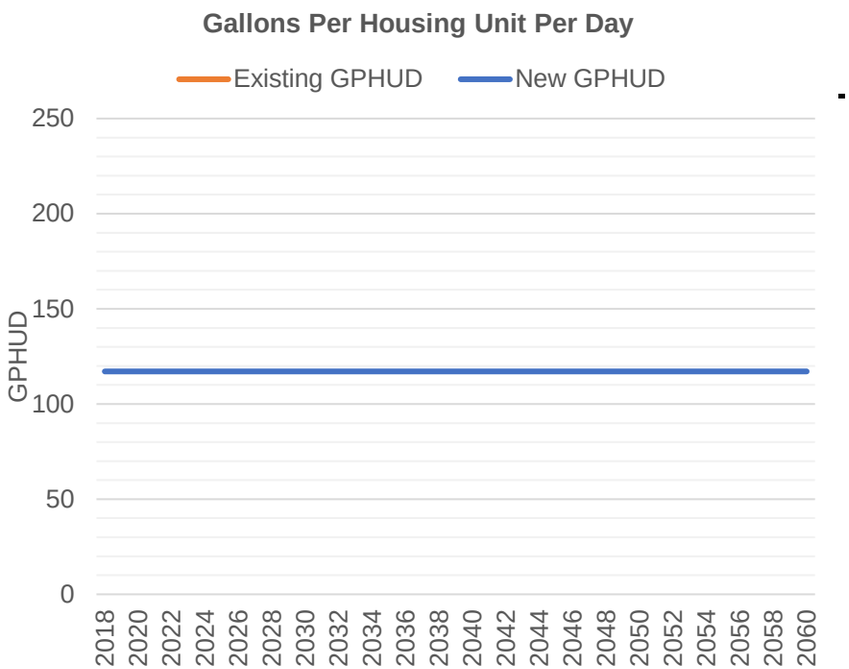
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	349	669	237	0	0	0	0	0	0	0	251	11
2019	349	667	237	0	0	0	0	0	0	0	250	11
2020	349	662	237	0	0	0	0	0	0	0	249	11
2021	349	661	237	0	0	0	0	0	0	0	248	11
2022	349	659	237	0	0	0	0	0	0	0	247	11
2023	349	656	237	0	0	0	0	0	0	0	246	11
2024	349	652	237	0	0	0	0	0	0	0	245	11
2025	349	651	237	0	0	0	0	0	0	0	243	11
2026	349	648	237	0	0	0	0	0	0	0	242	11
2027	349	646	237	0	0	0	0	0	0	0	241	11
2028	349	641	237	0	0	0	0	0	0	0	240	11
2029	349	640	237	0	0	0	0	0	0	0	239	11
2030	349	638	237	0	0	0	0	0	0	0	238	11
2031	349	635	237	0	0	0	0	0	0	0	237	11
2032	349	631	237	0	0	0	0	0	0	0	236	11
2033	349	630	237	0	0	0	0	0	0	0	235	11
2034	349	628	237	0	0	0	0	0	0	0	234	11
2035	349	625	237	0	0	0	0	0	0	0	233	11
2036	349	621	237	0	0	0	0	0	0	0	233	11
2037	349	620	237	0	0	0	0	0	0	0	232	11
2038	349	618	237	0	0	0	0	0	0	0	231	11
2039	349	615	237	0	0	0	0	0	0	0	230	11
2040	349	611	237	0	0	0	0	0	0	0	229	11
2041	349	610	237	0	0	0	0	0	0	0	228	11
2042	349	608	237	0	0	0	0	0	0	0	227	11
2043	349	605	237	0	0	0	0	0	0	0	226	11
2044	349	602	237	0	0	0	0	0	0	0	225	11
2045	349	602	237	0	0	0	0	0	0	0	225	11
2046	349	602	237	0	0	0	0	0	0	0	225	11
2047	349	602	237	0	0	0	0	0	0	0	225	11
2048	349	602	237	0	0	0	0	0	0	0	224	12
2049	349	602	237	0	0	0	0	0	0	0	219	17
2050	349	602	237	0	0	0	0	0	0	0	219	17
2051	349	602	237	0	0	0	0	0	0	0	219	17
2052	349	602	237	0	0	0	0	0	0	0	219	17
2053	349	602	237	0	0	0	0	0	0	0	219	17
2054	349	602	237	0	0	0	0	0	0	0	219	17
2055	349	602	237	0	0	0	0	0	0	0	219	17
2056	349	602	237	0	0	0	0	0	0	0	219	17
2057	349	602	237	0	0	0	0	0	0	0	219	17
2058	349	602	237	0	0	0	0	0	0	0	219	17
2059	349	602	237	0	0	0	0	0	0	0	219	17
2060	349	602	237	0	0	0	0	0	0	0	219	17

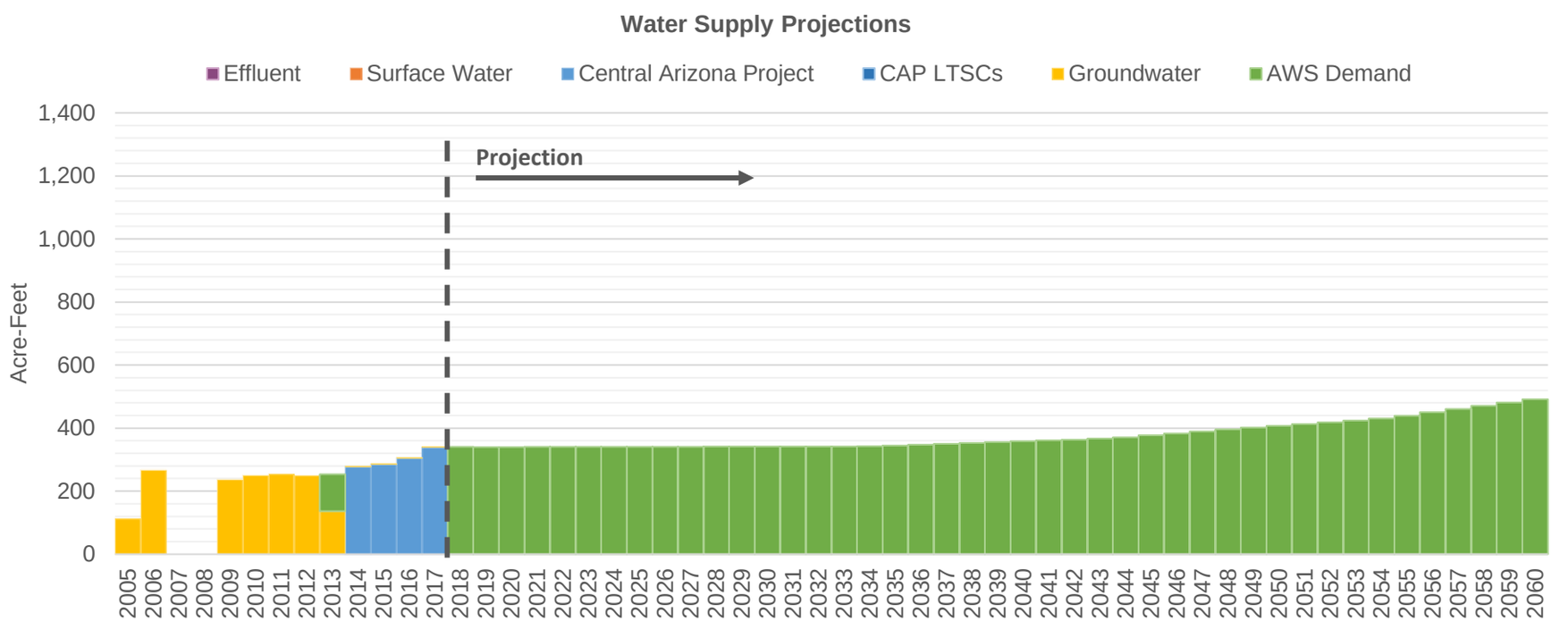
Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

MetroDiablo







Central Arizona Project Service Area Model

MetroDiablo

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

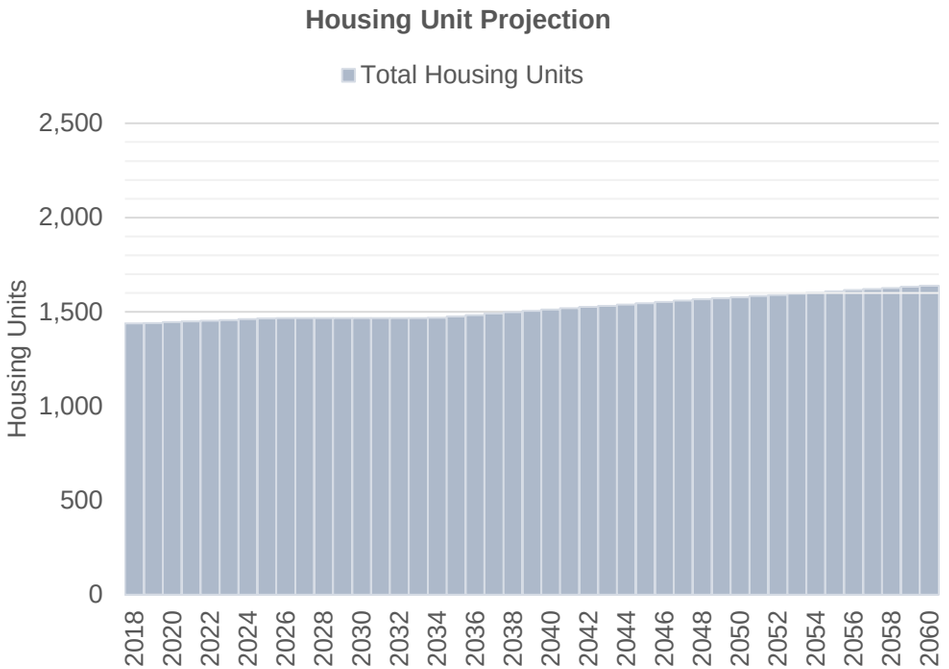
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

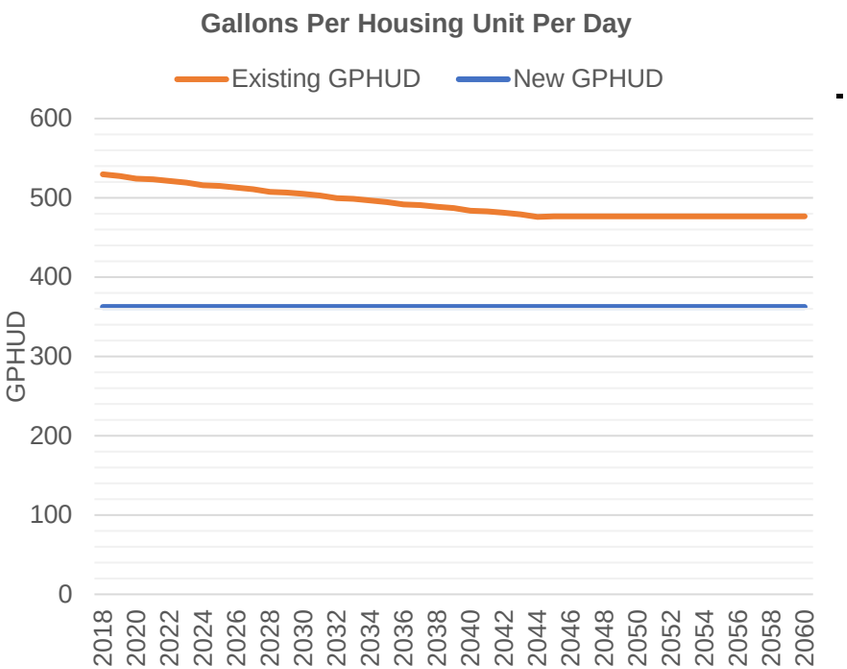
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,085	281	117	0	0	0	0	0	0	0	0	340
2019	1,096	280	117	0	0	0	0	0	0	0	0	340
2020	1,107	278	117	0	0	0	0	0	0	0	0	340
2021	1,118	278	117	0	0	0	0	0	0	0	0	340
2022	1,129	277	117	0	0	0	0	0	0	0	0	340
2023	1,140	276	117	0	0	0	0	0	0	0	0	340
2024	1,151	274	117	0	0	0	0	0	0	0	0	341
2025	1,163	273	117	0	0	0	0	0	0	0	0	341
2026	1,174	272	117	0	0	0	0	0	0	0	0	341
2027	1,185	271	117	0	0	0	0	0	0	0	0	341
2028	1,196	269	117	0	0	0	0	0	0	0	0	341
2029	1,207	269	117	0	0	0	0	0	0	0	0	341
2030	1,218	268	117	0	0	0	0	0	0	0	0	341
2031	1,229	267	117	0	0	0	0	0	0	0	0	342
2032	1,240	265	117	0	0	0	0	0	0	0	0	342
2033	1,251	265	117	0	0	0	0	0	0	0	0	342
2034	1,270	264	117	0	0	0	0	0	0	0	0	343
2035	1,302	263	117	0	0	0	0	0	0	0	0	345
2036	1,333	261	117	0	0	0	0	0	0	0	0	348
2037	1,364	261	117	0	0	0	0	0	0	0	0	350
2038	1,395	259	117	0	0	0	0	0	0	0	0	353
2039	1,425	258	117	0	0	0	0	0	0	0	0	356
2040	1,454	257	117	0	0	0	0	0	0	0	0	359
2041	1,483	256	117	0	0	0	0	0	0	0	0	361
2042	1,512	255	117	0	0	0	0	0	0	0	0	364
2043	1,547	253	117	0	0	0	0	0	0	0	0	367
2044	1,596	253	117	0	0	0	0	0	0	0	0	371
2045	1,644	253	117	0	0	0	0	0	0	0	0	377
2046	1,691	253	117	0	0	0	0	0	0	0	0	383
2047	1,737	253	117	0	0	0	0	0	0	0	0	389
2048	1,783	253	117	0	0	0	0	0	0	0	0	395
2049	1,827	253	117	0	0	0	0	0	0	0	0	401
2050	1,871	253	117	0	0	0	0	0	0	0	0	407
2051	1,914	253	117	0	0	0	0	0	0	0	0	413
2052	1,956	253	117	0	0	0	0	0	0	0	0	419
2053	1,998	253	117	0	0	0	0	0	0	0	0	424
2054	2,055	253	117	0	0	0	0	0	0	0	0	430
2055	2,138	253	117	0	0	0	0	0	0	0	0	439
2056	2,218	253	117	0	0	0	0	0	0	0	0	450
2057	2,297	253	117	0	0	0	0	0	0	0	0	461
2058	2,375	253	117	0	0	0	0	0	0	0	0	471
2059	2,450	253	117	0	0	0	0	0	0	0	0	481
2060	2,524	253	117	0	0	0	0	0	0	0	0	491

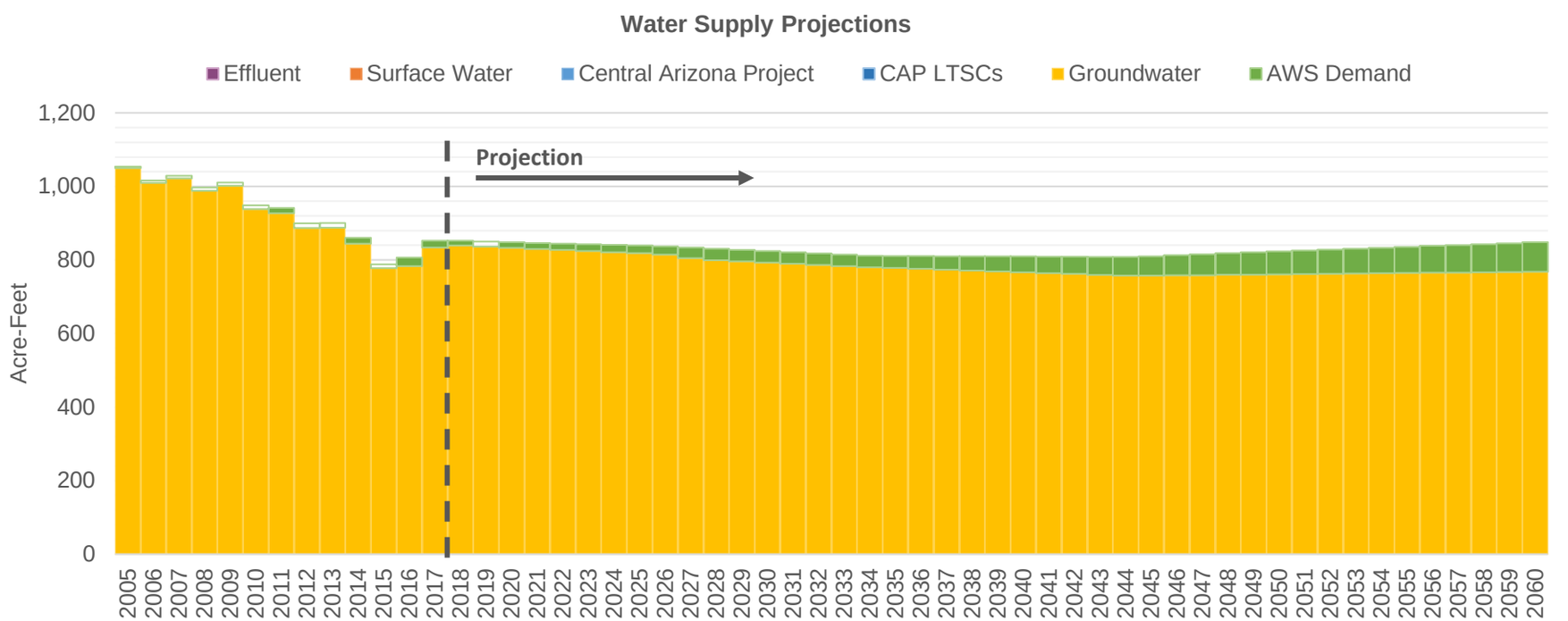
Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

MetroHub







Central Arizona Project Service Area Model

MetroHub

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

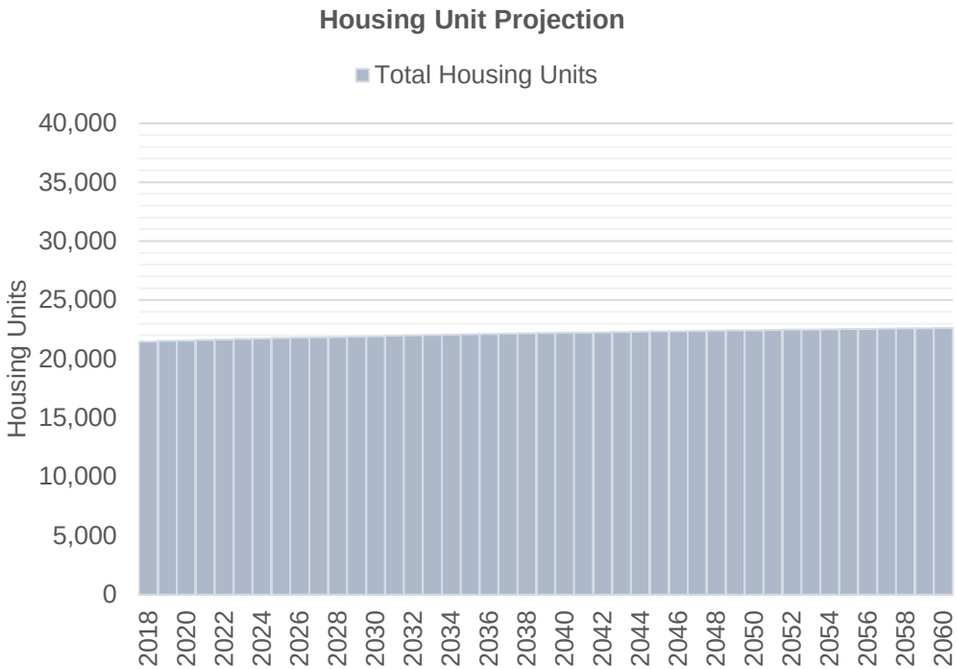
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

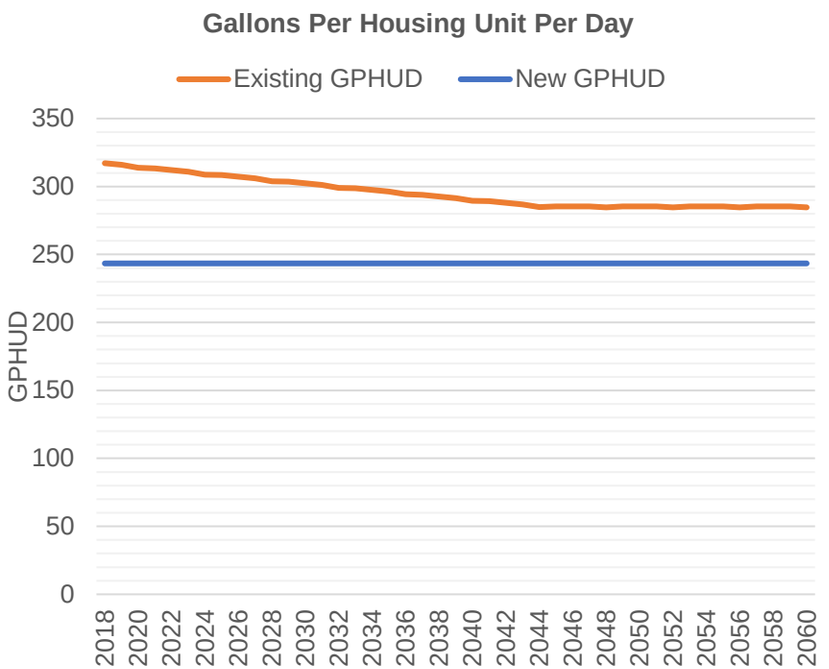
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,438	530	362	0	0	0	0	0	0	0	839	13
2019	1,441	528	362	0	0	0	0	0	0	0	836	14
2020	1,445	524	362	0	0	0	0	0	0	0	833	15
2021	1,449	523	362	0	0	0	0	0	0	0	830	16
2022	1,453	521	362	0	0	0	0	0	0	0	827	17
2023	1,457	519	362	0	0	0	0	0	0	0	824	18
2024	1,461	516	362	0	0	0	0	0	0	0	821	20
2025	1,465	515	362	0	0	0	0	0	0	0	819	21
2026	1,466	513	362	0	0	0	0	0	0	0	815	22
2027	1,466	511	362	0	0	0	0	0	0	0	805	29
2028	1,466	508	362	0	0	0	0	0	0	0	799	31
2029	1,466	507	362	0	0	0	0	0	0	0	796	31
2030	1,466	505	362	0	0	0	0	0	0	0	793	31
2031	1,466	503	362	0	0	0	0	0	0	0	790	31
2032	1,466	499	362	0	0	0	0	0	0	0	786	31
2033	1,466	499	362	0	0	0	0	0	0	0	783	31
2034	1,468	497	362	0	0	0	0	0	0	0	780	31
2035	1,476	495	362	0	0	0	0	0	0	0	779	32
2036	1,483	491	362	0	0	0	0	0	0	0	776	34
2037	1,491	491	362	0	0	0	0	0	0	0	774	36
2038	1,498	489	362	0	0	0	0	0	0	0	772	39
2039	1,505	487	362	0	0	0	0	0	0	0	769	41
2040	1,512	484	362	0	0	0	0	0	0	0	767	43
2041	1,519	483	362	0	0	0	0	0	0	0	764	45
2042	1,526	481	362	0	0	0	0	0	0	0	762	47
2043	1,532	479	362	0	0	0	0	0	0	0	760	49
2044	1,539	476	362	0	0	0	0	0	0	0	758	51
2045	1,546	477	362	0	0	0	0	0	0	0	757	53
2046	1,553	477	362	0	0	0	0	0	0	0	758	55
2047	1,559	477	362	0	0	0	0	0	0	0	759	57
2048	1,566	477	362	0	0	0	0	0	0	0	760	58
2049	1,572	477	362	0	0	0	0	0	0	0	760	60
2050	1,578	477	362	0	0	0	0	0	0	0	761	62
2051	1,584	477	362	0	0	0	0	0	0	0	762	64
2052	1,590	477	362	0	0	0	0	0	0	0	763	66
2053	1,596	477	362	0	0	0	0	0	0	0	763	68
2054	1,602	477	362	0	0	0	0	0	0	0	764	69
2055	1,609	477	362	0	0	0	0	0	0	0	765	71
2056	1,615	477	362	0	0	0	0	0	0	0	765	73
2057	1,621	477	362	0	0	0	0	0	0	0	766	75
2058	1,627	477	362	0	0	0	0	0	0	0	767	77
2059	1,633	477	362	0	0	0	0	0	0	0	767	78
2060	1,639	477	362	0	0	0	0	0	0	0	768	80

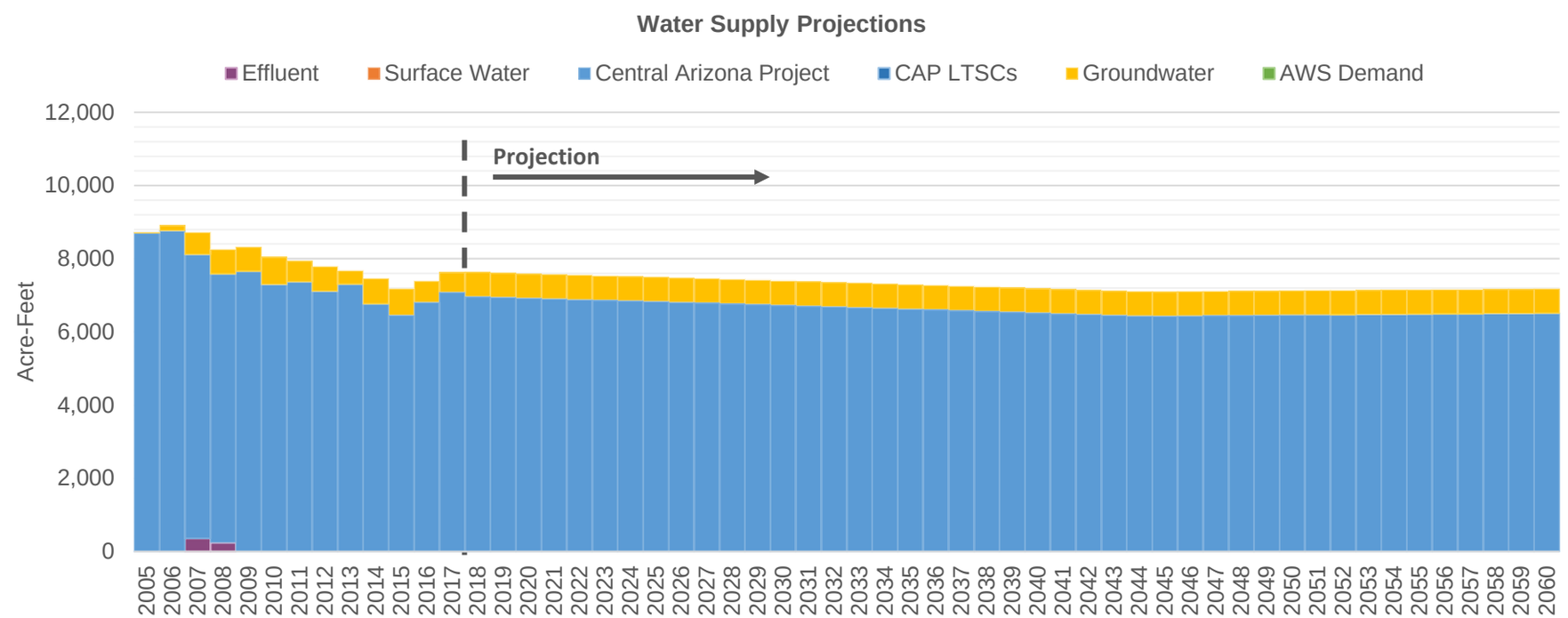
Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

MetroMain







Central Arizona Project Service Area Model

MetroMain

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

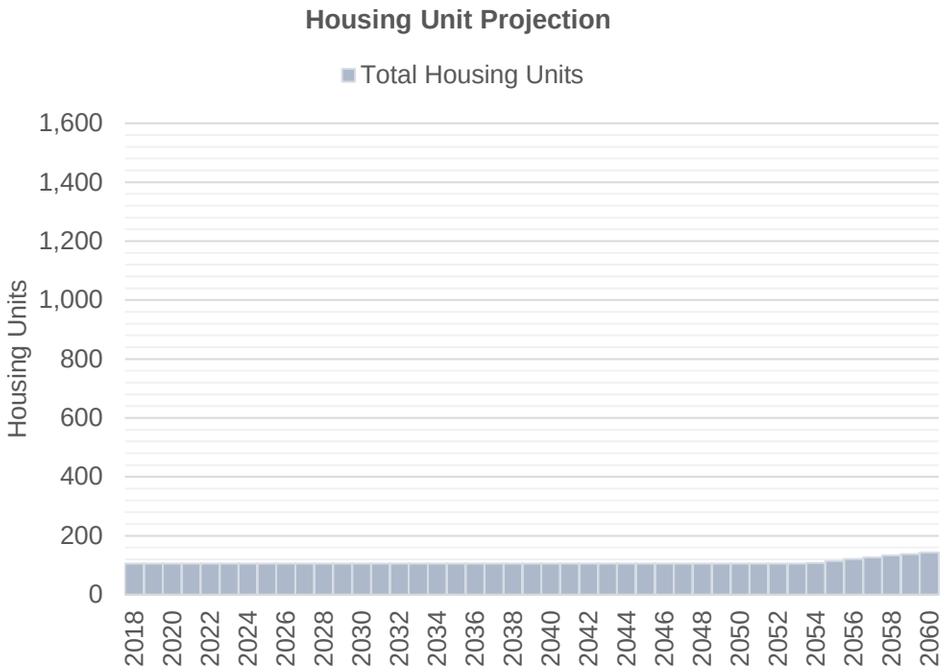
Demand Assumptions **Water Supply Projections** (Acre-Feet)

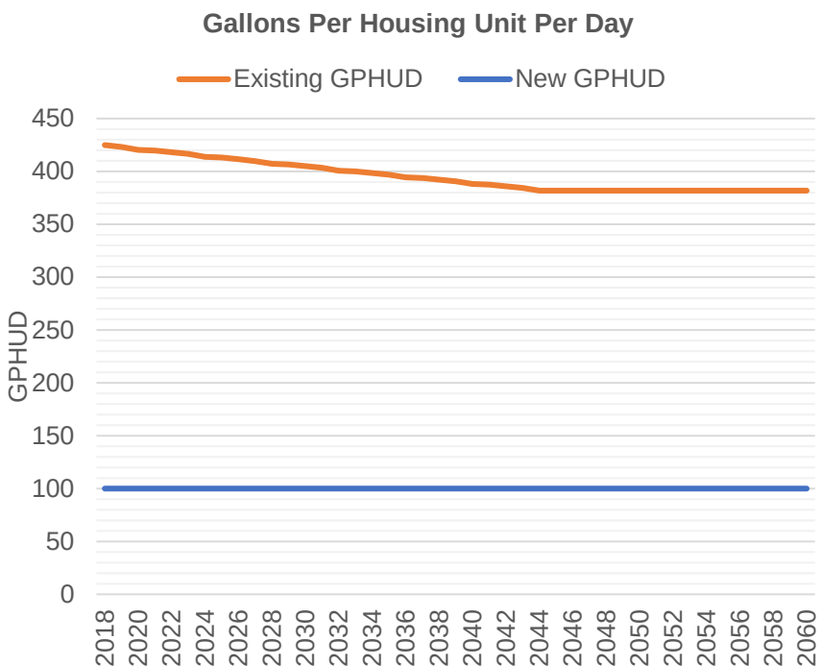
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	21,487	317	243	0	0	0	0	6,962	6,498	0	668	0
2019	21,527	316	243	0	0	0	0	6,939	6,521	0	668	0
2020	21,568	314	243	0	0	0	0	6,920	6,540	0	668	0
2021	21,610	313	243	0	0	0	0	6,901	6,559	0	668	0
2022	21,651	312	243	0	0	0	0	6,882	6,578	0	668	0
2023	21,693	311	243	0	0	0	0	6,863	6,597	0	668	0
2024	21,735	309	243	0	0	0	0	6,845	6,615	0	668	0
2025	21,777	308	243	0	0	0	0	6,827	6,633	0	668	0
2026	21,813	307	243	0	0	0	0	6,808	6,652	0	668	0
2027	21,845	306	243	0	0	0	0	6,787	6,673	0	668	0
2028	21,878	304	243	0	0	0	0	6,767	6,693	0	668	0
2029	21,909	303	243	0	0	0	0	6,746	6,714	0	668	0
2030	21,940	302	243	0	0	0	0	6,725	6,735	0	668	0
2031	21,973	301	243	0	0	0	0	6,705	6,755	0	668	0
2032	22,005	299	243	0	0	0	0	6,685	6,775	0	668	0
2033	22,037	299	243	0	0	0	0	6,665	6,795	0	668	0
2034	22,067	297	243	0	0	0	0	6,645	6,815	0	668	0
2035	22,094	296	243	0	0	0	0	6,624	6,836	0	668	0
2036	22,120	294	243	0	0	0	0	6,603	6,857	0	668	0
2037	22,146	294	243	0	0	0	0	6,581	6,879	0	668	0
2038	22,171	293	243	0	0	0	0	6,560	5,982	0	668	0
2039	22,197	292	243	0	0	0	0	6,539	3,878	0	668	0
2040	22,222	290	243	0	0	0	0	6,518	5,794	0	668	0
2041	22,246	289	243	0	0	0	0	6,496	6,753	0	668	0
2042	22,270	288	243	0	0	0	0	6,475	6,655	0	668	0
2043	22,294	287	243	0	0	0	0	6,454	7,006	0	668	0
2044	22,316	285	243	0	0	0	0	6,433	7,027	0	668	0
2045	22,338	285	243	0	0	0	0	6,431	7,029	0	668	0
2046	22,359	285	243	0	0	0	0	6,436	6,589	0	668	0
2047	22,381	285	243	0	0	0	0	6,442	7,018	0	668	0
2048	22,401	285	243	0	0	0	0	6,449	6,576	0	668	0
2049	22,422	285	243	0	0	0	0	6,454	6,571	0	668	0
2050	22,442	285	243	0	0	0	0	6,459	6,566	0	668	0
2051	22,461	285	243	0	0	0	0	6,465	6,561	0	668	0
2052	22,481	285	243	0	0	0	0	6,471	5,621	0	668	0
2053	22,499	285	243	0	0	0	0	6,475	5,616	0	668	0
2054	22,518	285	243	0	0	0	0	6,480	4,094	0	668	0
2055	22,535	285	243	0	0	0	0	6,485	2,922	0	668	0
2056	22,553	285	243	0	0	0	0	6,491	1,165	0	668	0
2057	22,570	285	243	0	0	0	0	6,495	4,079	0	668	0
2058	22,586	285	243	0	0	0	0	6,499	4,658	0	668	0
2059	22,602	285	243	0	0	0	0	6,503	4,421	0	668	0
2060	22,618	285	243	0	0	0	0	6,509	4,415	0	668	0

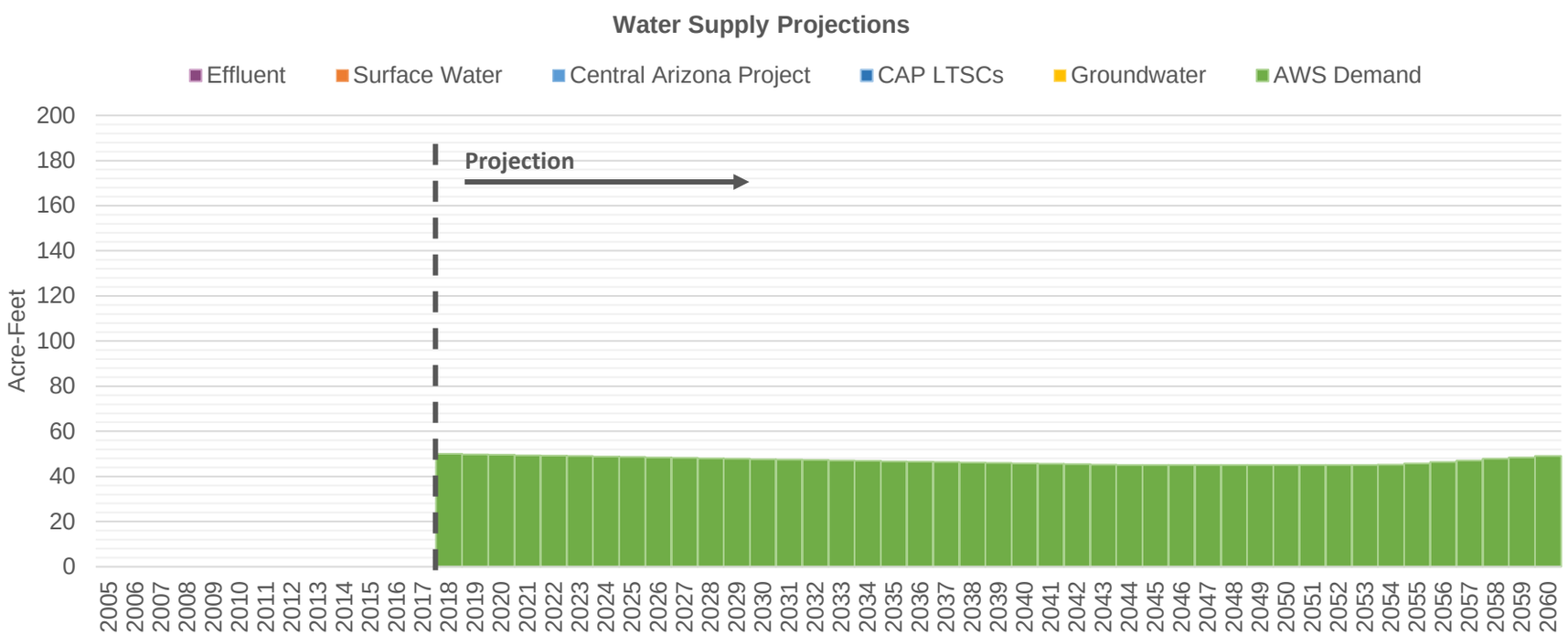
Central Arizona Project Service Area Model

MetroWest

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

MetroWest

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

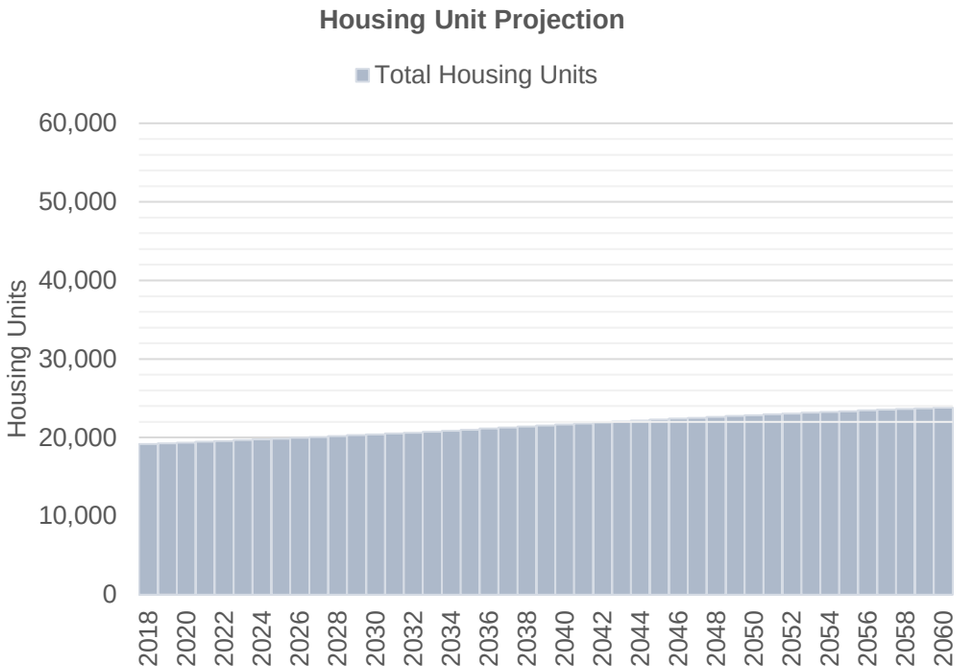
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

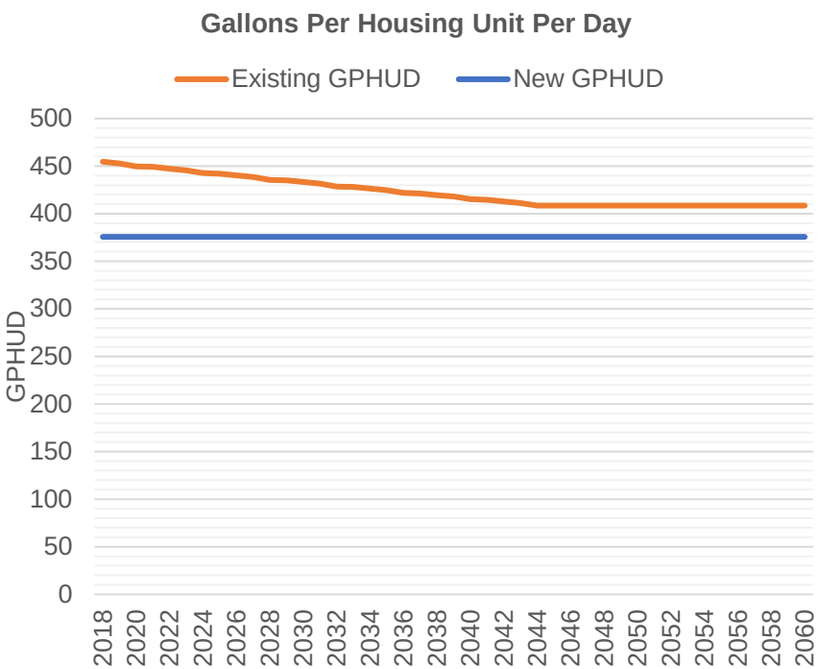
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	105	425	100	0	0	0	0	0	0	0	0	50
2019	105	423	100	0	0	0	0	0	0	0	0	50
2020	105	420	100	0	0	0	0	0	0	0	0	50
2021	105	420	100	0	0	0	0	0	0	0	0	49
2022	105	418	100	0	0	0	0	0	0	0	0	49
2023	105	416	100	0	0	0	0	0	0	0	0	49
2024	105	414	100	0	0	0	0	0	0	0	0	49
2025	105	413	100	0	0	0	0	0	0	0	0	49
2026	105	412	100	0	0	0	0	0	0	0	0	48
2027	105	410	100	0	0	0	0	0	0	0	0	48
2028	105	407	100	0	0	0	0	0	0	0	0	48
2029	105	407	100	0	0	0	0	0	0	0	0	48
2030	105	405	100	0	0	0	0	0	0	0	0	48
2031	105	403	100	0	0	0	0	0	0	0	0	47
2032	105	401	100	0	0	0	0	0	0	0	0	47
2033	105	400	100	0	0	0	0	0	0	0	0	47
2034	105	399	100	0	0	0	0	0	0	0	0	47
2035	105	397	100	0	0	0	0	0	0	0	0	47
2036	105	394	100	0	0	0	0	0	0	0	0	47
2037	105	394	100	0	0	0	0	0	0	0	0	46
2038	105	392	100	0	0	0	0	0	0	0	0	46
2039	105	391	100	0	0	0	0	0	0	0	0	46
2040	105	388	100	0	0	0	0	0	0	0	0	46
2041	105	388	100	0	0	0	0	0	0	0	0	46
2042	105	386	100	0	0	0	0	0	0	0	0	45
2043	105	384	100	0	0	0	0	0	0	0	0	45
2044	105	382	100	0	0	0	0	0	0	0	0	45
2045	105	382	100	0	0	0	0	0	0	0	0	45
2046	105	382	100	0	0	0	0	0	0	0	0	45
2047	105	382	100	0	0	0	0	0	0	0	0	45
2048	105	382	100	0	0	0	0	0	0	0	0	45
2049	105	382	100	0	0	0	0	0	0	0	0	45
2050	105	382	100	0	0	0	0	0	0	0	0	45
2051	105	382	100	0	0	0	0	0	0	0	0	45
2052	105	382	100	0	0	0	0	0	0	0	0	45
2053	105	382	100	0	0	0	0	0	0	0	0	45
2054	108	382	100	0	0	0	0	0	0	0	0	45
2055	114	382	100	0	0	0	0	0	0	0	0	46
2056	121	382	100	0	0	0	0	0	0	0	0	46
2057	127	382	100	0	0	0	0	0	0	0	0	47
2058	133	382	100	0	0	0	0	0	0	0	0	48
2059	138	382	100	0	0	0	0	0	0	0	0	48
2060	144	382	100	0	0	0	0	0	0	0	0	49

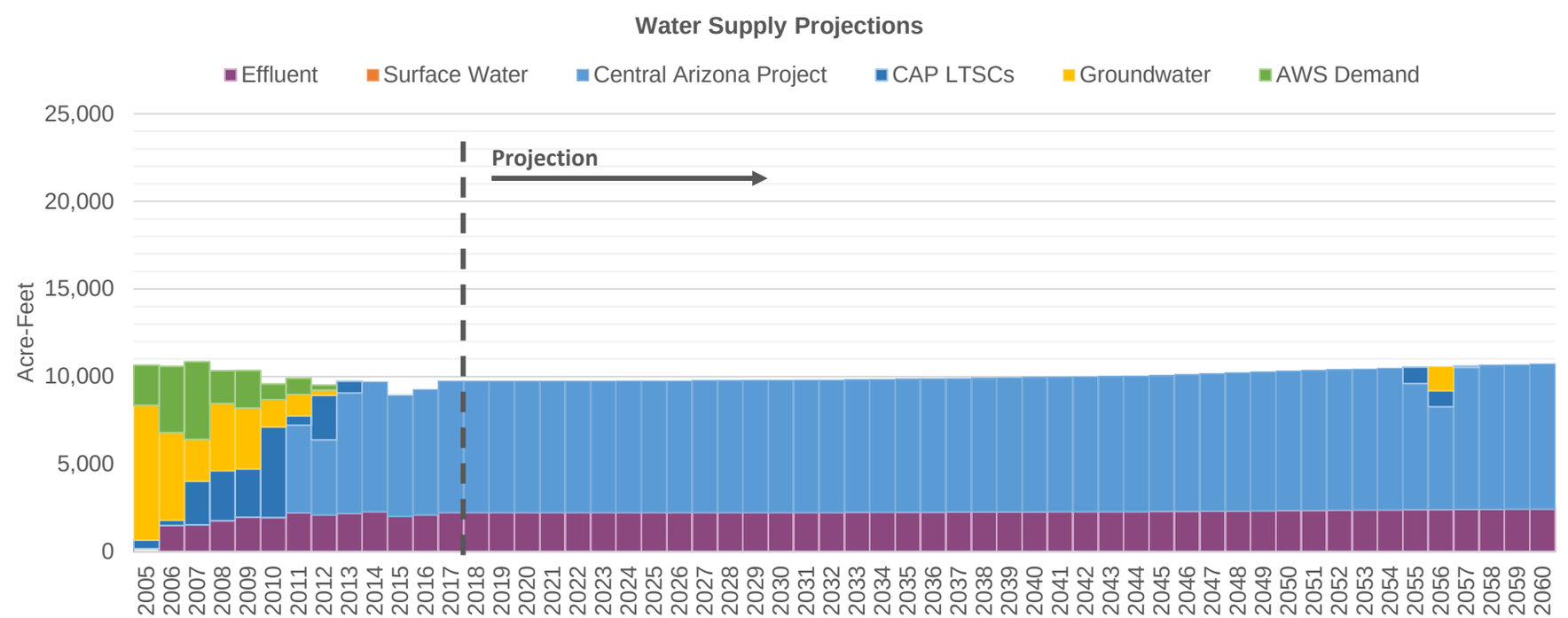
OroValley

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

OroValley

7/13/20 12:06 PM

Demand Assumptions

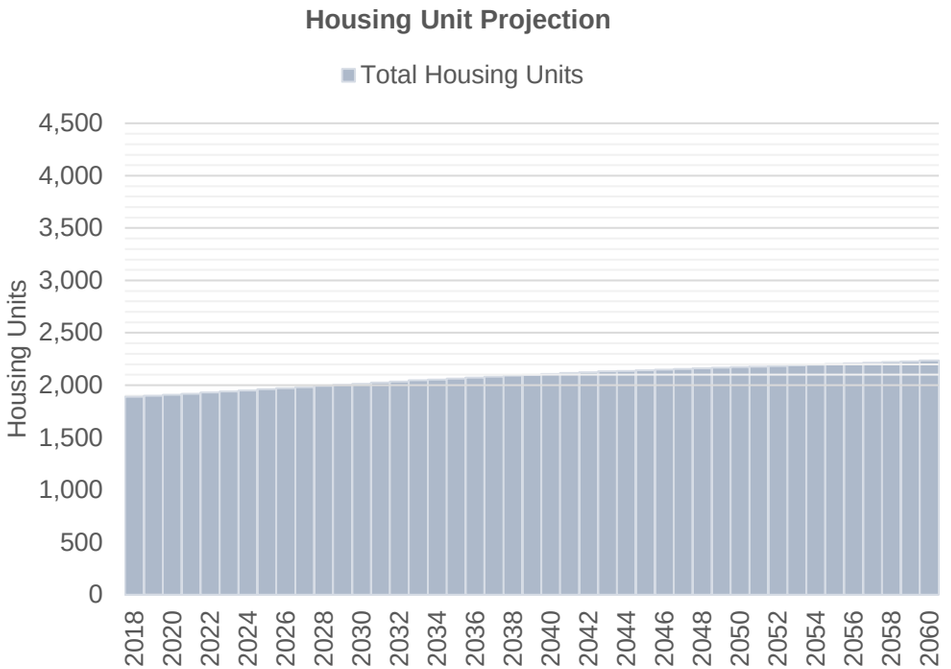
Water Supply Projections (Acre-Feet)

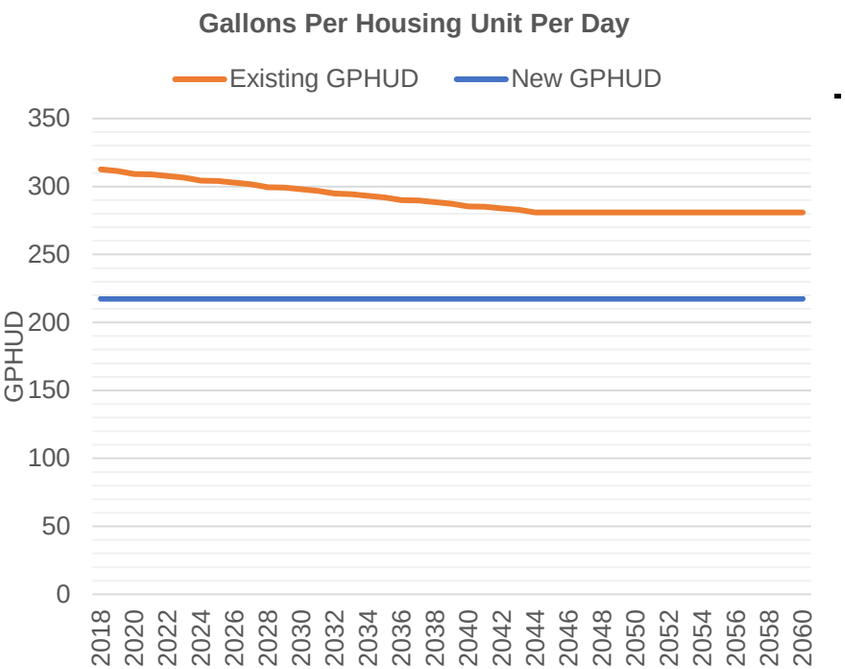
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	19,174	455	376	2,232	0	0	0	7,520	2,785	0	0	0
2019	19,271	453	376	2,232	0	0	0	7,510	2,795	0	0	0
2020	19,368	450	376	2,230	0	0	0	7,515	2,790	0	0	0
2021	19,467	449	376	2,230	0	0	0	7,517	2,788	0	0	0
2022	19,566	447	376	2,231	0	0	0	7,519	2,786	0	0	0
2023	19,666	446	376	2,232	0	0	0	7,522	2,783	0	0	0
2024	19,766	443	376	2,232	0	0	0	7,526	2,779	0	0	0
2025	19,866	442	376	2,233	0	0	0	7,529	2,776	0	0	0
2026	19,971	440	376	2,234	0	0	0	7,533	2,772	0	0	0
2027	20,082	439	376	2,235	0	0	0	7,540	2,765	0	0	0
2028	20,192	436	376	2,237	0	0	0	7,548	2,757	0	0	0
2029	20,300	435	376	2,239	0	0	0	7,553	2,752	0	0	0
2030	20,407	433	376	2,241	0	0	0	7,559	2,746	0	0	0
2031	20,519	432	376	2,243	0	0	0	7,566	2,739	0	0	0
2032	20,629	429	376	2,245	0	0	0	7,575	2,730	0	0	0
2033	20,738	428	376	2,248	0	0	0	7,580	2,725	0	0	0
2034	20,859	426	376	2,249	0	0	0	7,590	2,715	0	0	0
2035	20,999	425	376	2,252	0	0	0	7,606	2,699	0	0	0
2036	21,137	422	376	2,256	0	0	0	7,626	2,679	0	0	0
2037	21,273	421	376	2,262	0	0	0	7,639	2,666	0	0	0
2038	21,408	420	376	2,266	0	0	0	7,656	1,946	0	0	0
2039	21,540	418	376	2,271	0	0	0	7,671	303	0	0	0
2040	21,671	415	376	2,276	0	0	0	7,689	1,737	0	0	0
2041	21,800	415	376	2,281	0	0	0	7,700	2,444	0	0	0
2042	21,927	413	376	2,284	0	0	0	7,715	2,337	0	0	0
2043	22,050	411	376	2,289	0	0	0	7,728	2,577	0	0	0
2044	22,170	409	376	2,293	0	0	0	7,743	2,562	0	0	0
2045	22,287	409	376	2,297	0	0	0	7,775	2,530	0	0	0
2046	22,403	409	376	2,305	0	0	0	7,816	2,156	0	0	0
2047	22,516	409	376	2,316	0	0	0	7,853	2,452	0	0	0
2048	22,628	409	376	2,328	0	0	0	7,893	2,079	0	0	0
2049	22,737	409	376	2,339	0	0	0	7,924	2,048	0	0	0
2050	22,845	409	376	2,349	0	0	0	7,960	2,012	0	0	0
2051	22,950	409	376	2,359	0	0	0	7,995	1,977	0	0	0
2052	23,054	409	376	2,370	0	0	0	8,032	1,225	0	0	0
2053	23,155	409	376	2,381	0	0	0	8,060	1,197	0	0	0
2054	23,255	409	376	2,390	0	0	0	8,093	2	0	0	0
2055	23,354	409	376	2,399	0	0	0	7,202	0	924	0	0
2056	23,451	409	376	2,409	0	0	0	5,861	0	929	1,372	0
2057	23,545	409	376	2,419	0	0	0	8,095	0	92	0	0
2058	23,638	409	376	2,428	0	0	0	8,218	324	0	0	0
2059	23,728	409	376	2,437	0	0	0	8,248	116	0	0	0
2060	23,817	409	376	2,445	0	0	0	8,282	81	0	0	0

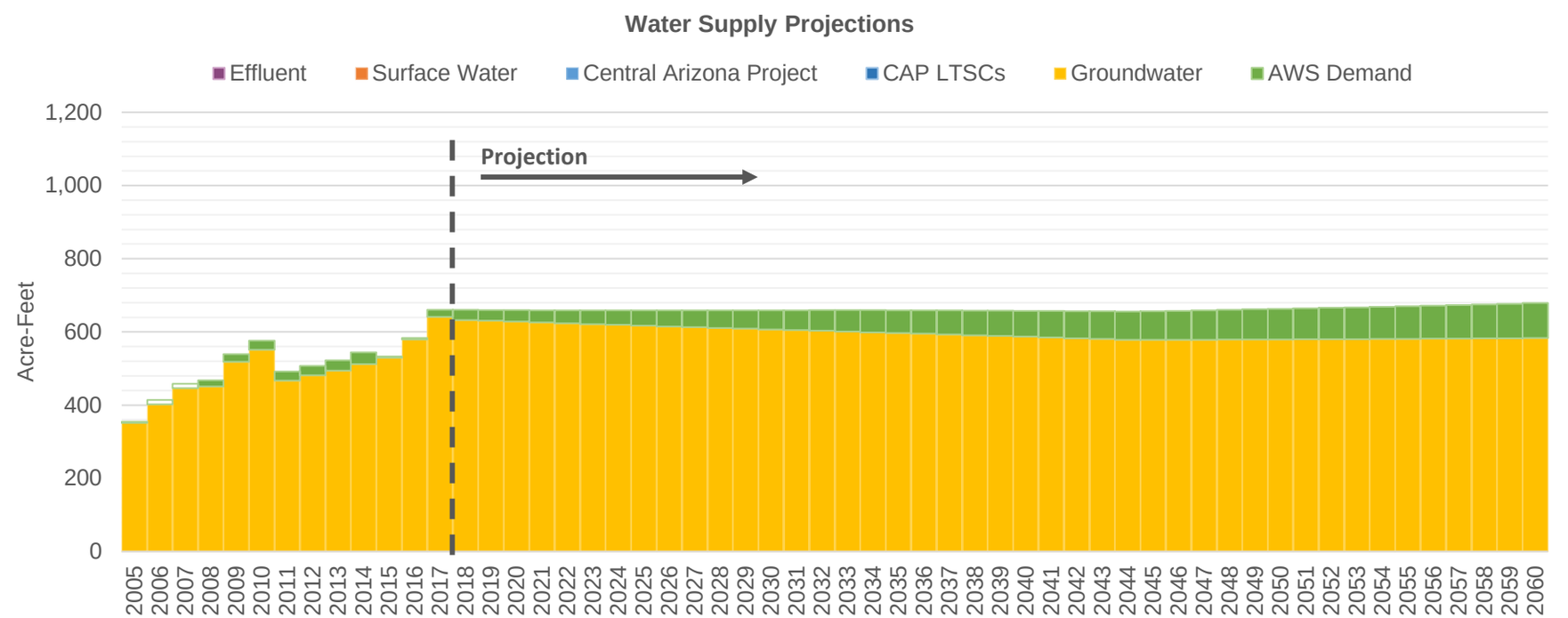
Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate

QuailCreek







Central Arizona Project Service Area Model

QuailCreek

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

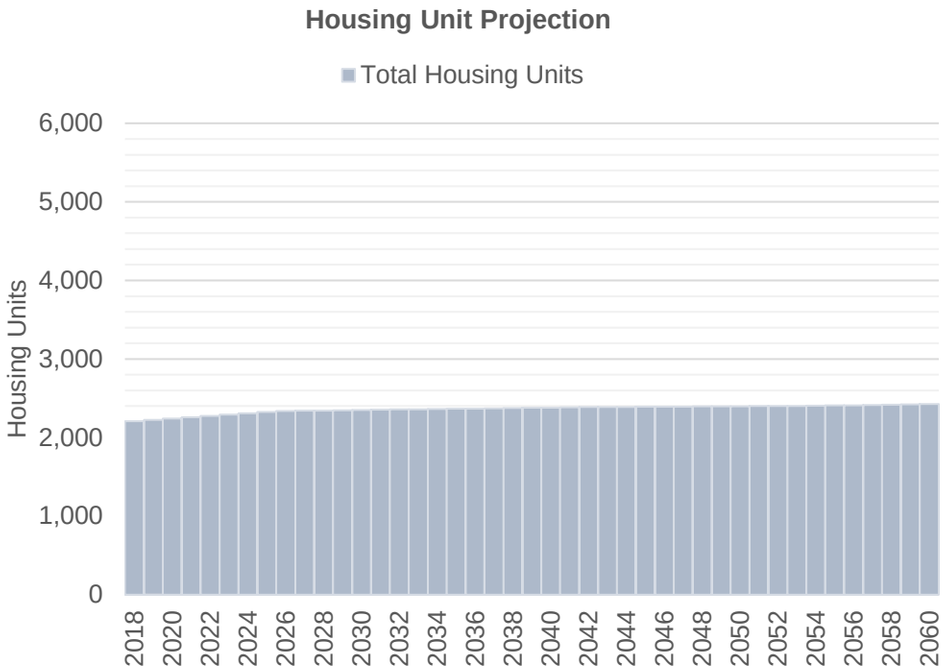
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

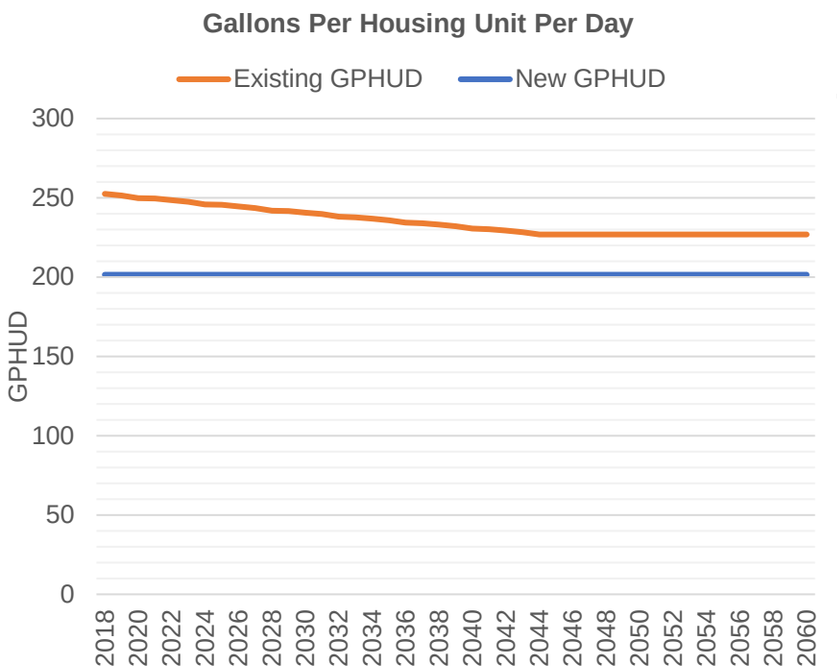
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,889	313	217	0	0	0	0	0	0	0	632	28
2019	1,899	311	217	0	0	0	0	0	0	0	631	29
2020	1,909	309	217	0	0	0	0	0	0	0	628	31
2021	1,919	309	217	0	0	0	0	0	0	0	626	33
2022	1,930	308	217	0	0	0	0	0	0	0	624	36
2023	1,940	306	217	0	0	0	0	0	0	0	621	38
2024	1,950	304	217	0	0	0	0	0	0	0	619	40
2025	1,961	304	217	0	0	0	0	0	0	0	617	42
2026	1,971	303	217	0	0	0	0	0	0	0	615	44
2027	1,982	302	217	0	0	0	0	0	0	0	613	46
2028	1,993	300	217	0	0	0	0	0	0	0	611	48
2029	2,003	299	217	0	0	0	0	0	0	0	609	50
2030	2,013	298	217	0	0	0	0	0	0	0	607	52
2031	2,024	297	217	0	0	0	0	0	0	0	605	54
2032	2.035	295	217	0	0	0	0	0	0	0	603	56
2033	2,046	294	217	0	0	0	0	0	0	0	601	58
2034	2,055	293	217	0	0	0	0	0	0	0	599	60
2035	2,064	292	217	0	0	0	0	0	0	0	597	62
2036	2,073	290	217	0	0	0	0	0	0	0	595	64
2037	2,082	290	217	0	0	0	0	0	0	0	593	66
2038	2,091	289	217	0	0	0	0	0	0	0	591	67
2039	2,099	287	217	0	0	0	0	0	0	0	589	69
2040	2,107	285	217	0	0	0	0	0	0	0	587	71
2041	2,116	285	217	0	0	0	0	0	0	0	585	72
2042	2,124	284	217	0	0	0	0	0	0	0	583	74
2043	2,131	283	217	0	0	0	0	0	0	0	581	75
2044	2,137	281	217	0	0	0	0	0	0	0	579	77
2045	2,143	281	217	0	0	0	0	0	0	0	578	78
2046	2,149	281	217	0	0	0	0	0	0	0	579	79
2047	2,155	281	217	0	0	0	0	0	0	0	579	80
2048	2,161	281	217	0	0	0	0	0	0	0	579	81
2049	2,166	281	217	0	0	0	0	0	0	0	579	83
2050	2,172	281	217	0	0	0	0	0	0	0	580	83
2051	2,177	281	217	0	0	0	0	0	0	0	580	85
2052	2,183	281	217	0	0	0	0	0	0	0	581	86
2053	2,188	281	217	0	0	0	0	0	0	0	580	87
2054	2,194	281	217	0	0	0	0	0	0	0	581	88
2055	2,201	281	217	0	0	0	0	0	0	0	581	89
2056	2,208	281	217	0	0	0	0	0	0	0	582	90
2057	2,215	281	217	0	0	0	0	0	0	0	582	92
2058	2,222	281	217	0	0	0	0	0	0	0	582	93
2059	2,228	281	217	0	0	0	0	0	0	0	583	94
2060	2,235	281	217	0	0	0	0	0	0	0	583	95

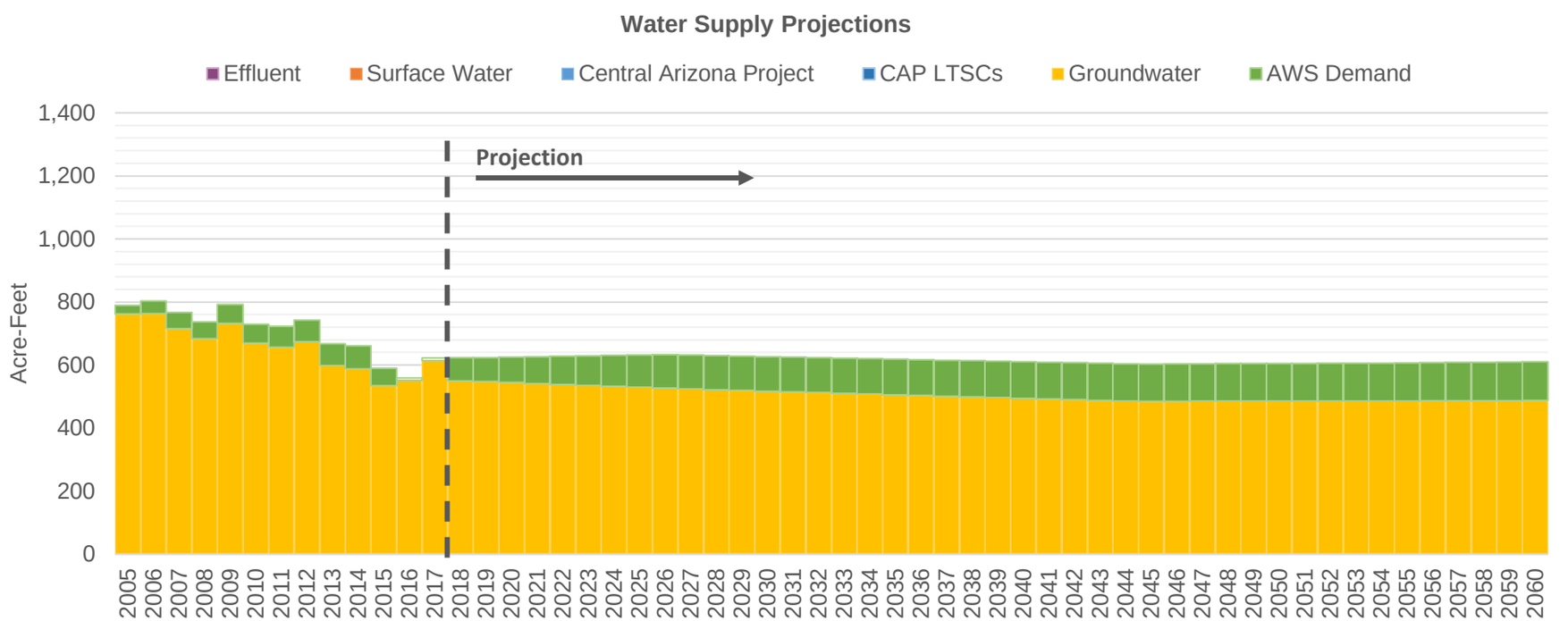
Central Arizona Project Service Area Model

RayWC

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

RayWC

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

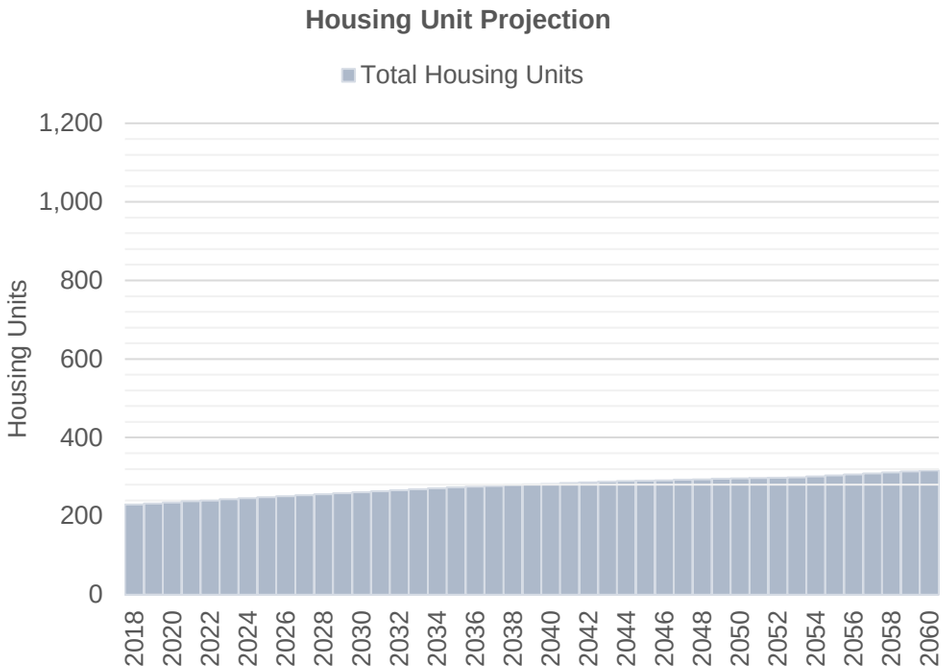
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

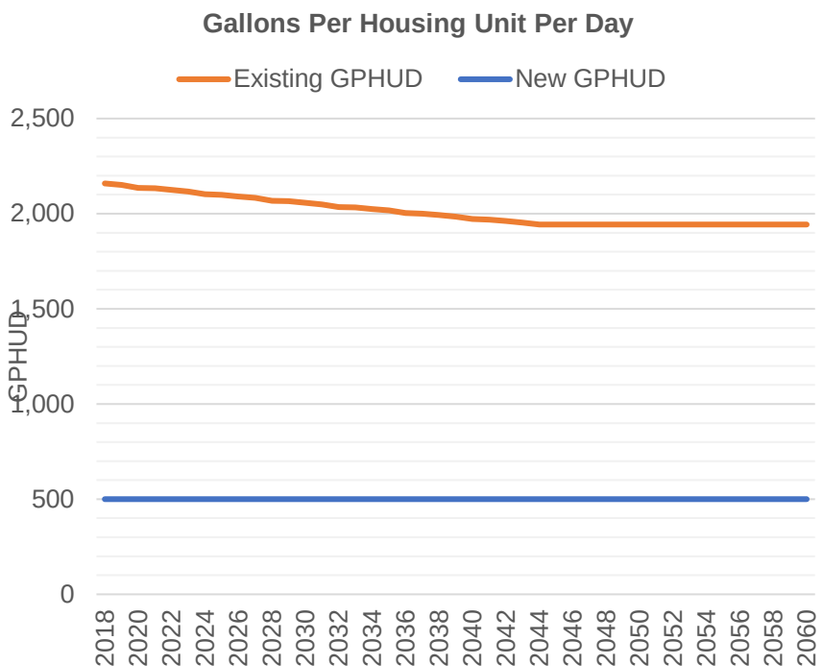
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,210	253	202	0	0	0	0	0	0	0	550	74
2019	2,226	252	202	0	0	0	0	0	0	0	548	76
2020	2,243	250	202	0	0	0	0	0	0	0	545	81
2021	2,260	250	202	0	0	0	0	0	0	0	541	86
2022	2,277	249	202	0	0	0	0	0	0	0	538	90
2023	2,294	248	202	0	0	0	0	0	0	0	535	94
2024	2,311	246	202	0	0	0	0	0	0	0	533	98
2025	2,328	246	202	0	0	0	0	0	0	0	530	102
2026	2,337	245	202	0	0	0	0	0	0	0	527	106
2027	2,341	244	202	0	0	0	0	0	0	0	524	108
2028	2,344	242	202	0	0	0	0	0	0	0	522	109
2029	2,347	242	202	0	0	0	0	0	0	0	519	109
2030	2,351	241	202	0	0	0	0	0	0	0	517	110
2031	2,354	240	202	0	0	0	0	0	0	0	515	111
2032	2.358	238	202	0	0	0	0	0	0	0	513	111
2033	2,361	238	202	0	0	0	0	0	0	0	510	112
2034	2,364	237	202	0	0	0	0	0	0	0	508	112
2035	2,367	236	202	0	0	0	0	0	0	0	506	113
2036	2,370	234	202	0	0	0	0	0	0	0	504	114
2037	2,373	234	202	0	0	0	0	0	0	0	501	114
2038	2,376	233	202	0	0	0	0	0	0	0	499	115
2039	2,379	232	202	0	0	0	0	0	0	0	497	115
2040	2,381	231	202	0	0	0	0	0	0	0	495	116
2041	2,384	230	202	0	0	0	0	0	0	0	492	116
2042	2,387	229	202	0	0	0	0	0	0	0	490	117
2043	2,389	228	202	0	0	0	0	0	0	0	488	117
2044	2,390	227	202	0	0	0	0	0	0	0	486	118
2045	2,392	227	202	0	0	0	0	0	0	0	485	118
2046	2,393	227	202	0	0	0	0	0	0	0	485	118
2047	2,395	227	202	0	0	0	0	0	0	0	485	118
2048	2,396	227	202	0	0	0	0	0	0	0	486	119
2049	2,397	227	202	0	0	0	0	0	0	0	486	119
2050	2,399	227	202	0	0	0	0	0	0	0	486	119
2051	2,400	227	202	0	0	0	0	0	0	0	486	119
2052	2,401	227	202	0	0	0	0	0	0	0	486	120
2053	2,402	227	202	0	0	0	0	0	0	0	486	120
2054	2,405	227	202	0	0	0	0	0	0	0	486	120
2055	2,408	227	202	0	0	0	0	0	0	0	486	120
2056	2,412	227	202	0	0	0	0	0	0	0	487	121
2057	2,415	227	202	0	0	0	0	0	0	0	487	122
2058	2,418	227	202	0	0	0	0	0	0	0	487	122
2059	2,422	227	202	0	0	0	0	0	0	0	487	123
2060	2,425	227	202	0	0	0	0	0	0	0	487	123

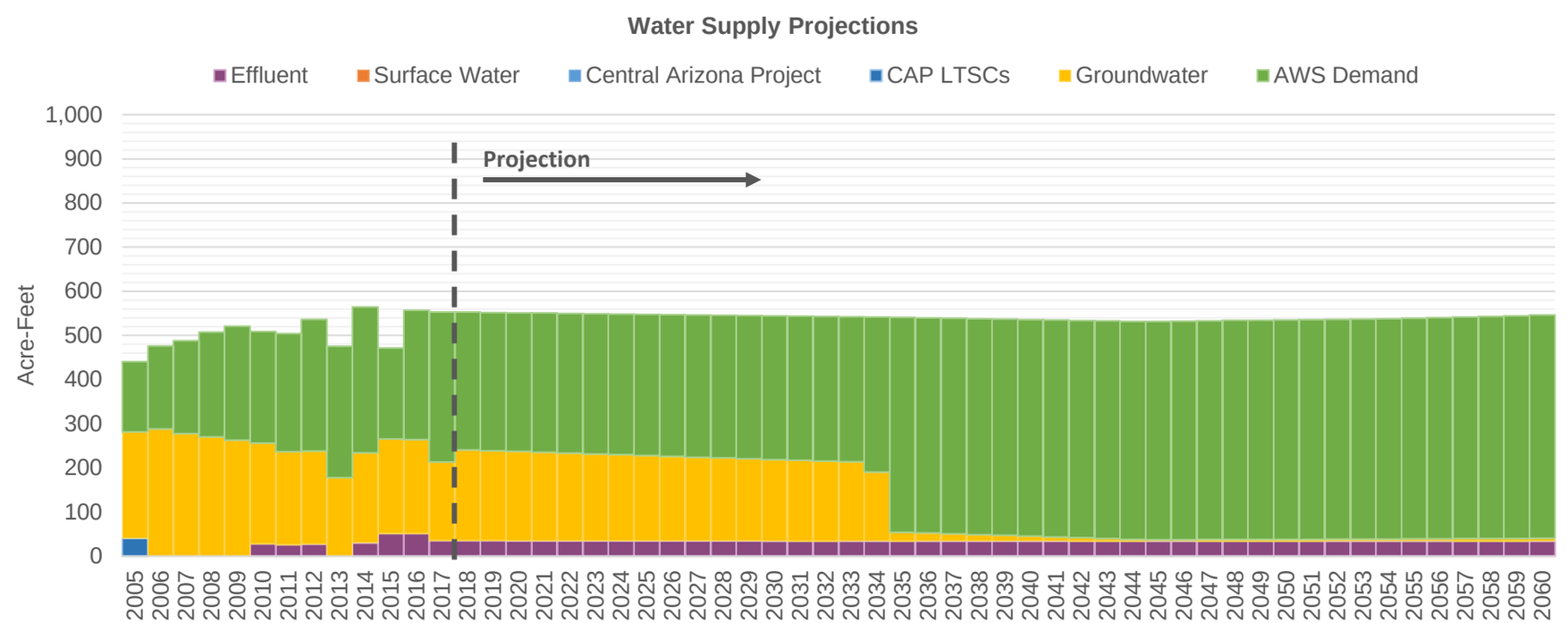
RidgeView

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

RidgeView

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

Demand Assumptions

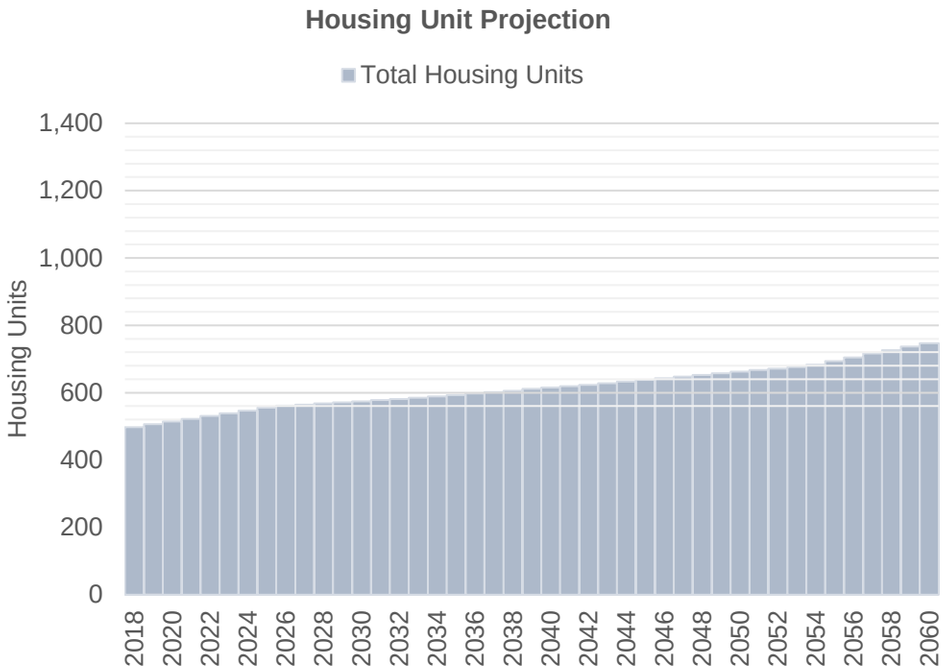
Water Supply Projections (Acre-Feet)

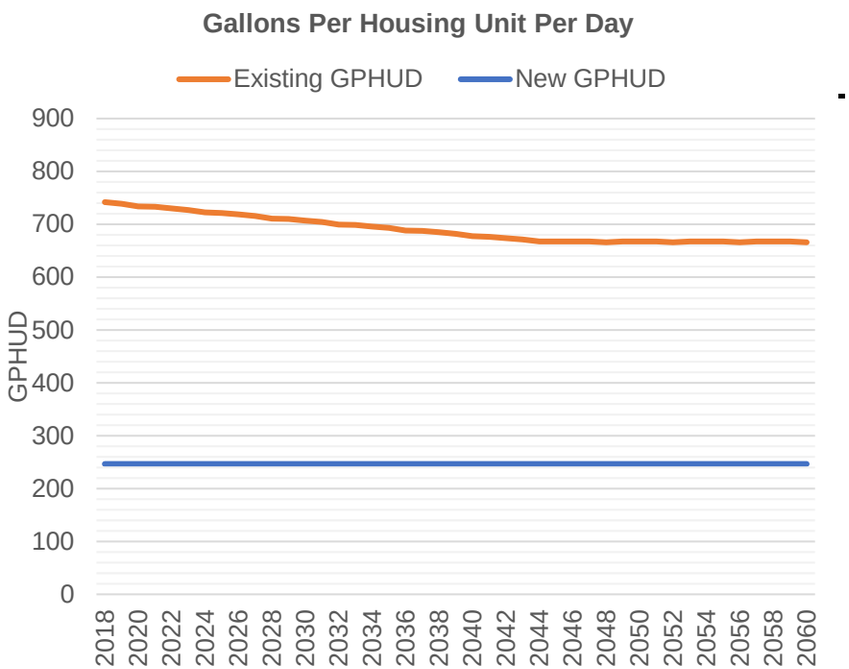
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	230	2,159	500	35	0	0	0	0	0	0	206	313
2019	232	2,150	500	35	0	0	0	0	0	0	204	313
2020	235	2,136	500	35	0	0	0	0	0	0	202	314
2021	238	2,133	500	35	0	0	0	0	0	0	200	316
2022	240	2,125	500	35	0	0	0	0	0	0	198	317
2023	243	2,116	500	35	0	0	0	0	0	0	197	318
2024	246	2,102	500	35	0	0	0	0	0	0	195	319
2025	248	2,099	500	35	0	0	0	0	0	0	193	320
2026	251	2,091	500	35	0	0	0	0	0	0	191	321
2027	253	2,083	500	35	0	0	0	0	0	0	190	322
2028	256	2,069	500	35	0	0	0	0	0	0	188	323
2029	258	2,066	500	35	0	0	0	0	0	0	186	324
2030	261	2,058	500	34	0	0	0	0	0	0	185	325
2031	263	2,049	500	34	0	0	0	0	0	0	183	327
2032	266	2,036	500	34	0	0	0	0	0	0	182	327
2033	268	2,033	500	34	0	0	0	0	0	0	180	329
2034	271	2,025	500	34	0	0	0	0	0	0	156	351
2035	273	2,017	500	34	0	0	0	0	0	0	20	487
2036	275	2,003	500	34	0	0	0	0	0	0	18	488
2037	277	2,001	500	34	0	0	0	0	0	0	17	488
2038	279	1,993	500	34	0	0	0	0	0	0	15	489
2039	281	1,985	500	34	0	0	0	0	0	0	13	490
2040	282	1,971	500	34	0	0	0	0	0	0	11	491
2041	284	1,969	500	34	0	0	0	0	0	0	10	491
2042	286	1,961	500	34	0	0	0	0	0	0	8	492
2043	288	1,953	500	34	0	0	0	0	0	0	6	493
2044	289	1,943	500	34	0	0	0	0	0	0	4	494
2045	290	1,943	500	34	0	0	0	0	0	0	4	494
2046	291	1,943	500	34	0	0	0	0	0	0	4	495
2047	293	1,943	500	34	0	0	0	0	0	0	4	495
2048	294	1,943	500	34	0	0	0	0	0	0	4	496
2049	295	1,943	500	34	0	0	0	0	0	0	4	497
2050	296	1,943	500	34	0	0	0	0	0	0	4	497
2051	297	1,943	500	34	0	0	0	0	0	0	4	497
2052	298	1,943	500	34	0	0	0	0	0	0	5	498
2053	299	1,943	500	34	0	0	0	0	0	0	5	498
2054	301	1,943	500	34	0	0	0	0	0	0	5	499
2055	304	1,943	500	34	0	0	0	0	0	0	5	500
2056	306	1,943	500	34	0	0	0	0	0	0	5	501
2057	309	1,943	500	34	0	0	0	0	0	0	6	502
2058	311	1,943	500	34	0	0	0	0	0	0	6	503
2059	314	1,943	500	34	0	0	0	0	0	0	6	504
2060	316	1,943	500	34	0	0	0	0	0	0	6	506

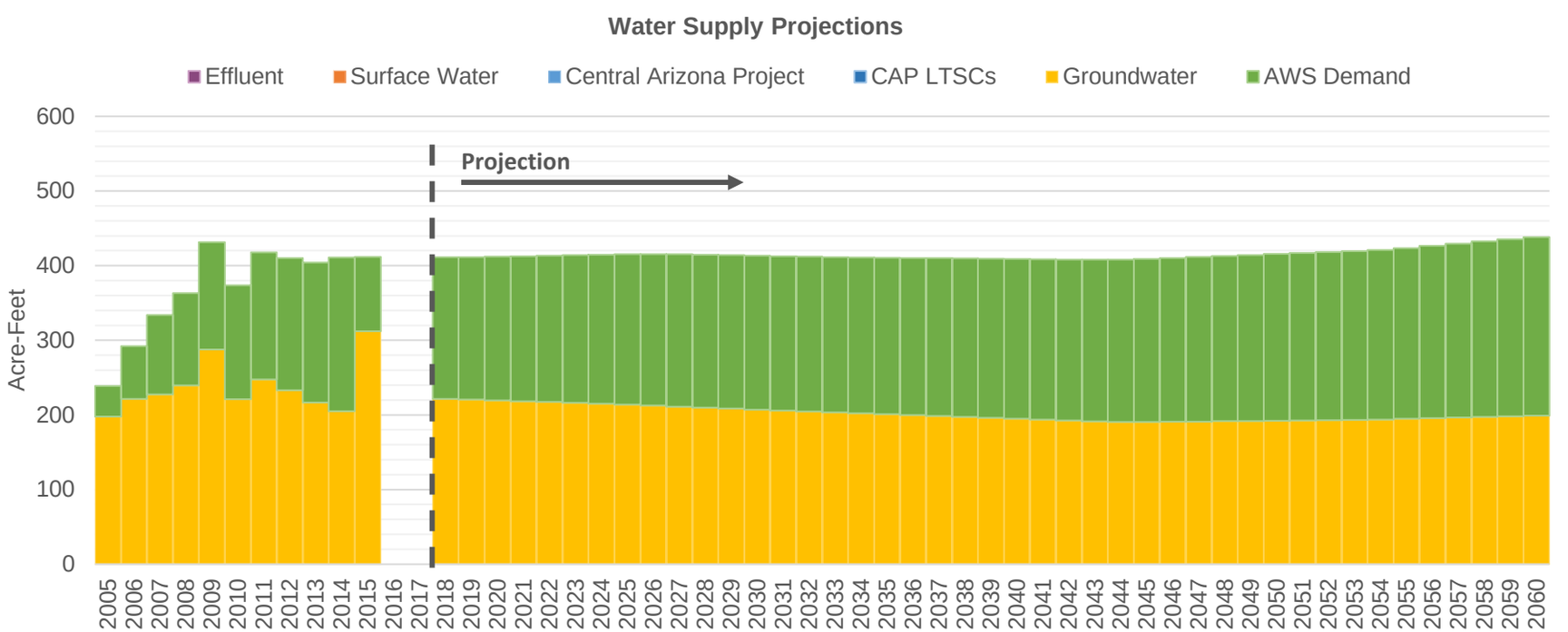
Saguaro

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

Saguaro

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

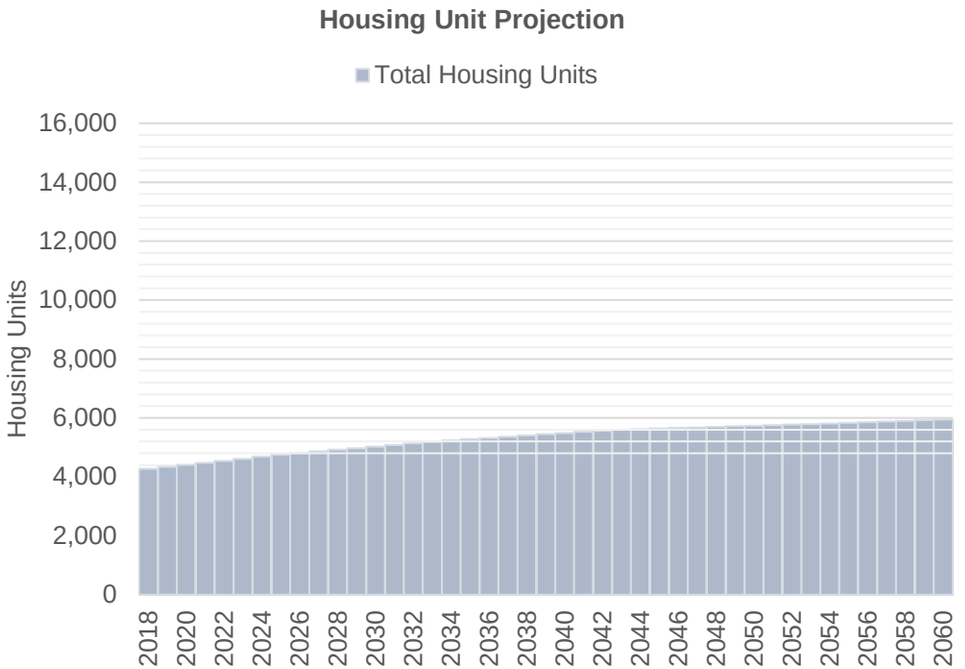
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

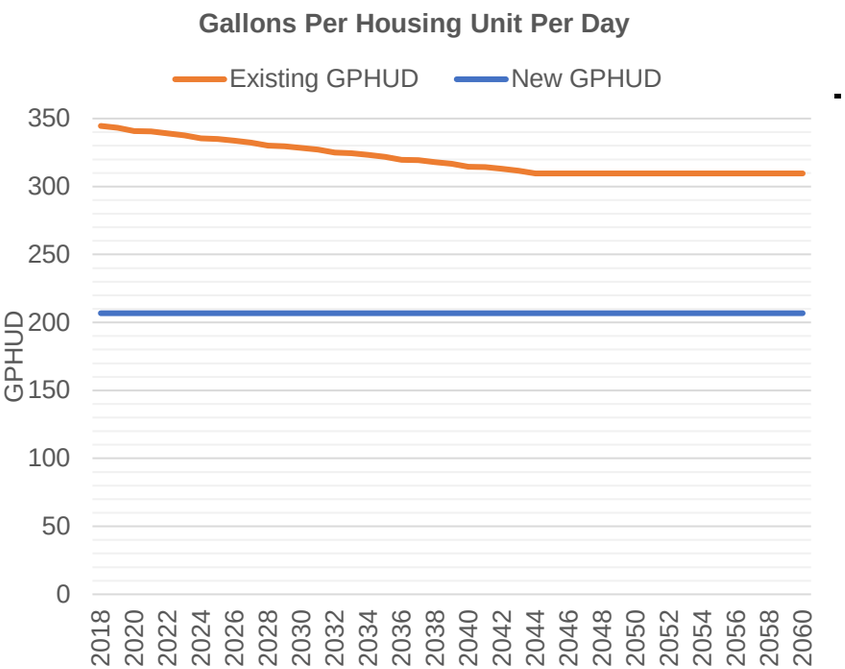
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	498	742	247	0	0	0	0	0	0	0	221	190
2019	506	739	247	0	0	0	0	0	0	0	221	191
2020	514	734	247	0	0	0	0	0	0	0	219	193
2021	522	733	247	0	0	0	0	0	0	0	218	194
2022	531	730	247	0	0	0	0	0	0	0	217	196
2023	539	727	247	0	0	0	0	0	0	0	216	198
2024	547	722	247	0	0	0	0	0	0	0	215	200
2025	555	721	247	0	0	0	0	0	0	0	214	201
2026	561	718	247	0	0	0	0	0	0	0	213	203
2027	564	716	247	0	0	0	0	0	0	0	211	204
2028	568	711	247	0	0	0	0	0	0	0	210	205
2029	571	710	247	0	0	0	0	0	0	0	209	205
2030	574	707	247	0	0	0	0	0	0	0	207	206
2031	578	704	247	0	0	0	0	0	0	0	206	207
2032	581	700	247	0	0	0	0	0	0	0	205	207
2033	585	699	247	0	0	0	0	0	0	0	203	208
2034	589	696	247	0	0	0	0	0	0	0	202	209
2035	593	693	247	0	0	0	0	0	0	0	201	210
2036	598	688	247	0	0	0	0	0	0	0	200	210
2037	602	688	247	0	0	0	0	0	0	0	199	211
2038	606	685	247	0	0	0	0	0	0	0	197	212
2039	611	682	247	0	0	0	0	0	0	0	196	213
2040	615	677	247	0	0	0	0	0	0	0	195	214
2041	619	677	247	0	0	0	0	0	0	0	194	215
2042	623	674	247	0	0	0	0	0	0	0	193	216
2043	628	671	247	0	0	0	0	0	0	0	192	216
2044	633	668	247	0	0	0	0	0	0	0	191	217
2045	638	668	247	0	0	0	0	0	0	0	190	218
2046	643	668	247	0	0	0	0	0	0	0	191	219
2047	648	668	247	0	0	0	0	0	0	0	191	220
2048	653	666	247	0	0	0	0	0	0	0	192	221
2049	658	668	247	0	0	0	0	0	0	0	192	222
2050	662	668	247	0	0	0	0	0	0	0	192	223
2051	667	668	247	0	0	0	0	0	0	0	193	224
2052	671	666	247	0	0	0	0	0	0	0	193	225
2053	676	668	247	0	0	0	0	0	0	0	193	226
2054	683	668	247	0	0	0	0	0	0	0	194	227
2055	694	668	247	0	0	0	0	0	0	0	195	229
2056	705	666	247	0	0	0	0	0	0	0	196	231
2057	716	668	247	0	0	0	0	0	0	0	197	233
2058	726	668	247	0	0	0	0	0	0	0	197	235
2059	737	668	247	0	0	0	0	0	0	0	198	237
2060	747	666	247	0	0	0	0	0	0	0	199	239

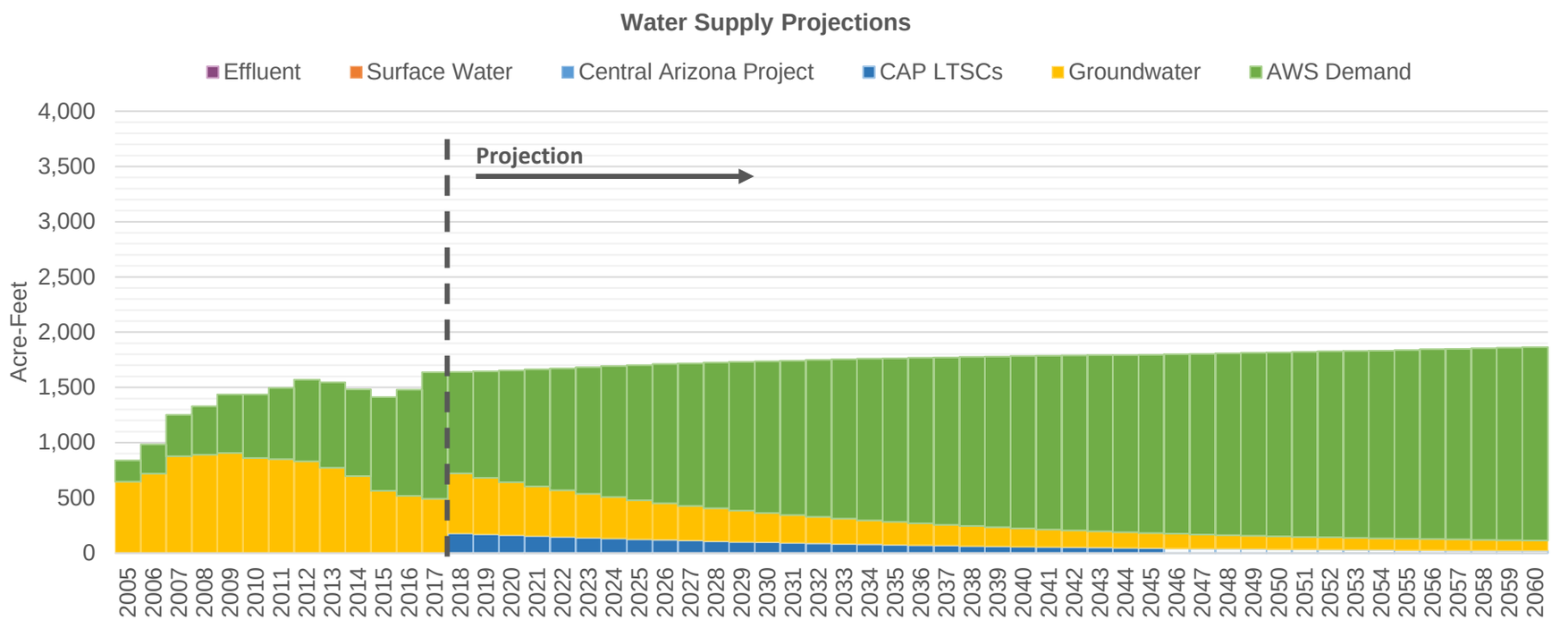
Central Arizona Project Service Area Model

Sahuarita

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

Sahuarita

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

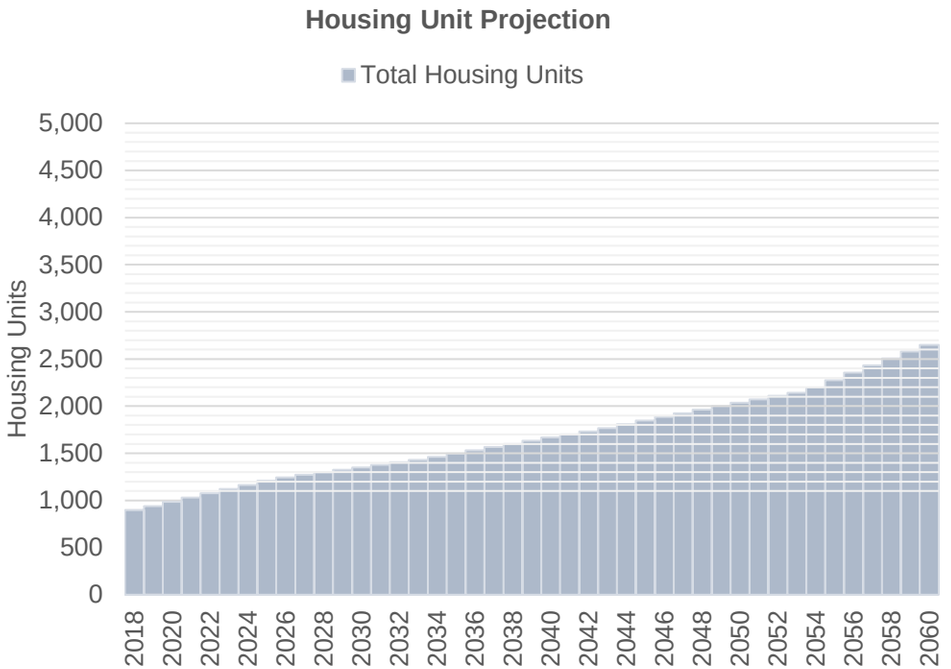
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

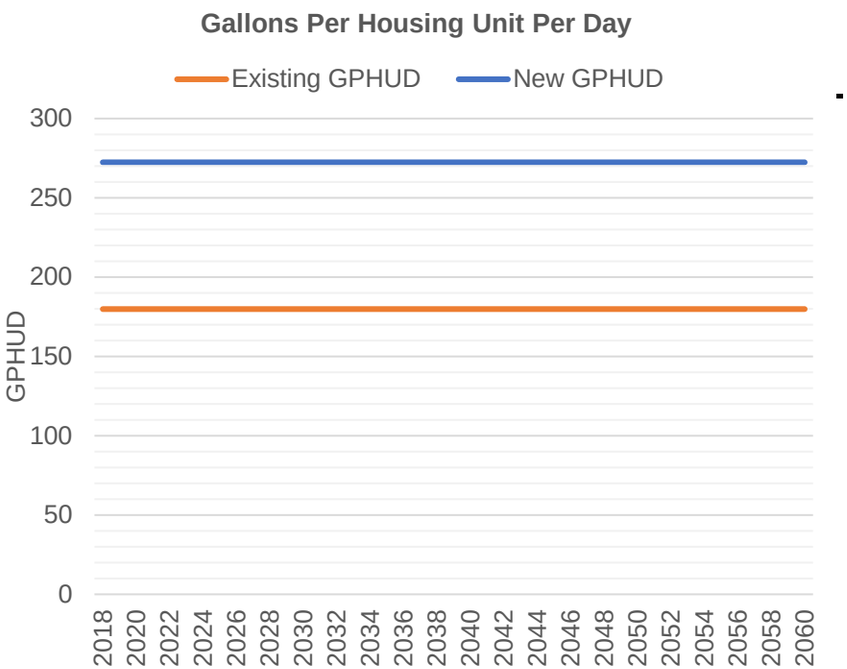
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,269	345	207	0	0	0	0	0	0	179	544	916
2019	4,337	343	207	0	0	0	0	0	0	171	510	964
2020	4,406	341	207	0	0	0	0	0	0	162	479	1,013
2021	4,475	340	207	0	0	0	0	0	0	154	450	1,059
2022	4,545	339	207	0	0	0	0	0	0	146	423	1,103
2023	4,615	338	207	0	0	0	0	0	0	139	398	1,145
2024	4,685	335	207	0	0	0	0	0	0	132	375	1,186
2025	4,756	335	207	0	0	0	0	0	0	125	354	1,223
2026	4,816	334	207	0	0	0	0	0	0	119	334	1,259
2027	4,869	332	207	0	0	0	0	0	0	113	315	1,290
2028	4,922	330	207	0	0	0	0	0	0	107	298	1,319
2029	4,974	330	207	0	0	0	0	0	0	102	282	1,346
2030	5,026	328	207	0	0	0	0	0	0	97	267	1,372
2031	5,080	327	207	0	0	0	0	0	0	92	253	1,396
2032	5.133	325	207	0	0	0	0	0	0	88	240	1.421
2033	5,186	324	207	0	0	0	0	0	0	83	228	1,443
2034	5,235	323	207	0	0	0	0	0	0	79	217	1,463
2035	5,278	322	207	0	0	0	0	0	0	75	207	1,482
2036	5,321	320	207	0	0	0	0	0	0	71	197	1,500
2037	5,364	319	207	0	0	0	0	0	0	68	188	1,516
2038	5,406	318	207	0	0	0	0	0	0	64	180	1,531
2039	5,447	317	207	0	0	0	0	0	0	61	173	1,545
2040	5,488	315	207	0	0	0	0	0	0	58	165	1,560
2041	5,528	314	207	0	0	0	0	0	0	55	159	1,572
2042	5,568	313	207	0	0	0	0	0	0	52	153	1,584
2043	5,601	312	207	0	0	0	0	0	0	50	147	1,595
2044	5,621	310	207	0	0	0	0	0	0	47	142	1,604
2045	5,641	310	207	0	0	0	0	0	0	45	137	1,613
2046	5,661	310	207	0	0	0	0	0	0	43	132	1,625
2047	5,680	310	207	0	0	0	0	0	0	41	128	1,636
2048	5,699	310	207	0	0	0	0	0	0	39	124	1,647
2049	5,717	310	207	0	0	0	0	0	0	37	120	1,656
2050	5,735	310	207	0	0	0	0	0	0	35	117	1,665
2051	5,753	310	207	0	0	0	0	0	0	33	114	1,674
2052	5,771	310	207	0	0	0	0	0	0	31	111	1,684
2053	5,788	310	207	0	0	0	0	0	0	30	108	1,691
2054	5,808	310	207	0	0	0	0	0	0	28	106	1,699
2055	5,831	310	207	0	0	0	0	0	0	27	104	1,708
2056	5,855	310	207	0	0	0	0	0	0	26	102	1,718
2057	5,877	310	207	0	0	0	0	0	0	24	100	1,726
2058	5,899	310	207	0	0	0	0	0	0	23	98	1,734
2059	5,921	310	207	0	0	0	0	0	0	22	96	1,742
2060	5,942	310	207	0	0	0	0	0	0	21	95	1,750

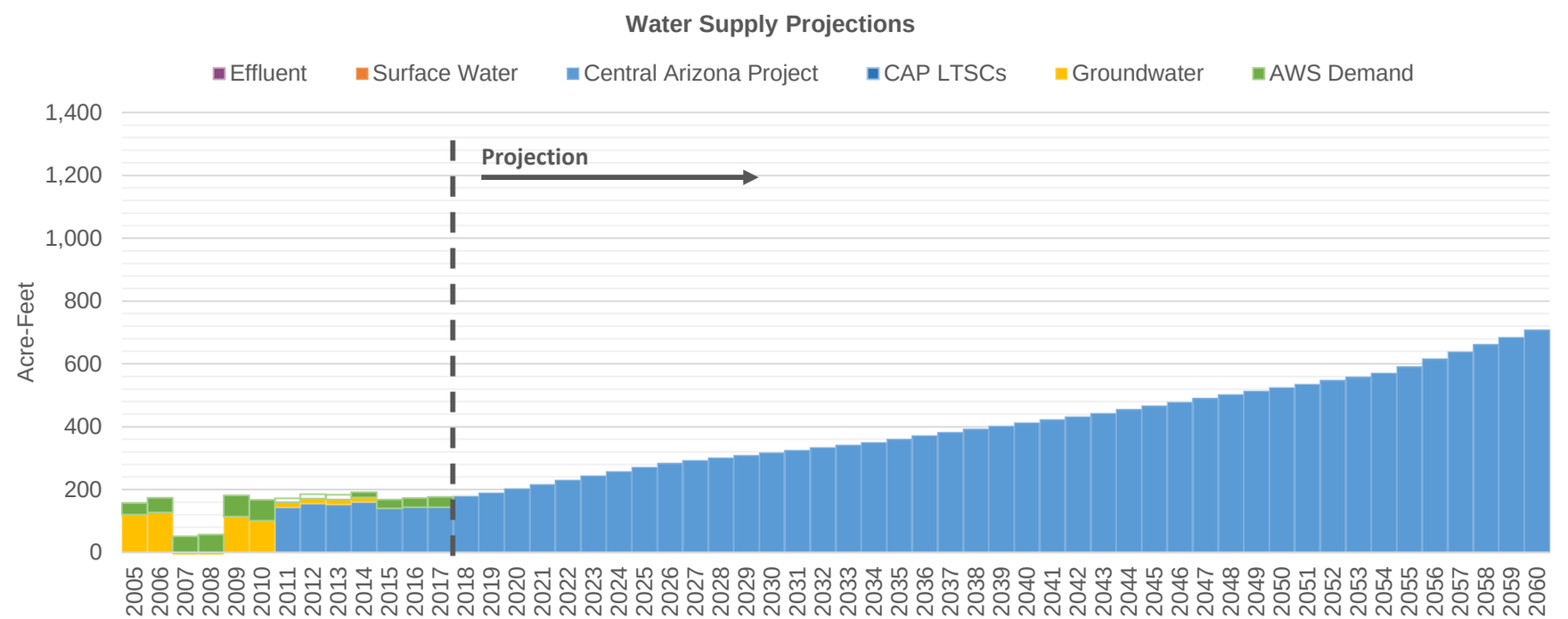
Central Arizona Project Service Area Model

SpanishTrailWC

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

SpanishTrailWC

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

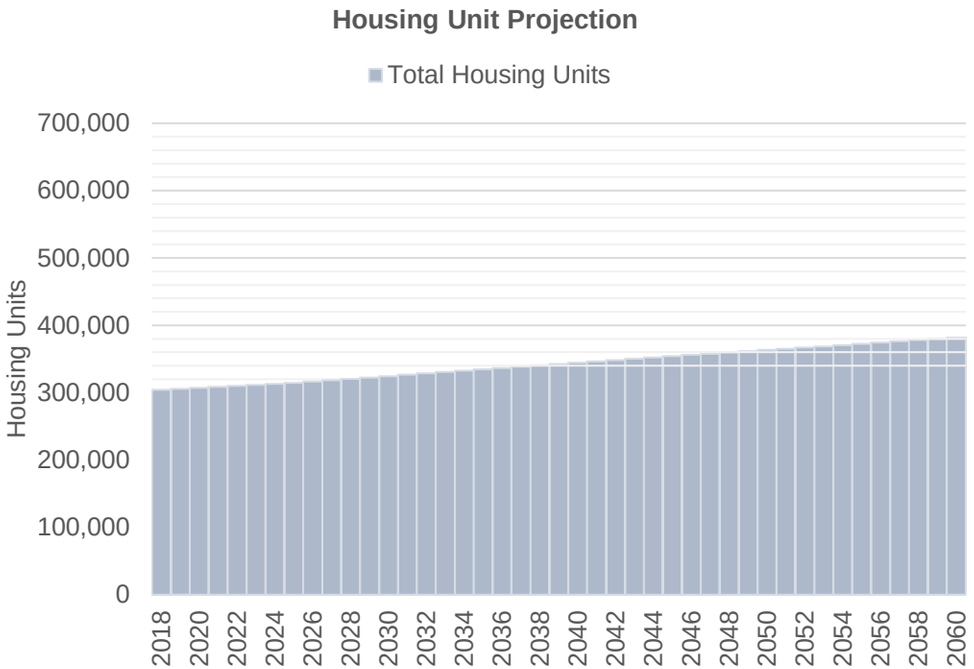
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

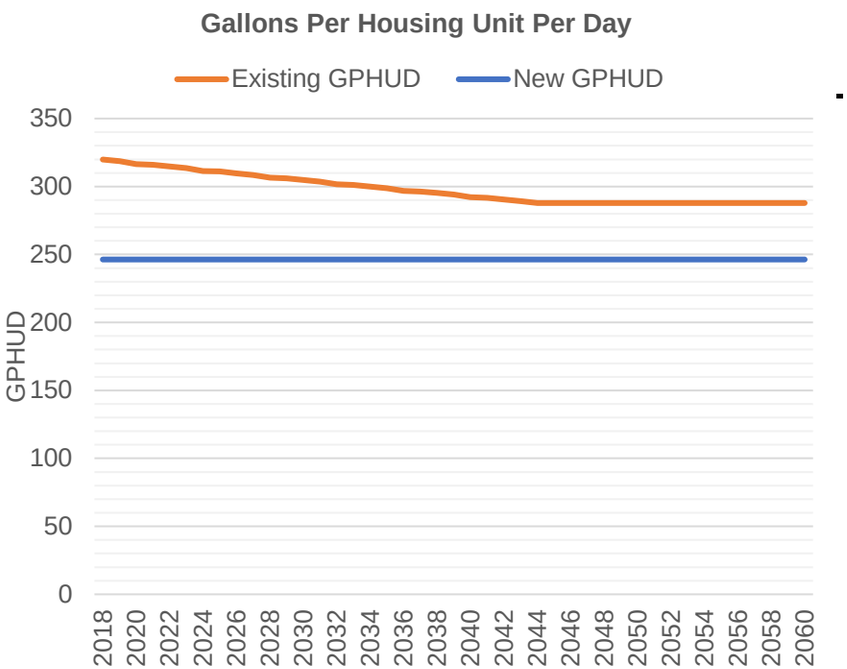
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	898	180	272	0	0	0	0	180	2,857	0	0	0
2019	941	180	272	0	0	0	0	189	2,848	0	0	0
2020	985	180	272	0	0	0	0	203	2,834	0	0	0
2021	1,030	180	272	0	0	0	0	216	2,821	0	0	0
2022	1,075	180	272	0	0	0	0	230	2,807	0	0	0
2023	1,120	180	272	0	0	0	0	244	2,793	0	0	0
2024	1,165	180	272	0	0	0	0	258	2,779	0	0	0
2025	1,210	180	272	0	0	0	0	271	2,766	0	0	0
2026	1,244	180	272	0	0	0	0	283	2,754	0	0	0
2027	1,271	180	272	0	0	0	0	293	2,744	0	0	0
2028	1,298	180	272	0	0	0	0	301	2,736	0	0	0
2029	1,324	180	272	0	0	0	0	309	2,728	0	0	0
2030	1,350	180	272	0	0	0	0	317	2,720	0	0	0
2031	1,378	180	272	0	0	0	0	325	2,712	0	0	0
2032	1.405	180	272	0	0	0	0	334	2.703	0	0	0
2033	1,431	180	272	0	0	0	0	342	2,695	0	0	0
2034	1,462	180	272	0	0	0	0	350	2,687	0	0	0
2035	1,497	180	272	0	0	0	0	360	2,677	0	0	0
2036	1,532	180	272	0	0	0	0	372	2,665	0	0	0
2037	1,566	180	272	0	0	0	0	382	2,655	0	0	0
2038	1,600	180	272	0	0	0	0	392	2,438	0	0	0
2039	1,634	180	272	0	0	0	0	402	1,948	0	0	0
2040	1,667	180	272	0	0	0	0	413	2,365	0	0	0
2041	1,700	180	272	0	0	0	0	423	2,567	0	0	0
2042	1,732	180	272	0	0	0	0	433	2,530	0	0	0
2043	1,767	180	272	0	0	0	0	443	2,594	0	0	0
2044	1,807	180	272	0	0	0	0	455	2,582	0	0	0
2045	1,847	180	272	0	0	0	0	466	2,571	0	0	0
2046	1,887	180	272	0	0	0	0	479	2,460	0	0	0
2047	1,925	180	272	0	0	0	0	491	2,546	0	0	0
2048	1,963	180	272	0	0	0	0	503	2,436	0	0	0
2049	2,001	180	272	0	0	0	0	514	2,425	0	0	0
2050	2,037	180	272	0	0	0	0	525	2,414	0	0	0
2051	2,073	180	272	0	0	0	0	536	2,403	0	0	0
2052	2,109	180	272	0	0	0	0	548	2,180	0	0	0
2053	2,143	180	272	0	0	0	0	558	2,171	0	0	0
2054	2,196	180	272	0	0	0	0	571	1,815	0	0	0
2055	2,276	180	272	0	0	0	0	591	1,531	0	0	0
2056	2,354	180	272	0	0	0	0	617	1,111	0	0	0
2057	2,431	180	272	0	0	0	0	639	1,747	0	0	0
2058	2,506	180	272	0	0	0	0	662	1,855	0	0	0
2059	2,579	180	272	0	0	0	0	685	1,780	0	0	0
2060	2,650	180	272	0	0	0	0	708	1,757	0	0	0

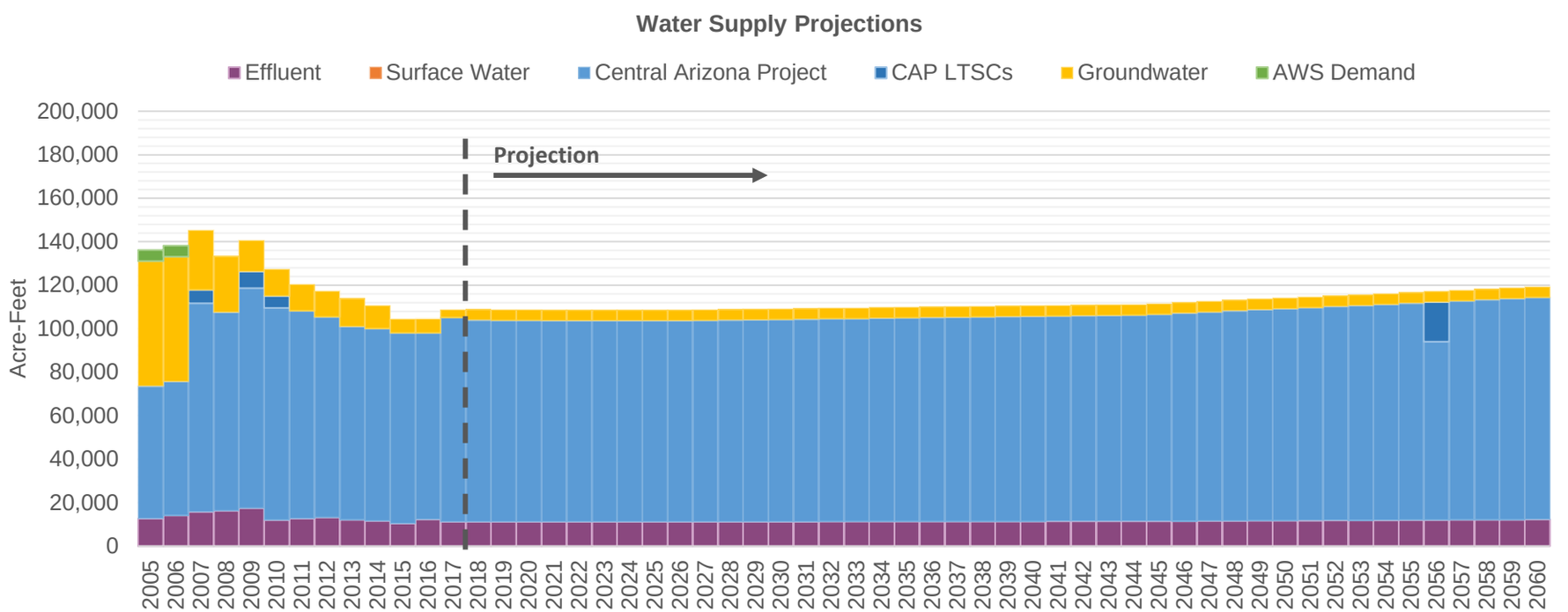
Central Arizona Project Service Area Model

Tucson

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

Tucson

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

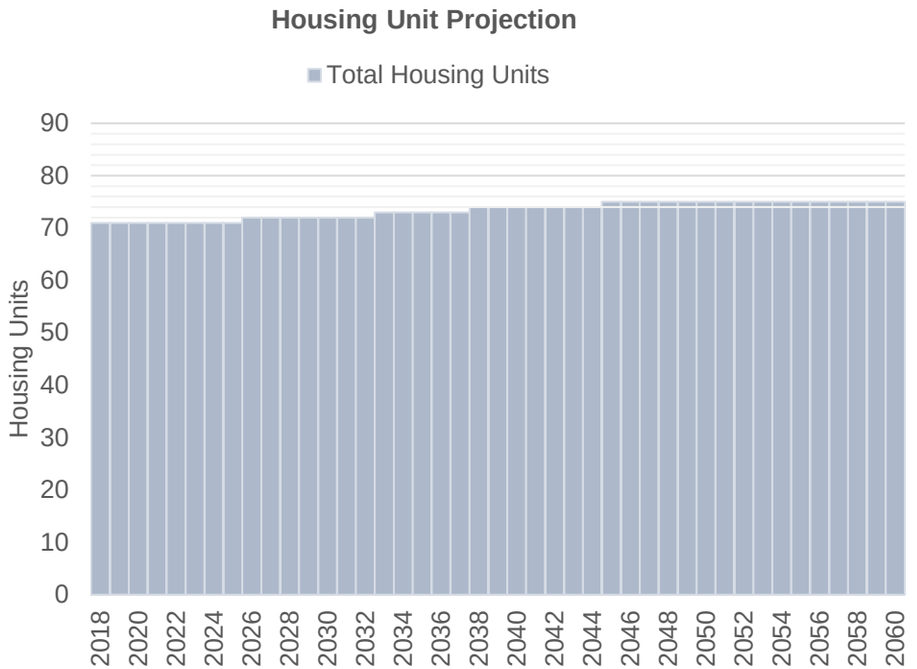
Demand Assumptions **Water Supply Projections** (Acre-Feet)

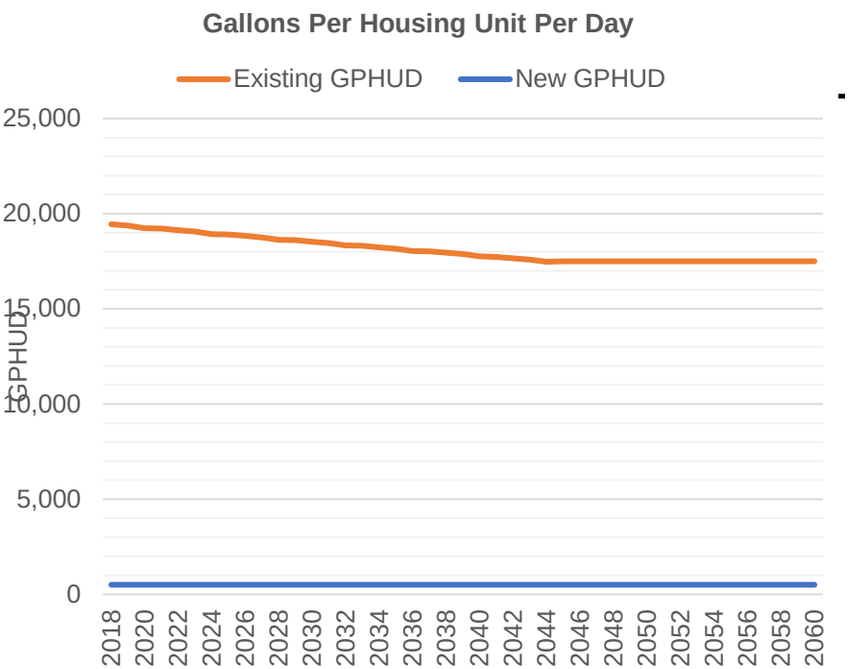
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	304,290	320	246	11,236	0	0	0	92,696	51,476	0	4,951	0
2019	305,746	319	246	11,236	0	0	0	92,551	51,621	0	4,951	0
2020	307,215	316	246	11,221	0	0	0	92,538	51,634	0	4,951	0
2021	308,698	316	246	11,218	0	0	0	92,514	51,658	0	4,951	0
2022	310,190	315	246	11,215	0	0	0	92,498	51,674	0	4,951	0
2023	311,691	314	246	11,213	0	0	0	92,484	51,688	0	4,951	0
2024	313,196	311	246	11,212	0	0	0	92,480	51,692	0	4,951	0
2025	314,705	311	246	11,211	0	0	0	92,466	51,706	0	4,951	0
2026	316,514	310	246	11,210	0	0	0	92,501	51,671	0	4,951	0
2027	318,564	309	246	11,213	0	0	0	92,609	51,563	0	4,951	0
2028	320,587	306	246	11,225	0	0	0	92,752	51,420	0	4,951	0
2029	322,582	306	246	11,241	0	0	0	92,860	51,312	0	4,951	0
2030	324,548	305	246	11,253	0	0	0	92,977	51,195	0	4,951	0
2031	326,605	304	246	11,267	0	0	0	93,104	51,068	0	4,951	0
2032	328,640	302	246	11,281	0	0	0	93,259	50,913	0	4,951	0
2033	330,653	301	246	11,299	0	0	0	93,370	50,802	0	4,951	0
2034	332,674	300	246	11,312	0	0	0	93,504	50,668	0	4,951	0
2035	334,718	299	246	11,327	0	0	0	93,642	50,530	0	4,951	0
2036	336,737	297	246	11,343	0	0	0	93,804	50,368	0	4,951	0
2037	338,730	296	246	11,361	0	0	0	93,910	50,262	0	4,951	0
2038	340,697	295	246	11,374	0	0	0	94,040	40,294	0	4,951	0
2039	342,637	294	246	11,389	0	0	0	94,163	17,407	0	4,951	0
2040	344,551	292	246	11,403	0	0	0	94,310	37,571	0	4,951	0
2041	346,436	292	246	11,420	0	0	0	94,389	47,531	0	4,951	0
2042	348,294	291	246	11,430	0	0	0	94,499	46,140	0	4,951	0
2043	350,185	289	246	11,442	0	0	0	94,608	49,564	0	4,951	0
2044	352,172	288	246	11,455	0	0	0	94,773	49,399	0	4,951	0
2045	354,127	288	246	11,473	0	0	0	95,150	49,022	0	4,951	0
2046	356,050	288	246	11,514	0	0	0	95,644	43,870	0	4,951	0
2047	357,939	288	246	11,569	0	0	0	96,115	48,057	0	4,951	0
2048	359,796	288	246	11,623	0	0	0	96,619	42,895	0	4,951	0
2049	361,619	288	246	11,681	0	0	0	97,027	42,486	0	4,951	0
2050	363,408	288	246	11,729	0	0	0	97,477	42,036	0	4,951	0
2051	365,163	288	246	11,780	0	0	0	97,915	41,598	0	4,951	0
2052	366,885	288	246	11,831	0	0	0	98,391	31,120	0	4,951	0
2053	368,573	288	246	11,885	0	0	0	98,760	30,751	0	4,951	0
2054	370,381	288	246	11,929	0	0	0	99,199	14,060	0	4,951	0
2055	372,385	288	246	11,979	0	0	0	99,675	1,081	0	4,951	0
2056	374,348	288	246	12,033	0	0	0	82,002	0	18,218	4,951	0
2057	376,268	288	246	12,095	0	0	0	100,642	12,617	0	4,951	0
2058	378,146	288	246	12,145	0	0	0	101,116	18,394	0	4,951	0
2059	379,981	288	246	12,199	0	0	0	101,574	15,435	0	4,951	0
2060	381,775	288	246	12,251	0	0	0	102,081	14,929	0	4,951	0

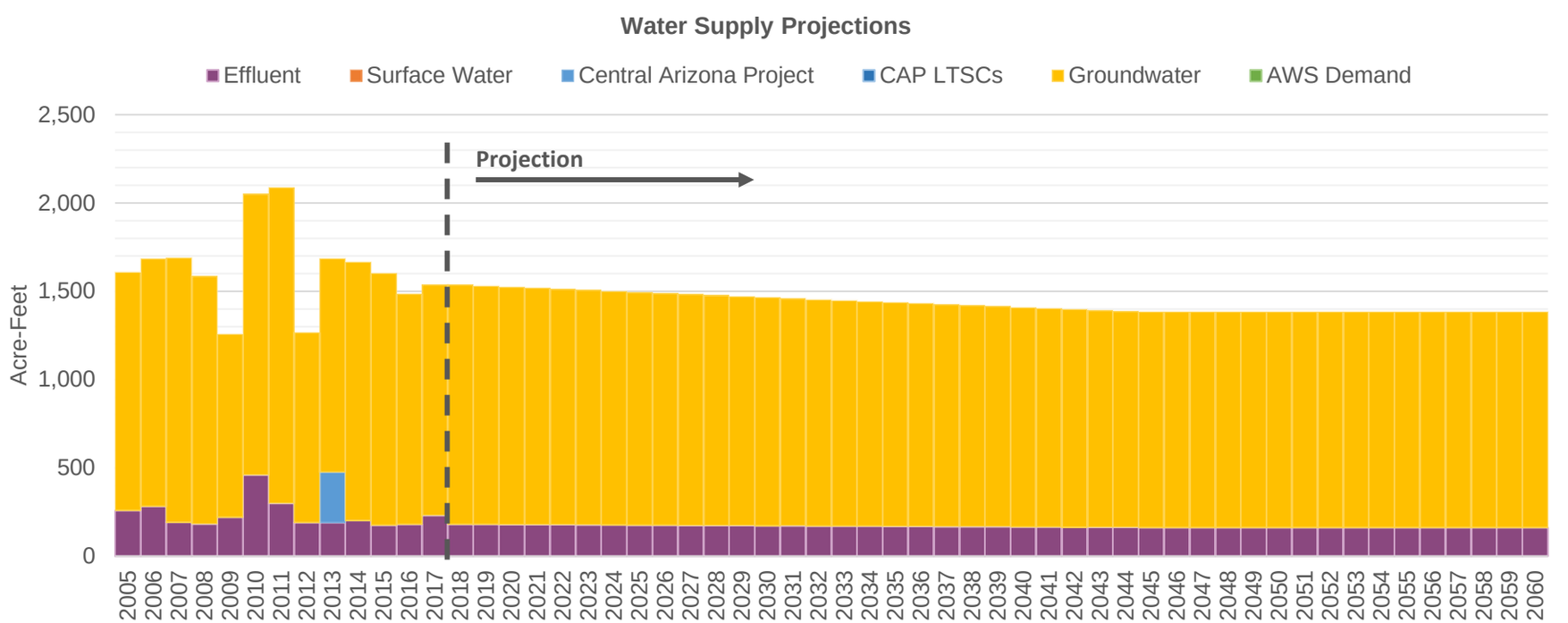
UniversityofAZ

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

UniversityofAZ

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

Demand Assumptions

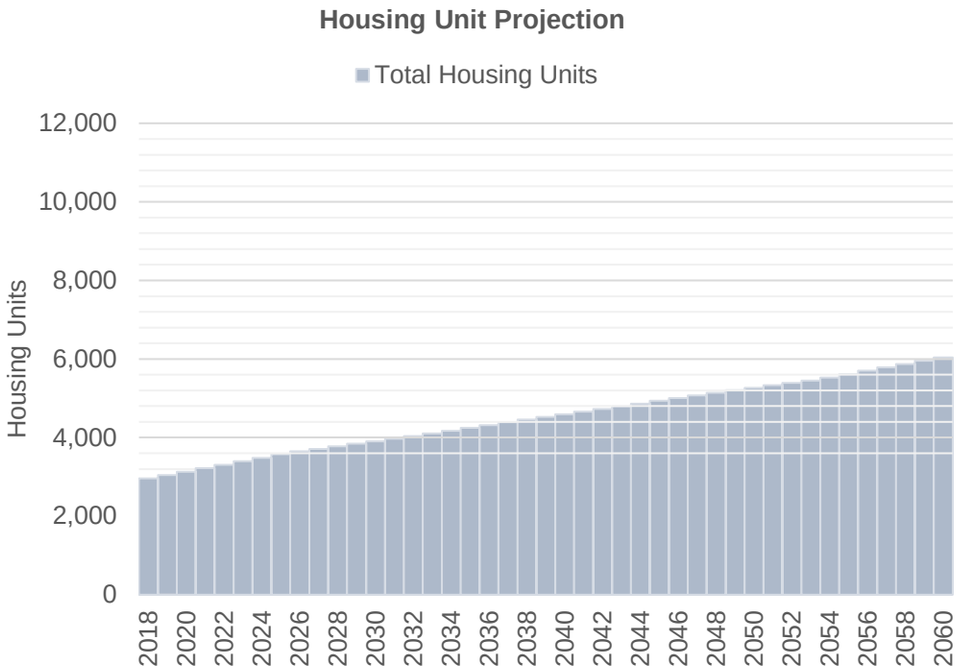
Water Supply Projections (Acre-Feet)

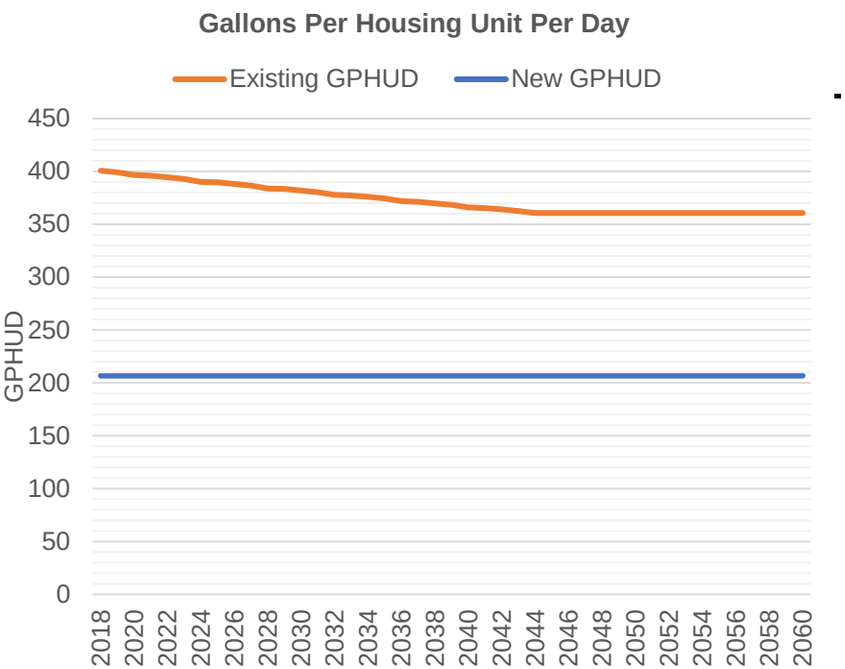
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	71	19,446	500	180	0	0	0	0	0	0	1,356	0
2019	71	19,368	500	180	0	0	0	0	0	0	1,350	0
2020	71	19,238	500	179	0	0	0	0	0	0	1,345	0
2021	71	19,214	500	179	0	0	0	0	0	0	1,339	0
2022	71	19,137	500	178	0	0	0	0	0	0	1,334	0
2023	71	19,060	500	177	0	0	0	0	0	0	1,329	0
2024	71	18,932	500	176	0	0	0	0	0	0	1,324	0
2025	71	18,908	500	176	0	0	0	0	0	0	1,318	0
2026	72	18,832	500	175	0	0	0	0	0	0	1,313	0
2027	72	18,757	500	174	0	0	0	0	0	0	1,308	0
2028	72	18,631	500	174	0	0	0	0	0	0	1,303	0
2029	72	18,607	500	173	0	0	0	0	0	0	1,298	0
2030	72	18,533	500	172	0	0	0	0	0	0	1,293	0
2031	72	18,459	500	172	0	0	0	0	0	0	1,287	0
2032	72	18,335	500	171	0	0	0	0	0	0	1,282	0
2033	73	18,311	500	170	0	0	0	0	0	0	1,277	0
2034	73	18,238	500	170	0	0	0	0	0	0	1,272	0
2035	73	18,165	500	169	0	0	0	0	0	0	1,267	0
2036	73	18,043	500	168	0	0	0	0	0	0	1,262	0
2037	73	18,020	500	168	0	0	0	0	0	0	1,257	0
2038	74	17,948	500	167	0	0	0	0	0	0	1,252	0
2039	74	17,876	500	166	0	0	0	0	0	0	1,248	0
2040	74	17,756	500	166	0	0	0	0	0	0	1,243	0
2041	74	17,733	500	165	0	0	0	0	0	0	1,238	0
2042	74	17,663	500	164	0	0	0	0	0	0	1,233	0
2043	74	17,592	500	164	0	0	0	0	0	0	1,228	0
2044	74	17,474	500	163	0	0	0	0	0	0	1,223	0
2045	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2046	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2047	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2048	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2049	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2050	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2051	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2052	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2053	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2054	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2055	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2056	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2057	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2058	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2059	75	17,501	500	162	0	0	0	0	0	0	1,223	0
2060	75	17,501	500	162	0	0	0	0	0	0	1,223	0

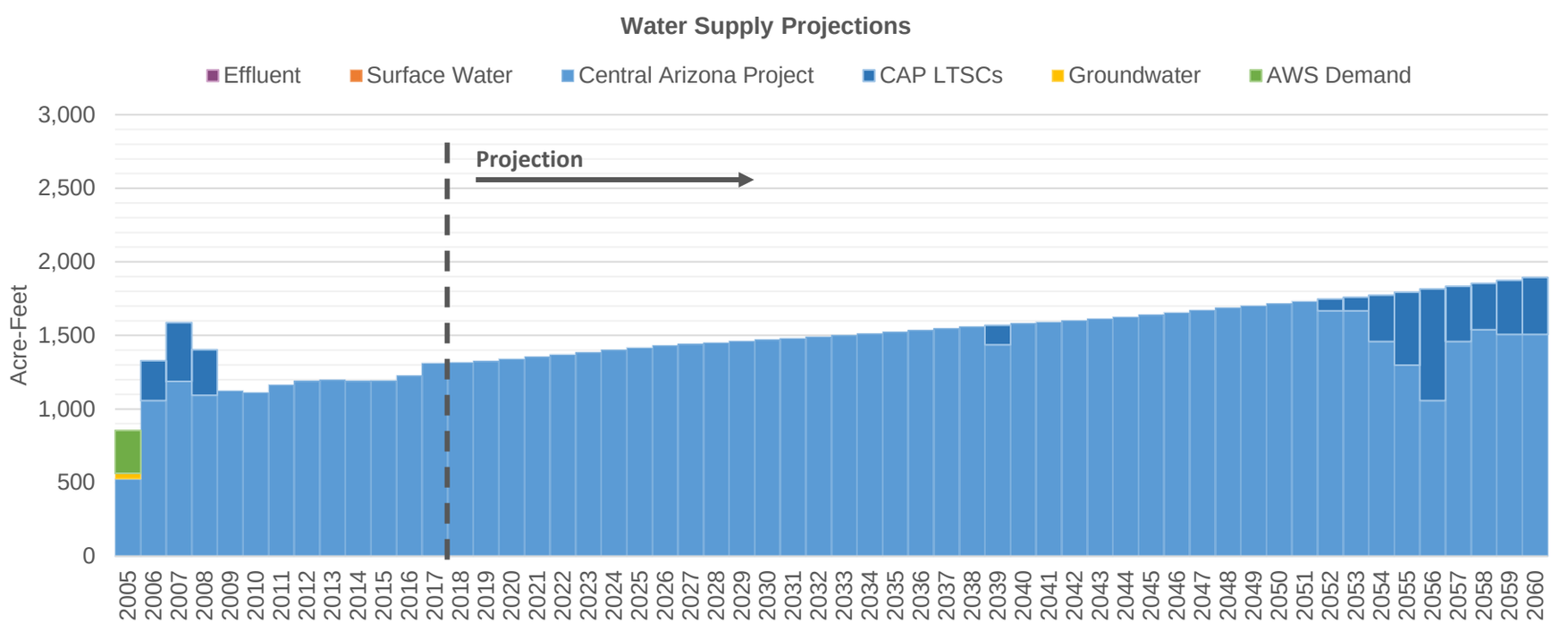
VailWC

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

VailWC

D. Slow, Compact, Very Dry Climate

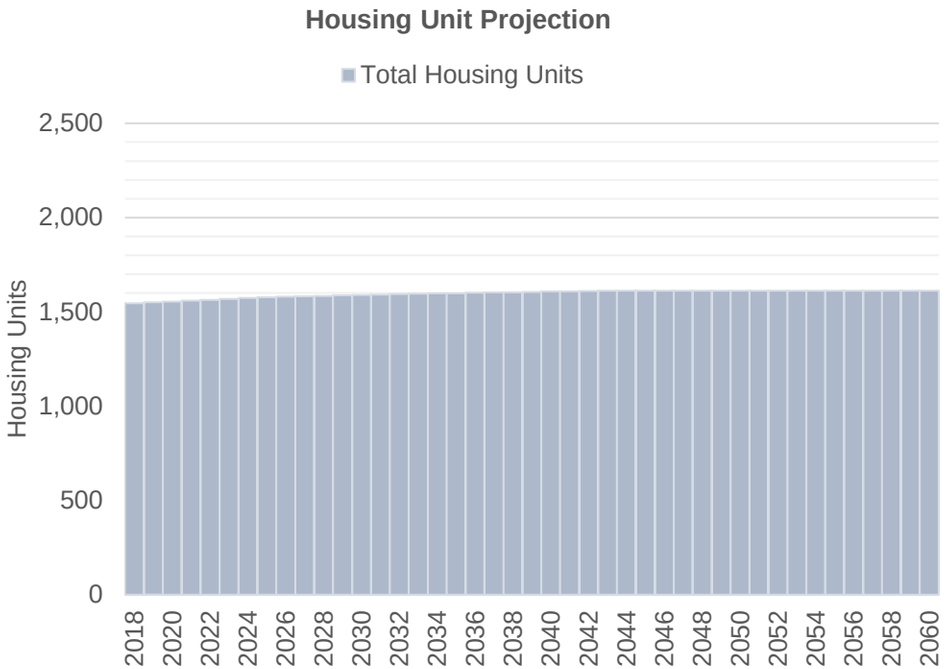
7/13/20 12:06 PM

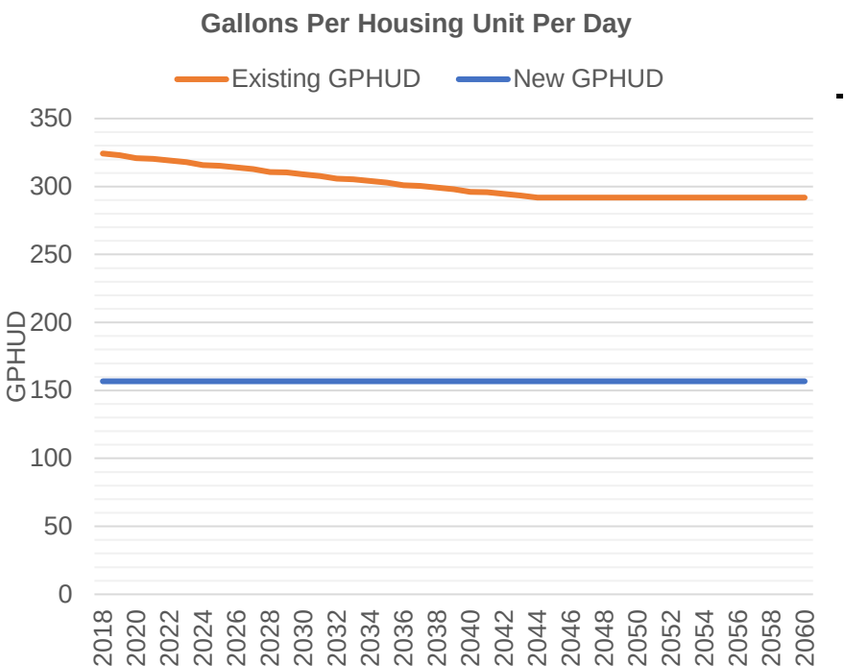
Date	Demand Assumptions: Housing Units	GPHUD		Water Supply Projections (Acre-Feet): Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,960	401	207	0	0	0	0	1,316	541	0	0	0
2019	3,046	399	207	0	0	0	0	1,325	532	0	0	0
2020	3,132	396	207	0	0	0	0	1,340	517	0	0	0
2021	3,220	396	207	0	0	0	0	1,355	502	0	0	0
2022	3,307	394	207	0	0	0	0	1,370	487	0	0	0
2023	3,396	393	207	0	0	0	0	1,385	472	0	0	0
2024	3,484	390	207	0	0	0	0	1,401	456	0	0	0
2025	3,573	390	207	0	0	0	0	1,416	441	0	0	0
2026	3,647	388	207	0	0	0	0	1,430	427	0	0	0
2027	3,713	387	207	0	0	0	0	1,441	416	0	0	0
2028	3,779	384	207	0	0	0	0	1,451	406	0	0	0
2029	3,843	383	207	0	0	0	0	1,461	396	0	0	0
2030	3,906	382	207	0	0	0	0	1,471	386	0	0	0
2031	3,973	380	207	0	0	0	0	1,481	376	0	0	0
2032	4.038	378	207	0	0	0	0	1.492	365	0	0	0
2033	4,103	377	207	0	0	0	0	1,501	356	0	0	0
2034	4,171	376	207	0	0	0	0	1,512	345	0	0	0
2035	4,244	374	207	0	0	0	0	1,523	334	0	0	0
2036	4,316	372	207	0	0	0	0	1,536	321	0	0	0
2037	4,387	371	207	0	0	0	0	1,547	310	0	0	0
2038	4,457	370	207	0	0	0	0	1,558	172	0	0	0
2039	4,526	368	207	0	0	0	0	1,437	0	132	0	0
2040	4,594	366	207	0	0	0	0	1,581	117	0	0	0
2041	4,661	365	207	0	0	0	0	1,591	237	0	0	0
2042	4,727	364	207	0	0	0	0	1,602	210	0	0	0
2043	4,795	363	207	0	0	0	0	1,613	244	0	0	0
2044	4,866	361	207	0	0	0	0	1,625	232	0	0	0
2045	4,935	361	207	0	0	0	0	1,639	218	0	0	0
2046	5,004	361	207	0	0	0	0	1,655	142	0	0	0
2047	5,071	361	207	0	0	0	0	1,670	187	0	0	0
2048	5,138	361	207	0	0	0	0	1,687	110	0	0	0
2049	5,203	361	207	0	0	0	0	1,701	96	0	0	0
2050	5,267	361	207	0	0	0	0	1,716	81	0	0	0
2051	5,329	361	207	0	0	0	0	1,731	66	0	0	0
2052	5,391	361	207	0	0	0	0	1,668	0	79	0	0
2053	5,451	361	207	0	0	0	0	1,668	0	91	0	0
2054	5,523	361	207	0	0	0	0	1,459	0	316	0	0
2055	5,613	361	207	0	0	0	0	1,298	0	496	0	0
2056	5,702	361	207	0	0	0	0	1,056	0	760	0	0
2057	5,788	361	207	0	0	0	0	1,459	0	376	0	0
2058	5,873	361	207	0	0	0	0	1,539	0	315	0	0
2059	5,955	361	207	0	0	0	0	1,507	0	366	0	0
2060	6,036	361	207	0	0	0	0	1,507	0	387	0	0

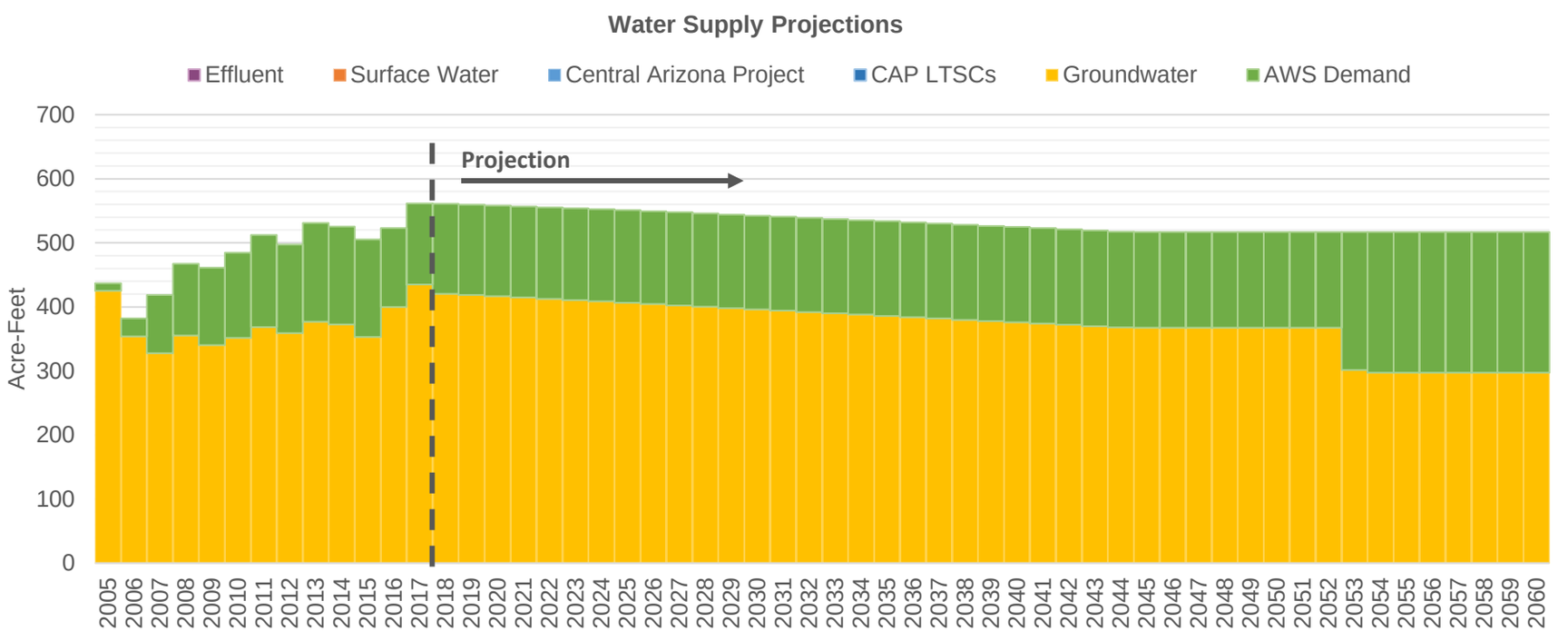
VoyagerWC

Central Arizona Project Service Area Model

D. Slow, Compact, Very Dry Climate







Central Arizona Project Service Area Model

VoyagerWC

D. Slow, Compact, Very Dry Climate

7/13/20 12:06 PM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,546	324	157	0	0	0	0	0	0	0	421	141
2019	1,551	323	157	0	0	0	0	0	0	0	419	141
2020	1,555	321	157	0	0	0	0	0	0	0	417	141
2021	1,560	320	157	0	0	0	0	0	0	0	415	142
2022	1,564	319	157	0	0	0	0	0	0	0	412	143
2023	1,569	318	157	0	0	0	0	0	0	0	411	143
2024	1,574	316	157	0	0	0	0	0	0	0	409	144
2025	1,578	315	157	0	0	0	0	0	0	0	407	145
2026	1,581	314	157	0	0	0	0	0	0	0	404	145
2027	1,583	313	157	0	0	0	0	0	0	0	402	145
2028	1,585	311	157	0	0	0	0	0	0	0	400	146
2029	1,587	310	157	0	0	0	0	0	0	0	398	146
2030	1,589	309	157	0	0	0	0	0	0	0	396	146
2031	1,592	308	157	0	0	0	0	0	0	0	394	146
2032	1,594	306	157	0	0	0	0	0	0	0	392	147
2033	1,596	305	157	0	0	0	0	0	0	0	390	147
2034	1,598	304	157	0	0	0	0	0	0	0	388	147
2035	1,599	303	157	0	0	0	0	0	0	0	386	148
2036	1,601	301	157	0	0	0	0	0	0	0	384	148
2037	1,603	301	157	0	0	0	0	0	0	0	382	148
2038	1,604	299	157	0	0	0	0	0	0	0	380	148
2039	1,606	298	157	0	0	0	0	0	0	0	378	148
2040	1,608	296	157	0	0	0	0	0	0	0	376	149
2041	1,609	296	157	0	0	0	0	0	0	0	374	149
2042	1,611	295	157	0	0	0	0	0	0	0	372	149
2043	1,612	293	157	0	0	0	0	0	0	0	370	149
2044	1,612	292	157	0	0	0	0	0	0	0	368	149
2045	1,612	292	157	0	0	0	0	0	0	0	367	149
2046	1,612	292	157	0	0	0	0	0	0	0	367	149
2047	1,612	292	157	0	0	0	0	0	0	0	367	149
2048	1,612	292	157	0	0	0	0	0	0	0	367	149
2049	1,612	292	157	0	0	0	0	0	0	0	367	149
2050	1,612	292	157	0	0	0	0	0	0	0	367	149
2051	1,612	292	157	0	0	0	0	0	0	0	367	149
2052	1,612	292	157	0	0	0	0	0	0	0	367	149
2053	1,612	292	157	0	0	0	0	0	0	0	301	215
2054	1,612	292	157	0	0	0	0	0	0	0	297	220
2055	1,612	292	157	0	0	0	0	0	0	0	297	220
2056	1,612	292	157	0	0	0	0	0	0	0	297	220
2057	1,612	292	157	0	0	0	0	0	0	0	297	220
2058	1,612	292	157	0	0	0	0	0	0	0	297	220
2059	1,612	292	157	0	0	0	0	0	0	0	297	220
2060	1,612	292	157	0	0	0	0	0	0	0	297	220

CAP:SAM Supply and Demand Projections by Water Provider

Scenario E

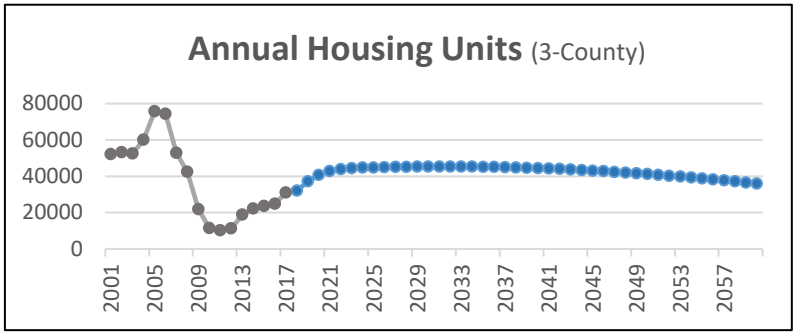
Climate: Worse Case
Growth Rate: Medium
Growth Pattern: Official
Relative Risk: Moderate

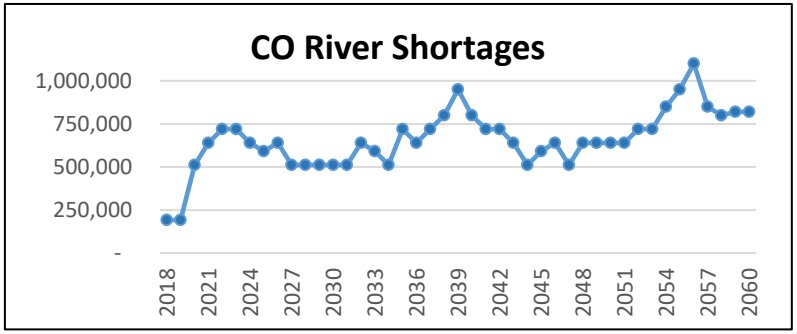
E. Official, Very Dry [LSCRBS]

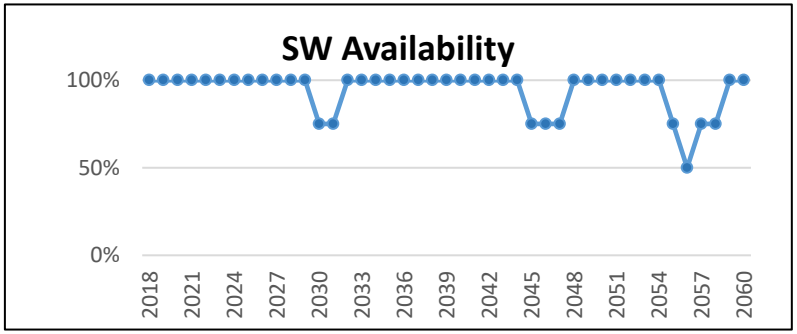
Run Date: 7/14/2020 **Filename:** CAPServiceArea_v3.50_LSCRBS_AC

Growth rate based on Medium growth series from the AZ Dept. of Administration and growth pattern from PAG, standard CAP-SAM

Allow Shortages	Yes	
Select CRSS Array	3	*3=Synthetic*
Use Specific Trace	Yes	
Selected Trace	3	*1=Moderate; 2=Deep; 3=Slight*
AWBA Max M&I	20%	
Surface Water Scenario	3	*1=No Reduction; 2=Occational; 3=Frequent*
Use CAP Buildup	Yes	
CAP Buildup Scenario	2	*1=2035; 2=2045*
HU Growth Pattern	1	*1=Baseline*
HU Forecast	2	*1=Use Curve; 2=Eller Forecast*
HU Curve	2	
HU Growth Start Rate	0%	
HU Ordinary Level	45,000	
HU Rate @ 50 yrs	-2%	
GPHUD Change Existing	-0.4%	*per year*
GPHUD Max Change Existing	-10%	
GPHUD Min Existing	200	
GPHUD Scenario New	1	
GPHUD Change New	0.0%	*per year*
Ag Climate Adjustment	0.2	
Ag Efficiency Increase	0.1%	*per year*
Ag Efficiency Goal	80%	
Ag Replace Crop CU	3.24	
Ag Intensity Scenario	2	
Ag Develop on Crops	50%	*Perecent of max on active Ag*
Ag Acres Replace Percent	0%	
Ag Replace Crop Year	2025	



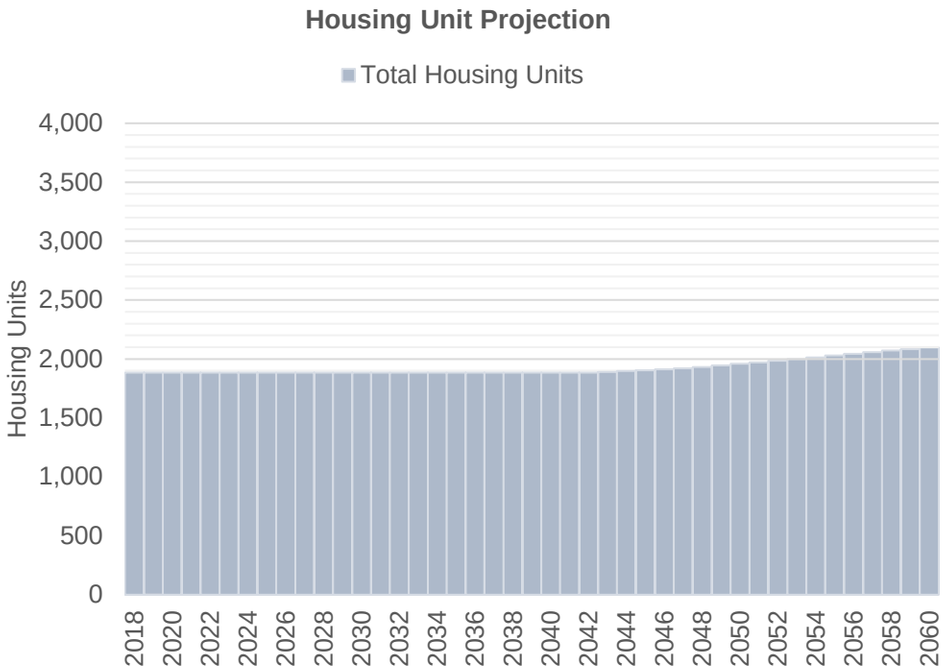


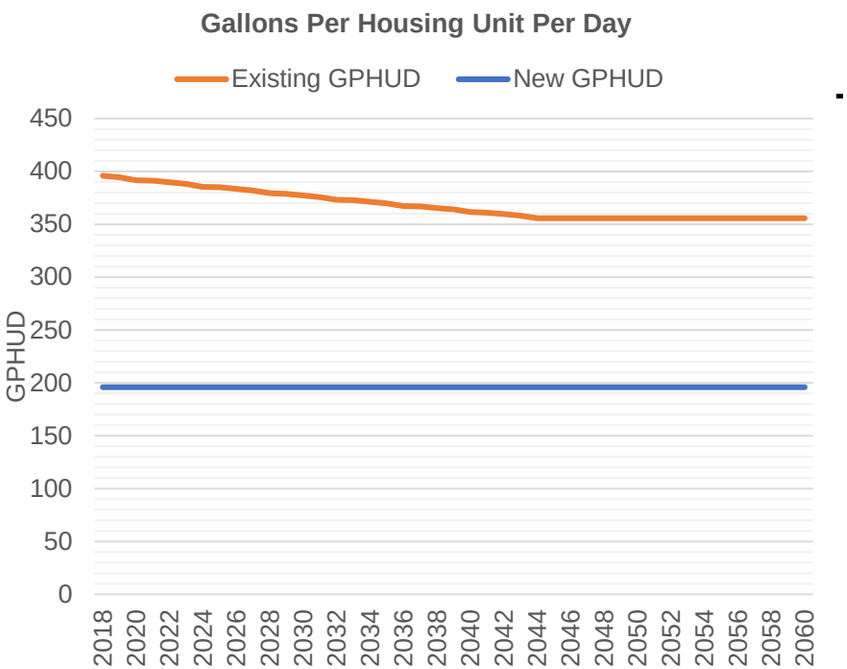


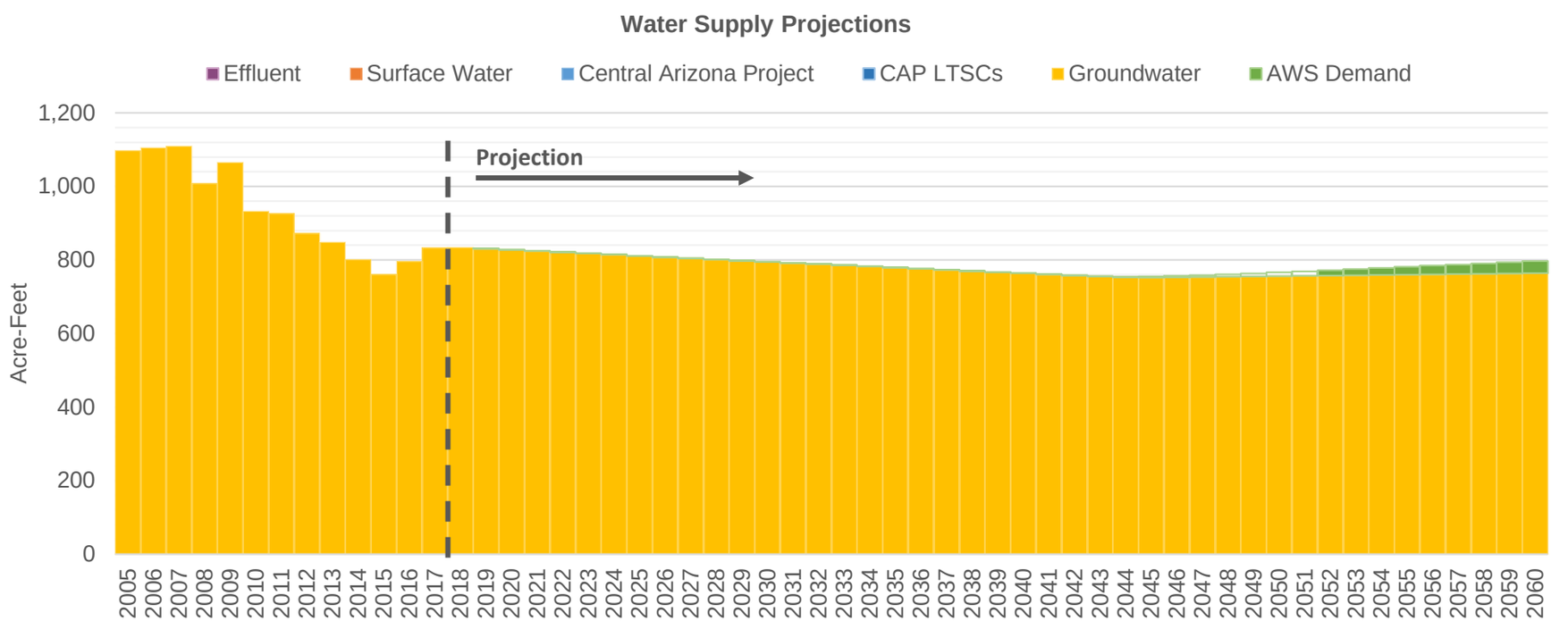
Central Arizona Project Service Area Model

AvraWaterCoop

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

AvraWaterCoop

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

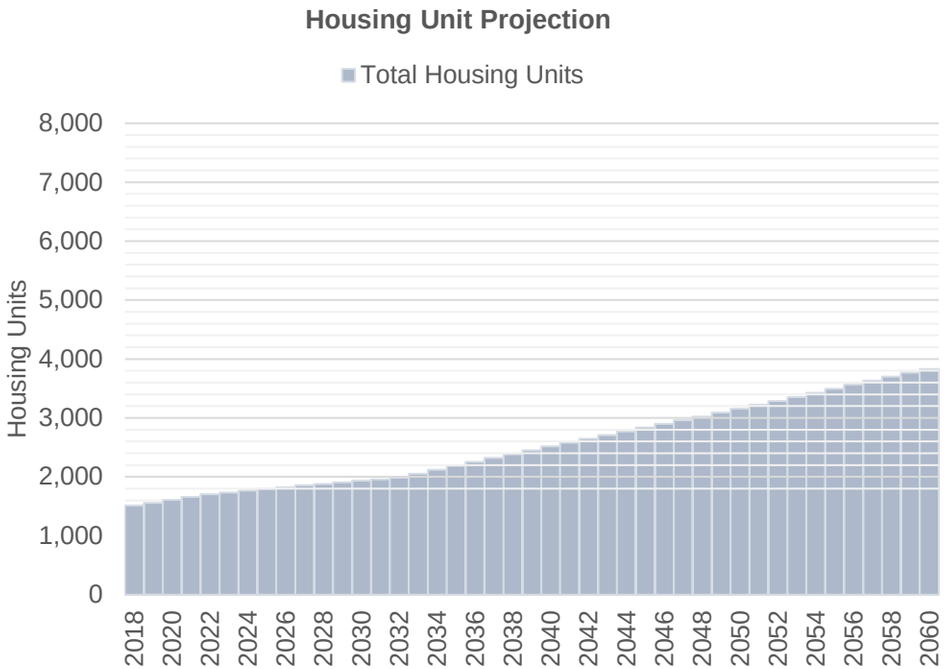
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

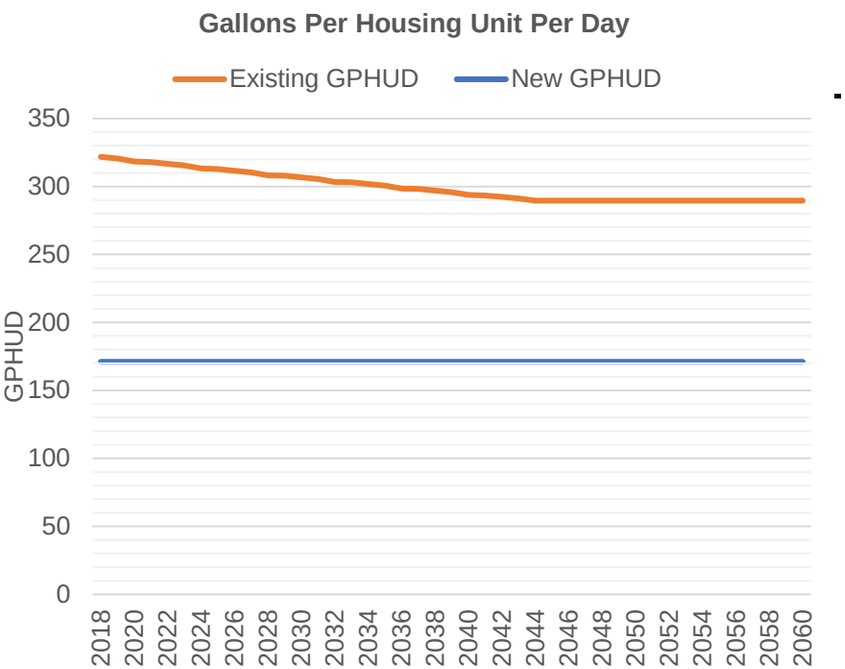
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,883	396	196	0	0	0	0	0	0	0	834	0
2019	1,883	394	196	0	0	0	0	0	0	0	831	0
2020	1,883	392	196	0	0	0	0	0	0	0	827	0
2021	1,883	391	196	0	0	0	0	0	0	0	824	0
2022	1,883	390	196	0	0	0	0	0	0	0	821	0
2023	1,883	388	196	0	0	0	0	0	0	0	818	0
2024	1,883	385	196	0	0	0	0	0	0	0	814	0
2025	1,883	385	196	0	0	0	0	0	0	0	811	0
2026	1,883	383	196	0	0	0	0	0	0	0	808	0
2027	1,883	382	196	0	0	0	0	0	0	0	805	0
2028	1,883	379	196	0	0	0	0	0	0	0	801	0
2029	1,883	379	196	0	0	0	0	0	0	0	798	0
2030	1,883	377	196	0	0	0	0	0	0	0	795	0
2031	1,883	376	196	0	0	0	0	0	0	0	792	0
2032	1,883	373	196	0	0	0	0	0	0	0	789	0
2033	1,883	373	196	0	0	0	0	0	0	0	785	0
2034	1,883	371	196	0	0	0	0	0	0	0	782	0
2035	1,883	370	196	0	0	0	0	0	0	0	779	0
2036	1,883	367	196	0	0	0	0	0	0	0	776	0
2037	1,883	367	196	0	0	0	0	0	0	0	773	0
2038	1,883	365	196	0	0	0	0	0	0	0	770	0
2039	1,883	364	196	0	0	0	0	0	0	0	767	0
2040	1,883	361	196	0	0	0	0	0	0	0	764	0
2041	1,883	361	196	0	0	0	0	0	0	0	761	0
2042	1,883	360	196	0	0	0	0	0	0	0	758	0
2043	1,889	358	196	0	0	0	0	0	0	0	755	0
2044	1,897	356	196	0	0	0	0	0	0	0	753	1
2045	1,905	356	196	0	0	0	0	0	0	0	752	3
2046	1,913	356	196	0	0	0	0	0	0	0	753	4
2047	1,921	356	196	0	0	0	0	0	0	0	753	5
2048	1,932	356	196	0	0	0	0	0	0	0	754	6
2049	1,945	356	196	0	0	0	0	0	0	0	755	8
2050	1,959	356	196	0	0	0	0	0	0	0	756	10
2051	1,972	356	196	0	0	0	0	0	0	0	757	13
2052	1,986	356	196	0	0	0	0	0	0	0	757	15
2053	2,000	356	196	0	0	0	0	0	0	0	758	17
2054	2,014	356	196	0	0	0	0	0	0	0	759	19
2055	2,029	356	196	0	0	0	0	0	0	0	760	22
2056	2,043	356	196	0	0	0	0	0	0	0	761	24
2057	2,057	356	196	0	0	0	0	0	0	0	762	26
2058	2,071	356	196	0	0	0	0	0	0	0	762	28
2059	2,084	356	196	0	0	0	0	0	0	0	763	31
2060	2,098	356	196	0	0	0	0	0	0	0	764	33

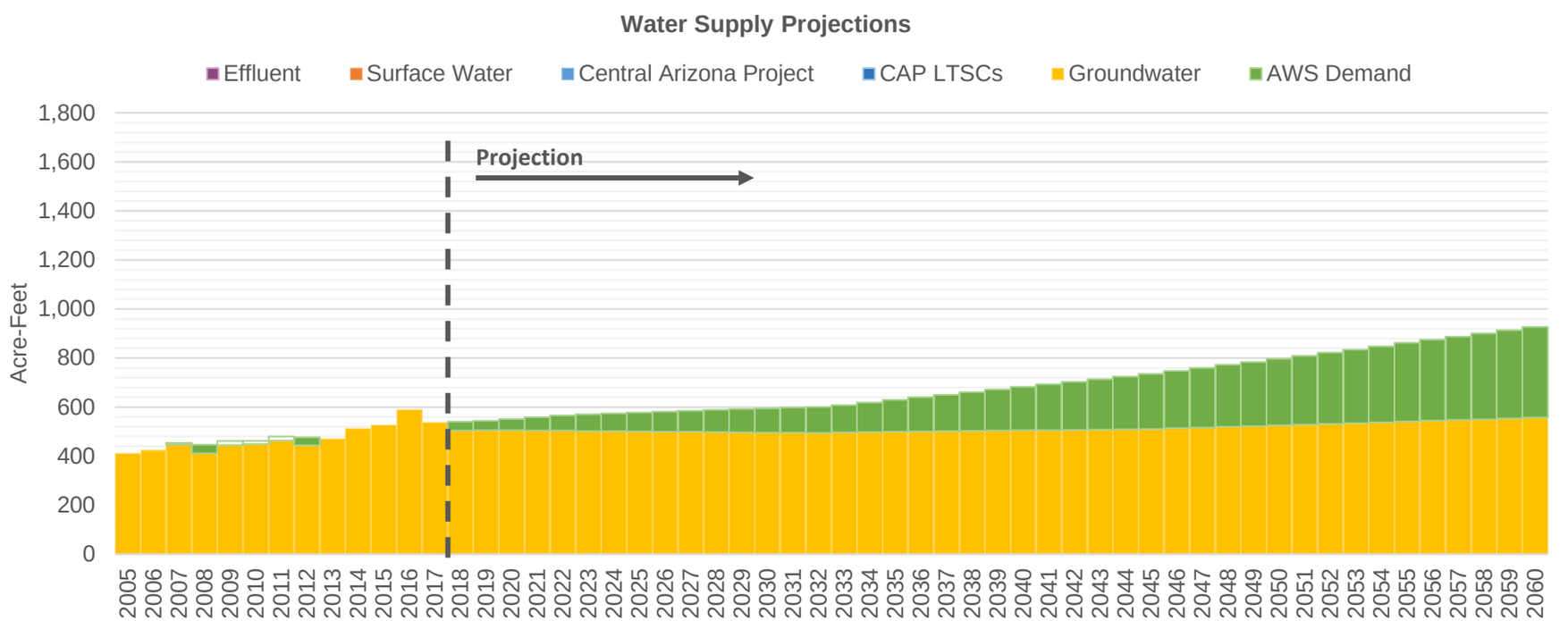
Central Arizona Project Service Area Model

AZWCOracle

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

AZWCOracle

E. Official, Very Dry [LSCRBS]

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Demand Assumptions

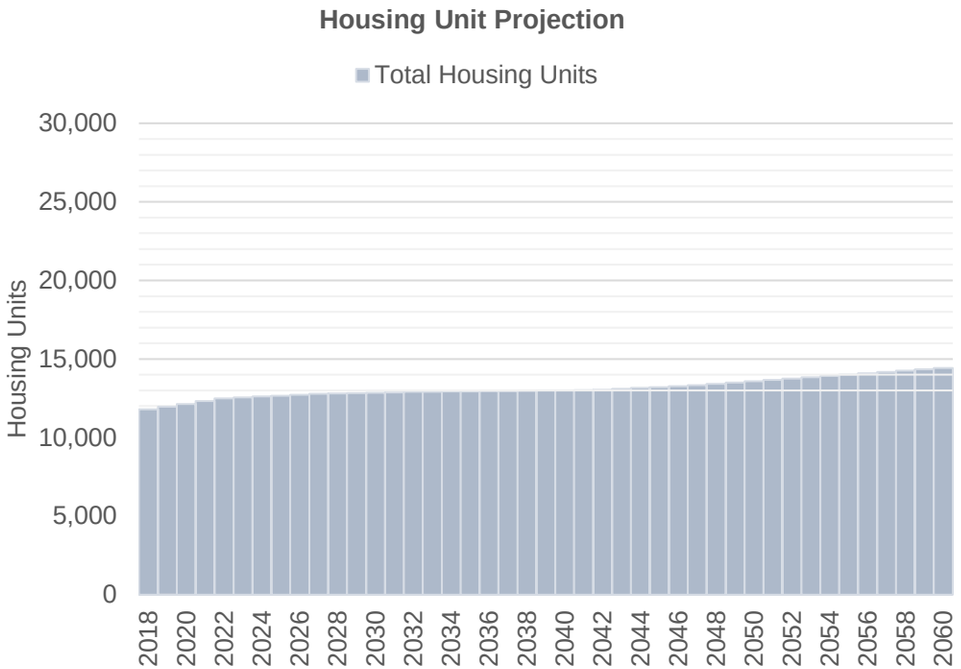
Water Supply Projections (Acre-Feet)

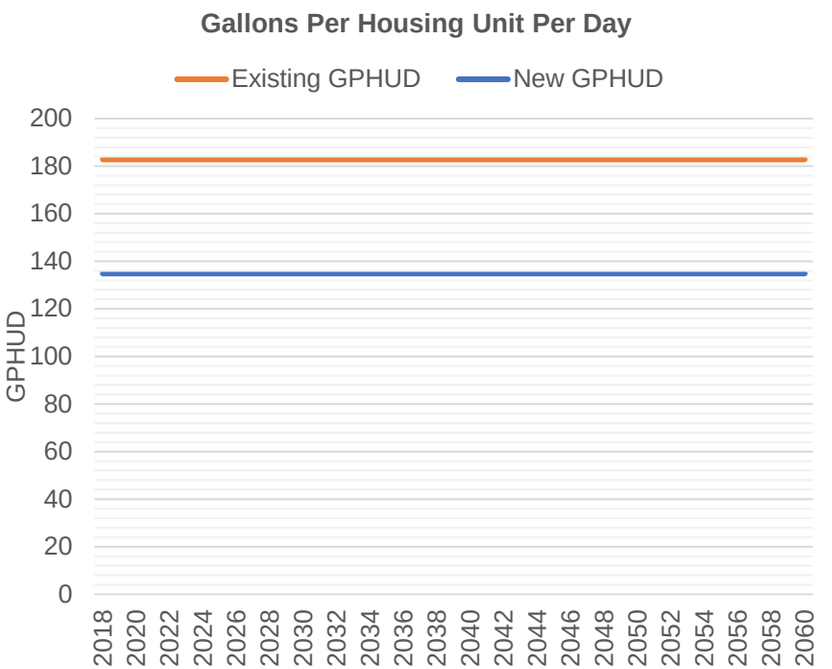
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,516	322	171	0	0	0	0	0	0	0	505	36
2019	1,560	321	171	0	0	0	0	0	0	0	505	39
2020	1,608	318	171	0	0	0	0	0	0	0	505	46
2021	1,658	318	171	0	0	0	0	0	0	0	504	54
2022	1,703	317	171	0	0	0	0	0	0	0	504	62
2023	1,733	315	171	0	0	0	0	0	0	0	502	69
2024	1,764	313	171	0	0	0	0	0	0	0	501	73
2025	1,794	313	171	0	0	0	0	0	0	0	500	78
2026	1,825	312	171	0	0	0	0	0	0	0	500	82
2027	1,855	310	171	0	0	0	0	0	0	0	499	87
2028	1,881	308	171	0	0	0	0	0	0	0	498	91
2029	1,908	308	171	0	0	0	0	0	0	0	497	95
2030	1,934	307	171	0	0	0	0	0	0	0	496	99
2031	1,960	305	171	0	0	0	0	0	0	0	495	103
2032	1,988	303	171	0	0	0	0	0	0	0	495	106
2033	2,055	303	171	0	0	0	0	0	0	0	498	110
2034	2,121	302	171	0	0	0	0	0	0	0	499	120
2035	2,187	301	171	0	0	0	0	0	0	0	500	130
2036	2,253	299	171	0	0	0	0	0	0	0	501	139
2037	2,319	298	171	0	0	0	0	0	0	0	502	149
2038	2,385	297	171	0	0	0	0	0	0	0	503	159
2039	2,451	296	171	0	0	0	0	0	0	0	504	168
2040	2,516	294	171	0	0	0	0	0	0	0	505	178
2041	2,580	293	171	0	0	0	0	0	0	0	506	187
2042	2,645	292	171	0	0	0	0	0	0	0	507	197
2043	2,709	291	171	0	0	0	0	0	0	0	508	206
2044	2,772	290	171	0	0	0	0	0	0	0	509	215
2045	2,835	290	171	0	0	0	0	0	0	0	511	225
2046	2,898	290	171	0	0	0	0	0	0	0	514	234
2047	2,960	290	171	0	0	0	0	0	0	0	516	243
2048	3,025	290	171	0	0	0	0	0	0	0	520	252
2049	3,092	290	171	0	0	0	0	0	0	0	523	262
2050	3,158	290	171	0	0	0	0	0	0	0	526	271
2051	3,223	290	171	0	0	0	0	0	0	0	529	281
2052	3,287	290	171	0	0	0	0	0	0	0	532	290
2053	3,355	290	171	0	0	0	0	0	0	0	535	300
2054	3,426	290	171	0	0	0	0	0	0	0	538	310
2055	3,496	290	171	0	0	0	0	0	0	0	541	320
2056	3,565	290	171	0	0	0	0	0	0	0	545	330
2057	3,633	290	171	0	0	0	0	0	0	0	547	340
2058	3,700	290	171	0	0	0	0	0	0	0	550	350
2059	3,766	290	171	0	0	0	0	0	0	0	553	360
2060	3,831	290	171	0	0	0	0	0	0	0	558	370

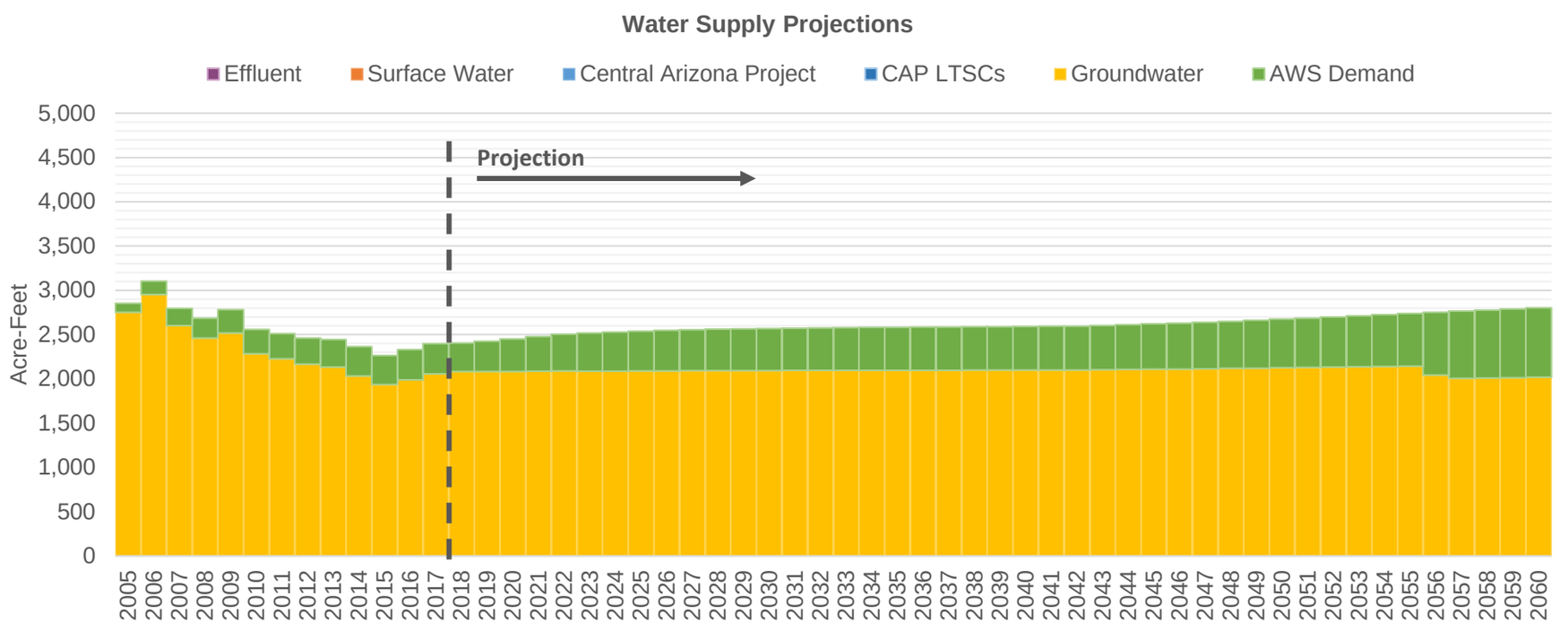
Central Arizona Project Service Area Model

CommWaterGreenVly

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

CommWaterGre

E. Official, Very Dry [LSCRBS]

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Demand Assumptions

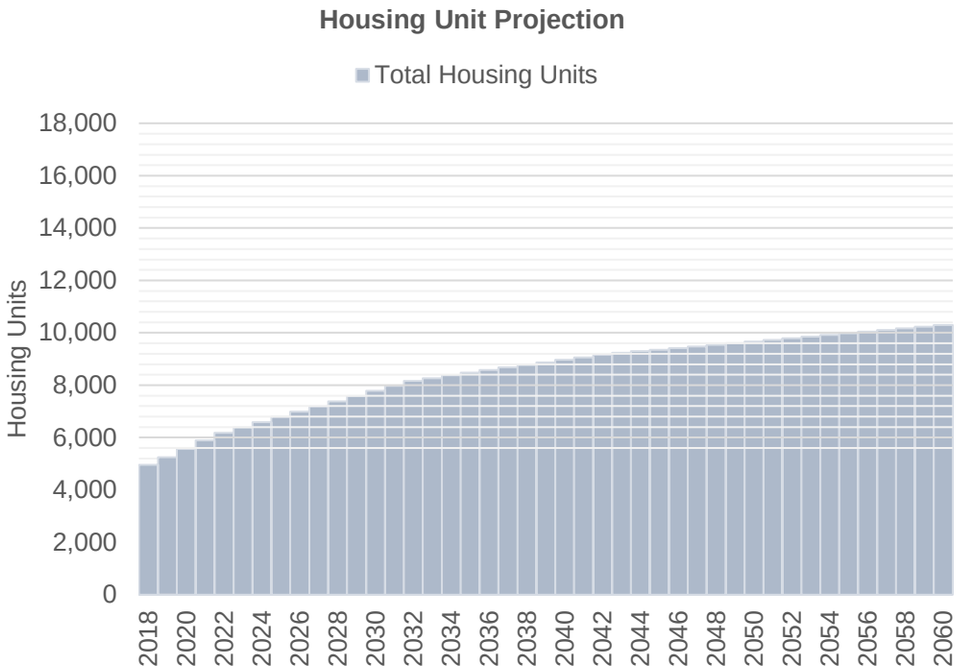
Water Supply Projections (Acre-Feet)

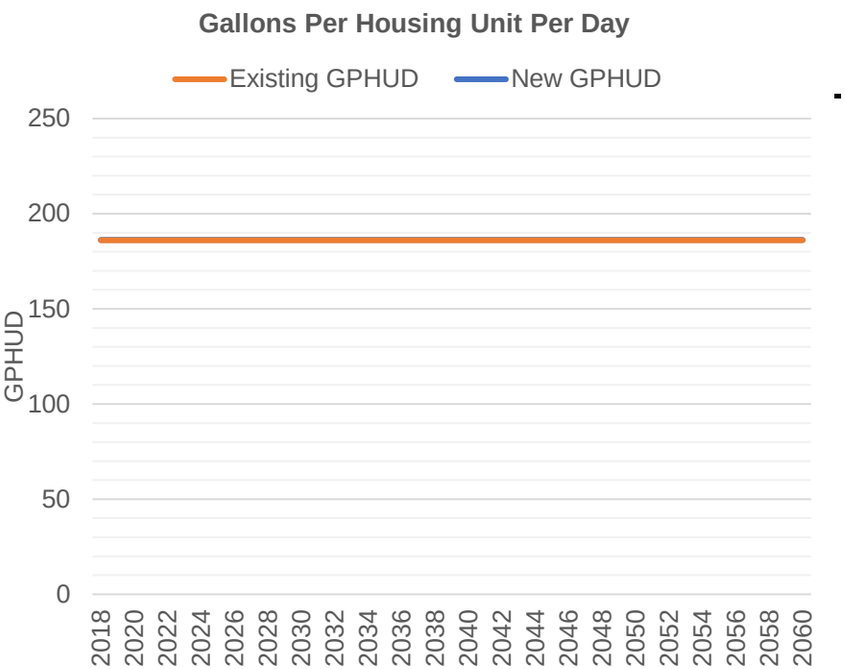
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	11,794	183	135	0	0	0	0	0	0	0	2,082	322
2019	11,963	183	135	0	0	0	0	0	0	0	2,085	338
2020	12,143	183	135	0	0	0	0	0	0	0	2,083	366
2021	12,332	183	135	0	0	0	0	0	0	0	2,086	391
2022	12,485	183	135	0	0	0	0	0	0	0	2,088	415
2023	12,546	183	135	0	0	0	0	0	0	0	2,086	434
2024	12,608	183	135	0	0	0	0	0	0	0	2,088	441
2025	12,669	183	135	0	0	0	0	0	0	0	2,089	449
2026	12,731	183	135	0	0	0	0	0	0	0	2,091	456
2027	12,787	183	135	0	0	0	0	0	0	0	2,093	463
2028	12,810	183	135	0	0	0	0	0	0	0	2,093	470
2029	12,833	183	135	0	0	0	0	0	0	0	2,093	472
2030	12,856	183	135	0	0	0	0	0	0	0	2,094	475
2031	12,879	183	135	0	0	0	0	0	0	0	2,095	478
2032	12,902	183	135	0	0	0	0	0	0	0	2,096	480
2033	12,914	183	135	0	0	0	0	0	0	0	2,096	483
2034	12,926	183	135	0	0	0	0	0	0	0	2,096	484
2035	12,937	183	135	0	0	0	0	0	0	0	2,097	485
2036	12,949	183	135	0	0	0	0	0	0	0	2,098	487
2037	12,961	183	135	0	0	0	0	0	0	0	2,098	488
2038	12,976	183	135	0	0	0	0	0	0	0	2,098	489
2039	12,990	183	135	0	0	0	0	0	0	0	2,099	491
2040	13,005	183	135	0	0	0	0	0	0	0	2,100	493
2041	13,020	183	135	0	0	0	0	0	0	0	2,100	494
2042	13,034	183	135	0	0	0	0	0	0	0	2,100	496
2043	13,094	183	135	0	0	0	0	0	0	0	2,104	498
2044	13,156	183	135	0	0	0	0	0	0	0	2,107	505
2045	13,217	183	135	0	0	0	0	0	0	0	2,109	512
2046	13,278	183	135	0	0	0	0	0	0	0	2,112	518
2047	13,338	183	135	0	0	0	0	0	0	0	2,114	525
2048	13,412	183	135	0	0	0	0	0	0	0	2,118	532
2049	13,497	183	135	0	0	0	0	0	0	0	2,122	540
2050	13,581	183	135	0	0	0	0	0	0	0	2,125	549
2051	13,665	183	135	0	0	0	0	0	0	0	2,129	558
2052	13,747	183	135	0	0	0	0	0	0	0	2,133	567
2053	13,833	183	135	0	0	0	0	0	0	0	2,136	576
2054	13,921	183	135	0	0	0	0	0	0	0	2,140	585
2055	14,009	183	135	0	0	0	0	0	0	0	2,143	595
2056	14,095	183	135	0	0	0	0	0	0	0	2,045	708
2057	14,180	183	135	0	0	0	0	0	0	0	2,007	757
2058	14,264	183	135	0	0	0	0	0	0	0	2,011	766
2059	14,346	183	135	0	0	0	0	0	0	0	2,014	775
2060	14,427	183	135	0	0	0	0	0	0	0	2,019	784

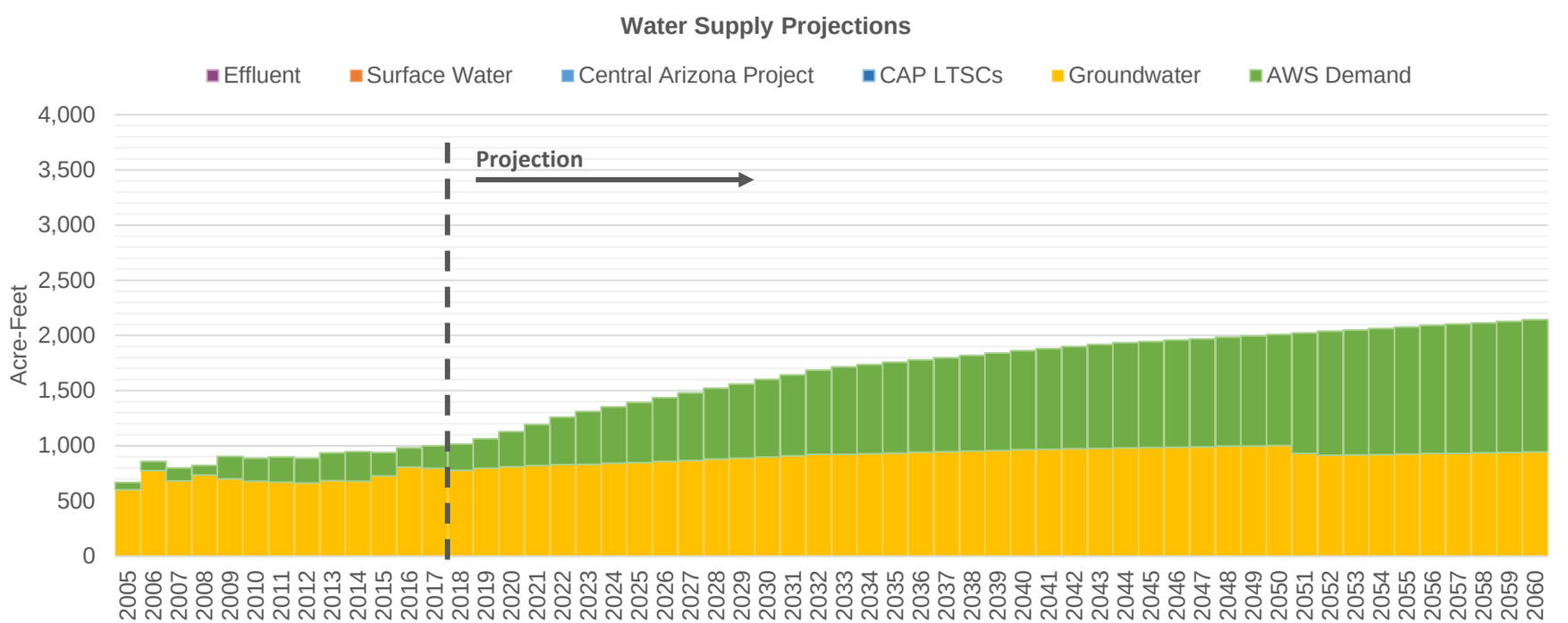
Central Arizona Project Service Area Model

FarmersWC

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

FarmersWC

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions

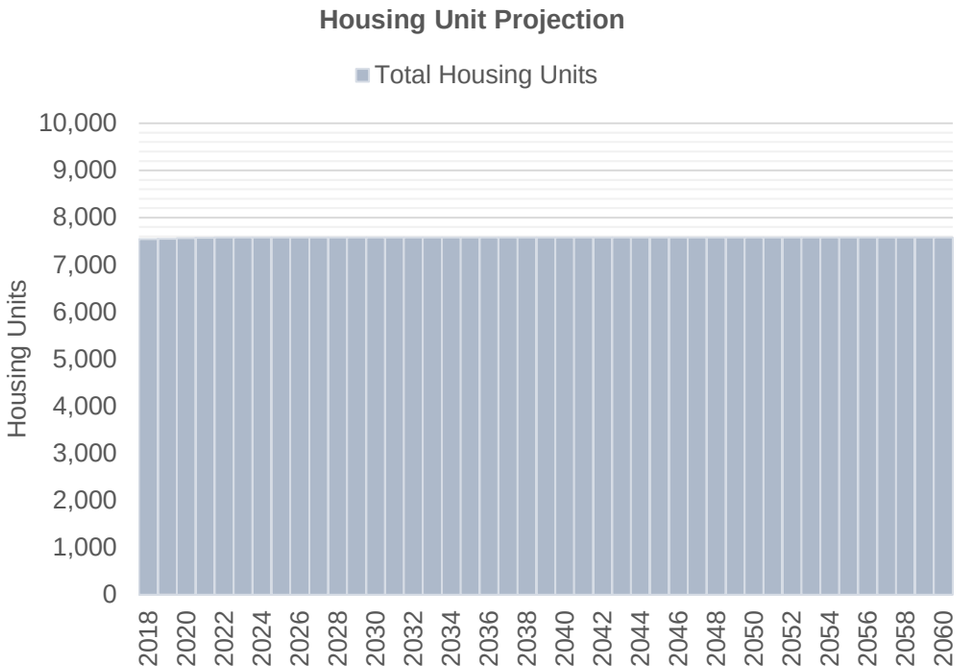
Water Supply Projections (Acre-Feet)

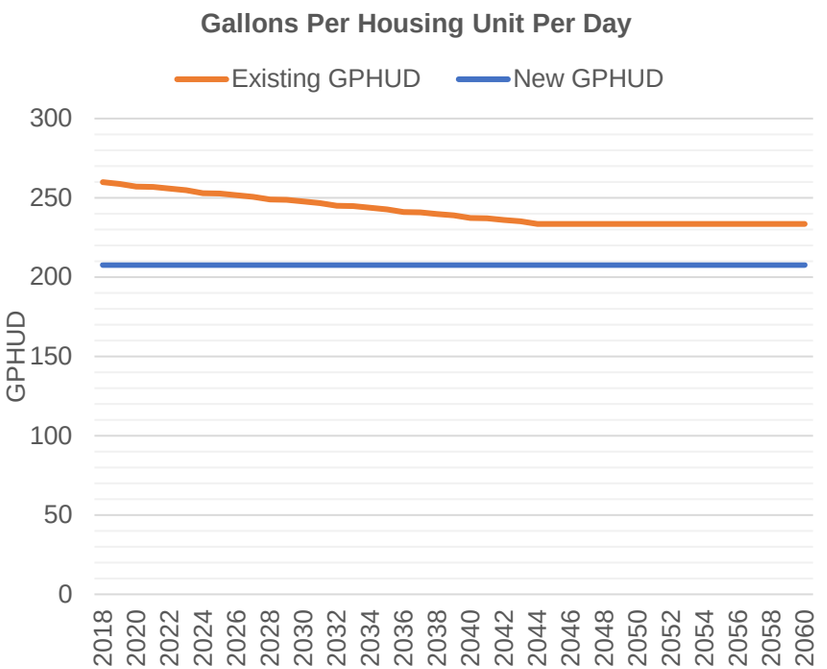
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,959	186	186	0	0	0	0	0	0	0	779	238
2019	5,250	186	186	0	0	0	0	0	0	0	798	266
2020	5,564	186	186	0	0	0	0	0	0	0	810	318
2021	5,894	186	186	0	0	0	0	0	0	0	821	373
2022	6,189	186	186	0	0	0	0	0	0	0	830	429
2023	6,388	186	186	0	0	0	0	0	0	0	832	479
2024	6,589	186	186	0	0	0	0	0	0	0	841	512
2025	6,790	186	186	0	0	0	0	0	0	0	848	546
2026	6,991	186	186	0	0	0	0	0	0	0	858	578
2027	7,192	186	186	0	0	0	0	0	0	0	868	611
2028	7,387	186	186	0	0	0	0	0	0	0	879	643
2029	7,583	186	186	0	0	0	0	0	0	0	887	673
2030	7,780	186	186	0	0	0	0	0	0	0	898	704
2031	7,976	186	186	0	0	0	0	0	0	0	909	733
2032	8.169	186	186	0	0	0	0	0	0	0	922	763
2033	8,271	186	186	0	0	0	0	0	0	0	922	792
2034	8,373	186	186	0	0	0	0	0	0	0	928	807
2035	8,474	186	186	0	0	0	0	0	0	0	934	822
2036	8,576	186	186	0	0	0	0	0	0	0	942	838
2037	8,677	186	186	0	0	0	0	0	0	0	946	853
2038	8,774	186	186	0	0	0	0	0	0	0	951	868
2039	8,872	186	186	0	0	0	0	0	0	0	957	883
2040	8,969	186	186	0	0	0	0	0	0	0	965	897
2041	9,065	186	186	0	0	0	0	0	0	0	968	912
2042	9,161	186	186	0	0	0	0	0	0	0	974	926
2043	9,232	186	186	0	0	0	0	0	0	0	977	941
2044	9,294	186	186	0	0	0	0	0	0	0	982	952
2045	9,356	186	186	0	0	0	0	0	0	0	983	961
2046	9,418	186	186	0	0	0	0	0	0	0	987	970
2047	9,479	186	186	0	0	0	0	0	0	0	991	980
2048	9,541	186	186	0	0	0	0	0	0	0	997	989
2049	9,605	186	186	0	0	0	0	0	0	0	998	998
2050	9,668	186	186	0	0	0	0	0	0	0	1,002	1,008
2051	9,731	186	186	0	0	0	0	0	0	0	929	1,093
2052	9,792	186	186	0	0	0	0	0	0	0	916	1,122
2053	9,856	186	186	0	0	0	0	0	0	0	917	1,132
2054	9,921	186	186	0	0	0	0	0	0	0	921	1,141
2055	9,985	186	186	0	0	0	0	0	0	0	924	1,151
2056	10,049	186	186	0	0	0	0	0	0	0	931	1,161
2057	10,111	186	186	0	0	0	0	0	0	0	932	1,170
2058	10,173	186	186	0	0	0	0	0	0	0	935	1,180
2059	10,233	186	186	0	0	0	0	0	0	0	939	1,189
2060	10,293	186	186	0	0	0	0	0	0	0	945	1,198

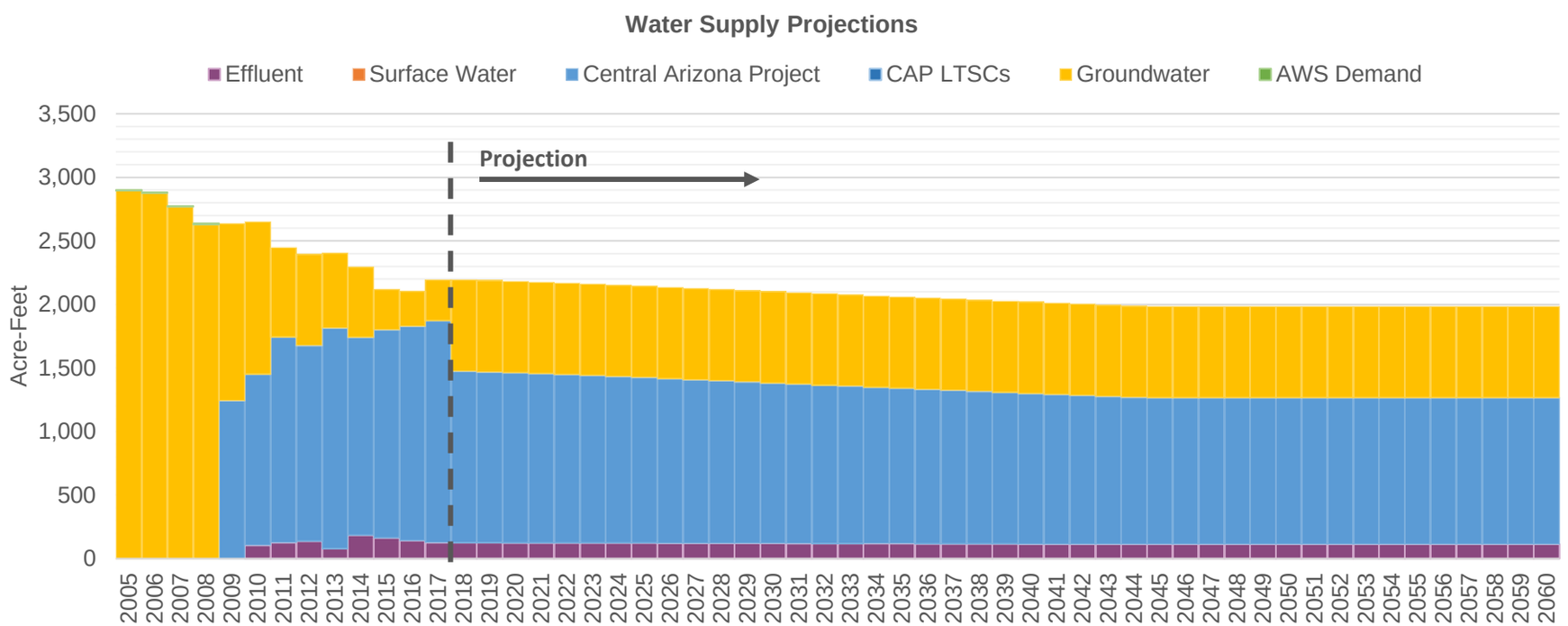
Central Arizona Project Service Area Model

FWID

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

FWID

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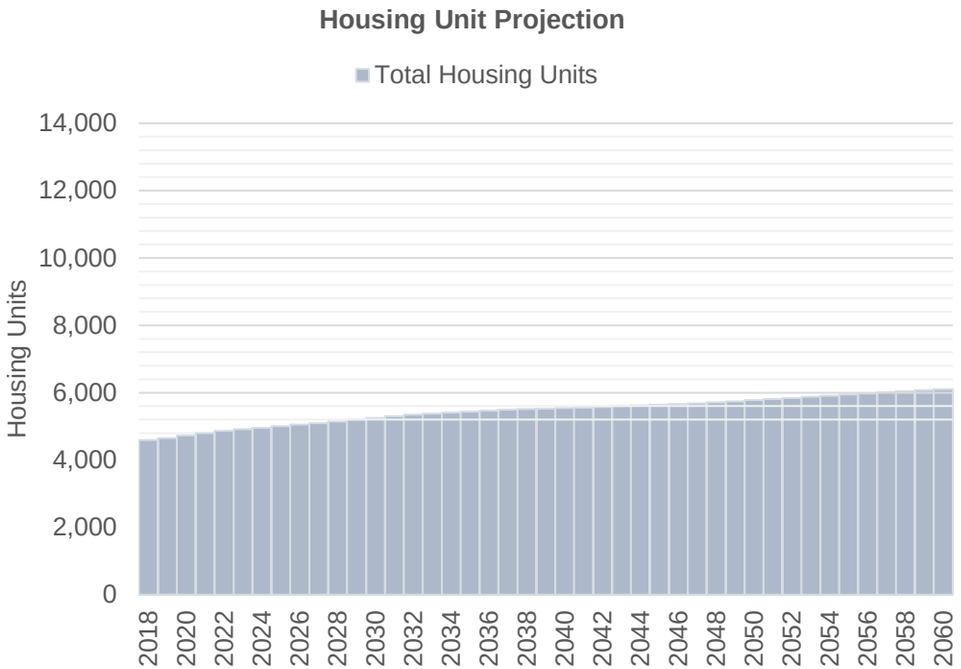
7/14/20 9:06 AM

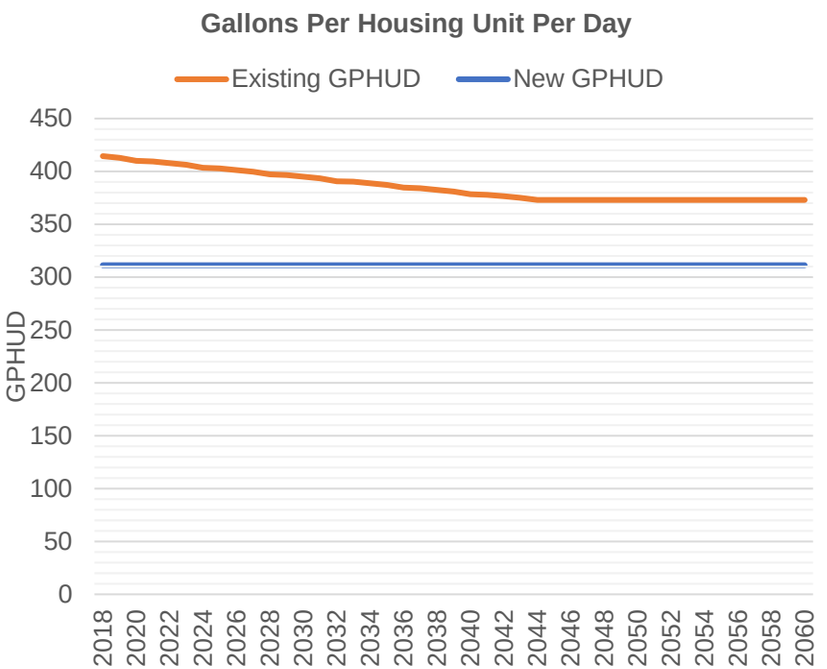
Date	Demand Assumptions: Housing Units	GPHUD		Effluent	Water Supply Projections (Acre-Feet): Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	7,542	260	208	125	0	0	0	1,350	1,523	0	719	0
2019	7,552	259	208	125	0	0	0	1,343	1,530	0	719	0
2020	7,563	257	208	125	0	0	0	1,338	1,535	0	719	0
2021	7,574	257	208	124	0	0	0	1,332	1,541	0	719	0
2022	7,581	256	208	124	0	0	0	1,325	1,548	0	719	0
2023	7,581	255	208	124	0	0	0	1,318	1,555	0	719	0
2024	7,581	253	208	123	0	0	0	1,310	1,563	0	719	0
2025	7,581	253	208	123	0	0	0	1,302	1,571	0	719	0
2026	7,581	252	208	122	0	0	0	1,294	1,579	0	719	0
2027	7,581	251	208	122	0	0	0	1,286	1,587	0	719	0
2028	7,581	249	208	121	0	0	0	1,278	1,595	0	719	0
2029	7,581	249	208	121	0	0	0	1,270	1,603	0	719	0
2030	7,581	248	208	120	0	0	0	1,262	1,611	0	719	0
2031	7,581	247	208	120	0	0	0	1,254	1,619	0	719	0
2032	7,581	245	208	119	0	0	0	1,246	1,627	0	719	0
2033	7,581	245	208	119	0	0	0	1,238	1,635	0	719	0
2034	7,581	244	208	118	0	0	0	1,231	1,642	0	719	0
2035	7,581	243	208	118	0	0	0	1,223	1,650	0	719	0
2036	7,581	241	208	117	0	0	0	1,215	1,658	0	719	0
2037	7,581	241	208	117	0	0	0	1,207	1,666	0	719	0
2038	7,581	240	208	116	0	0	0	1,200	1,477	0	719	0
2039	7,581	239	208	116	0	0	0	1,192	1,031	0	719	0
2040	7,581	237	208	115	0	0	0	1,185	1,443	0	719	0
2041	7,581	237	208	115	0	0	0	1,177	1,651	0	719	0
2042	7,581	236	208	115	0	0	0	1,169	1,633	0	719	0
2043	7,581	235	208	114	0	0	0	1,162	1,711	0	719	0
2044	7,581	234	208	114	0	0	0	1,154	1,719	0	719	0
2045	7,581	234	208	113	0	0	0	1,153	1,720	0	719	0
2046	7,581	234	208	113	0	0	0	1,153	1,627	0	719	0
2047	7,581	234	208	113	0	0	0	1,153	1,720	0	719	0
2048	7,581	234	208	113	0	0	0	1,153	1,627	0	719	0
2049	7,581	234	208	113	0	0	0	1,153	1,627	0	719	0
2050	7,581	234	208	113	0	0	0	1,153	1,627	0	719	0
2051	7,581	234	208	113	0	0	0	1,153	1,627	0	719	0
2052	7,581	234	208	113	0	0	0	1,153	1,428	0	719	0
2053	7,581	234	208	113	0	0	0	1,153	1,428	0	719	0
2054	7,581	234	208	113	0	0	0	1,153	1,104	0	719	0
2055	7,581	234	208	113	0	0	0	1,153	855	0	719	0
2056	7,581	234	208	113	0	0	0	1,153	481	0	719	0
2057	7,581	234	208	113	0	0	0	1,153	1,104	0	719	0
2058	7,581	234	208	113	0	0	0	1,153	1,229	0	719	0
2059	7,581	234	208	113	0	0	0	1,153	1,179	0	719	0
2060	7,581	234	208	113	0	0	0	1,153	1,179	0	719	0

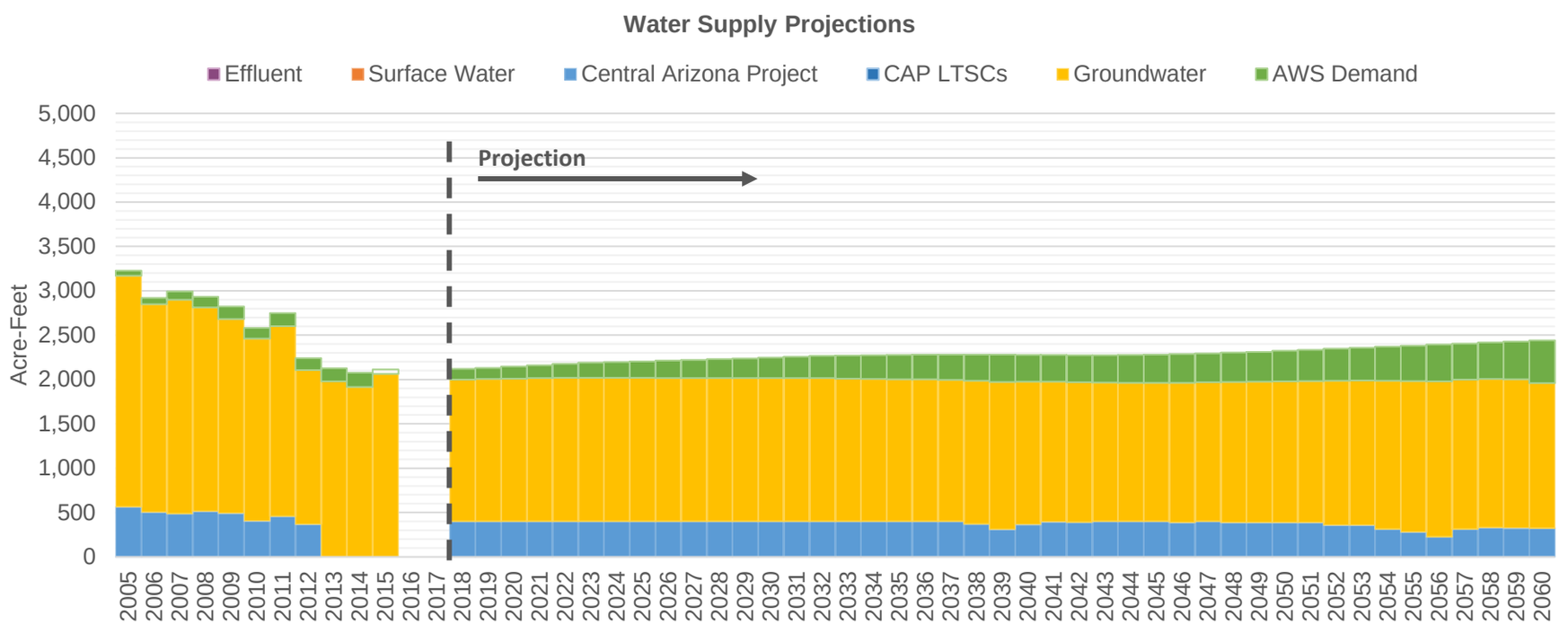
Central Arizona Project Service Area Model

GVDWID

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

GVDWID

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

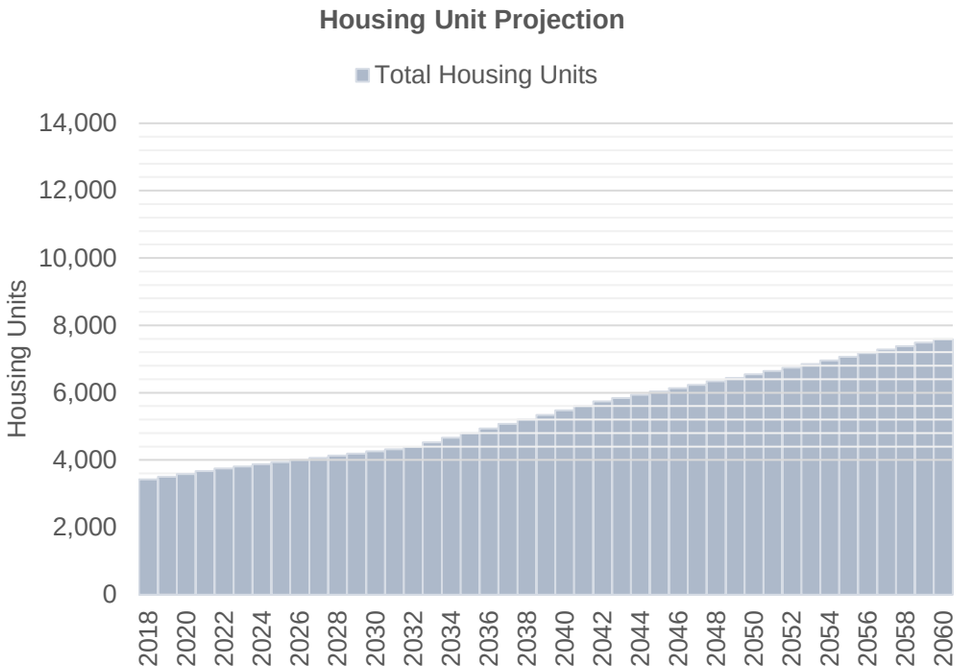
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

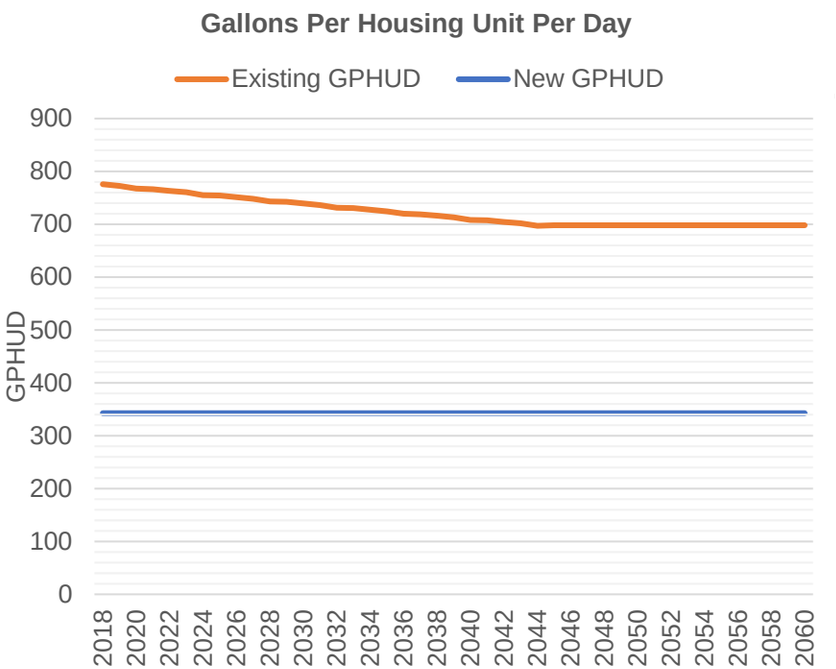
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,590	414	311	0	0	0	399	0	0	0	1,602	119
2019	4,656	413	311	0	0	0	399	0	0	0	1,606	125
2020	4,726	410	311	0	0	0	399	0	0	0	1,611	135
2021	4,800	410	311	0	0	0	399	0	0	0	1,616	146
2022	4,867	408	311	0	0	0	399	0	0	0	1,620	159
2023	4,913	406	311	0	0	0	399	0	0	0	1,620	170
2024	4,959	404	311	0	0	0	399	0	0	0	1,620	178
2025	5,005	403	311	0	0	0	399	0	0	0	1,620	186
2026	5,051	401	311	0	0	0	399	0	0	0	1,619	195
2027	5,098	400	311	0	0	0	399	0	0	0	1,618	203
2028	5,147	397	311	0	0	0	399	0	0	0	1,619	212
2029	5,197	397	311	0	0	0	399	0	0	0	1,618	222
2030	5,246	395	311	0	0	0	399	0	0	0	1,617	231
2031	5,296	393	311	0	0	0	399	0	0	0	1,617	241
2032	5.345	391	311	0	0	0	399	0	0	0	1.617	251
2033	5,375	390	311	0	0	0	399	0	0	0	1,612	261
2034	5,405	389	311	0	0	0	399	0	0	0	1,609	267
2035	5,435	387	311	0	0	0	399	0	0	0	1,605	273
2036	5,464	385	311	0	0	0	399	0	0	0	1,602	279
2037	5,494	384	311	0	0	0	399	0	0	0	1,598	284
2038	5,511	383	311	0	0	0	372	0	0	0	1,616	295
2039	5,527	381	311	0	0	0	309	0	0	0	1,663	308
2040	5,543	378	311	0	0	0	365	0	0	0	1,611	302
2041	5,559	378	311	0	0	0	393	0	0	0	1,582	301
2042	5,575	376	311	0	0	0	389	0	0	0	1,580	305
2043	5,604	375	311	0	0	0	399	0	0	0	1,568	306
2044	5,625	373	311	0	0	0	399	0	0	0	1,565	312
2045	5,645	373	311	0	0	0	399	0	0	0	1,564	316
2046	5,665	373	311	0	0	0	386	0	0	0	1,578	323
2047	5,685	373	311	0	0	0	399	0	0	0	1,570	325
2048	5,712	373	311	0	0	0	386	0	0	0	1,586	331
2049	5,745	373	311	0	0	0	386	0	0	0	1,589	337
2050	5,777	373	311	0	0	0	386	0	0	0	1,594	344
2051	5,810	373	311	0	0	0	386	0	0	0	1,598	350
2052	5,841	373	311	0	0	0	358	0	0	0	1,626	362
2053	5,875	373	311	0	0	0	358	0	0	0	1,630	369
2054	5,910	373	311	0	0	0	313	0	0	0	1,671	385
2055	5,944	373	311	0	0	0	279	0	0	0	1,704	399
2056	5,978	373	311	0	0	0	227	0	0	0	1,751	416
2057	6,012	373	311	0	0	0	313	0	0	0	1,685	407
2058	6,045	373	311	0	0	0	331	0	0	0	1,675	411
2059	6,077	373	311	0	0	0	324	0	0	0	1,680	425
2060	6,109	373	311	0	0	0	324	0	0	0	1,636	481

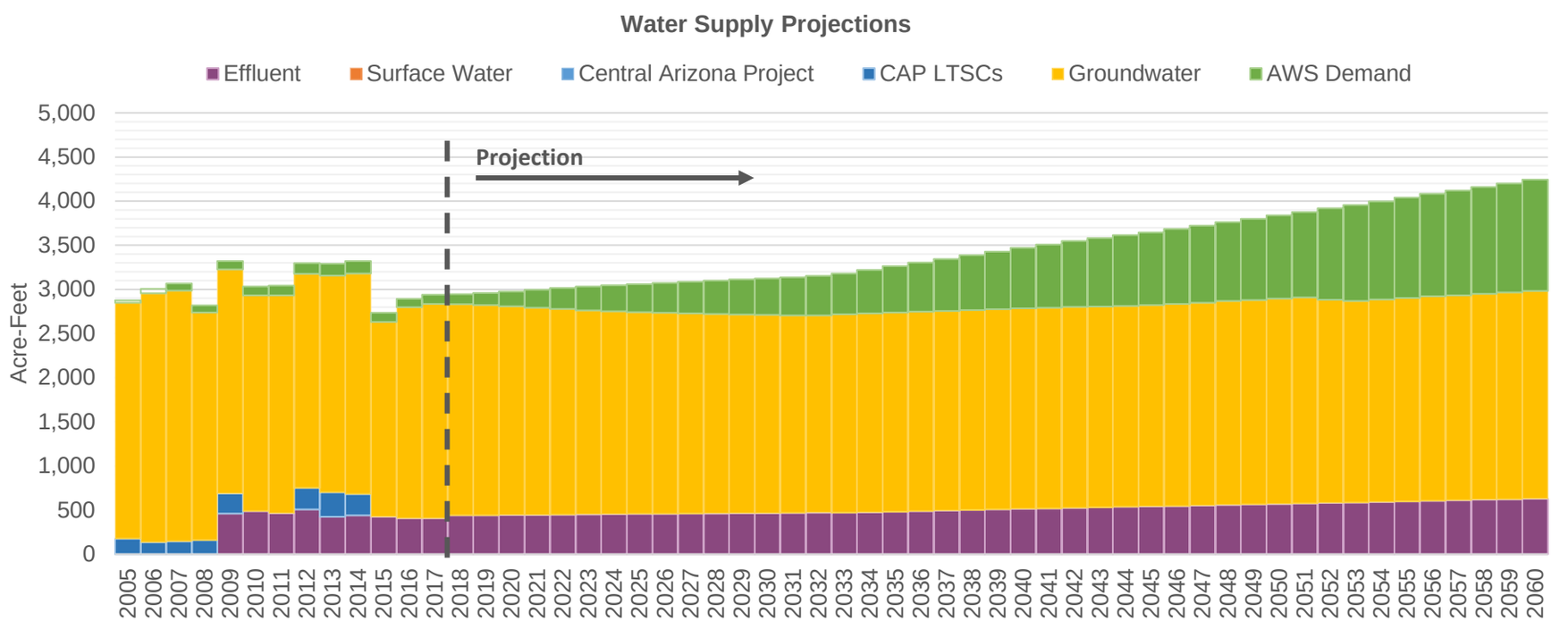
LagoDelOro

Central Arizona Project Service Area Model

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

LagoDelOro

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions

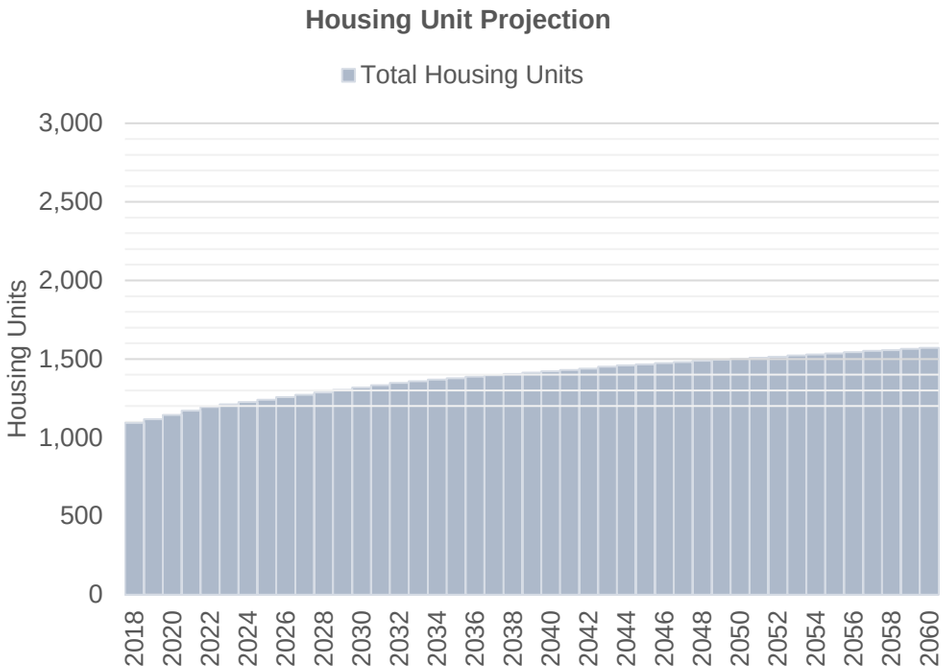
Water Supply Projections (Acre-Feet)

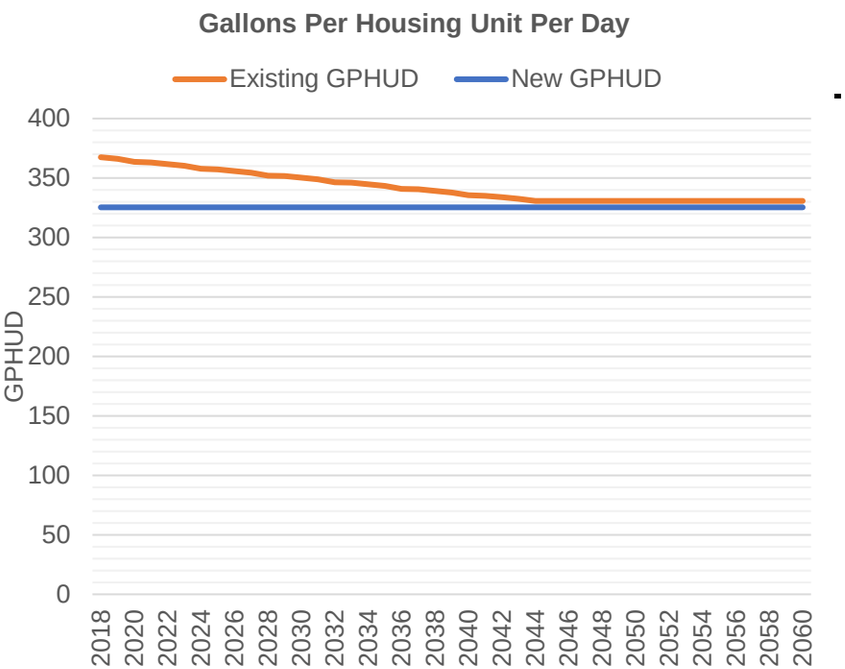
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,423	776	343	441	0	0	0	0	0	0	2,391	116
2019	3,499	773	343	441	0	0	0	0	0	0	2,382	135
2020	3,581	768	343	443	0	0	0	0	0	0	2,365	169
2021	3,668	767	343	445	0	0	0	0	0	0	2,346	206
2022	3,748	763	343	448	0	0	0	0	0	0	2,330	240
2023	3,811	760	343	452	0	0	0	0	0	0	2,311	271
2024	3,875	755	343	454	0	0	0	0	0	0	2,299	294
2025	3,939	754	343	456	0	0	0	0	0	0	2,286	318
2026	4,002	751	343	458	0	0	0	0	0	0	2,276	338
2027	4,066	748	343	460	0	0	0	0	0	0	2,268	358
2028	4,130	743	343	462	0	0	0	0	0	0	2,261	377
2029	4,193	742	343	464	0	0	0	0	0	0	2,253	396
2030	4,257	739	343	466	0	0	0	0	0	0	2,246	413
2031	4,320	736	343	468	0	0	0	0	0	0	2,239	431
2032	4.387	731	343	470	0	0	0	0	0	0	2.237	447
2033	4,524	731	343	472	0	0	0	0	0	0	2,246	462
2034	4,660	728	343	476	0	0	0	0	0	0	2,252	494
2035	4,797	725	343	482	0	0	0	0	0	0	2,256	524
2036	4,933	720	343	488	0	0	0	0	0	0	2,261	556
2037	5,069	719	343	495	0	0	0	0	0	0	2,262	588
2038	5,204	716	343	501	0	0	0	0	0	0	2,266	620
2039	5,338	713	343	507	0	0	0	0	0	0	2,268	652
2040	5,472	708	343	513	0	0	0	0	0	0	2,273	684
2041	5,605	707	343	519	0	0	0	0	0	0	2,274	715
2042	5,738	705	343	525	0	0	0	0	0	0	2,277	747
2043	5,842	702	343	531	0	0	0	0	0	0	2,275	778
2044	5,941	697	343	536	0	0	0	0	0	0	2,276	802
2045	6,040	698	343	541	0	0	0	0	0	0	2,281	825
2046	6,137	698	343	546	0	0	0	0	0	0	2,290	849
2047	6,234	698	343	551	0	0	0	0	0	0	2,299	872
2048	6,335	698	343	557	0	0	0	0	0	0	2,311	895
2049	6,439	698	343	563	0	0	0	0	0	0	2,318	918
2050	6,542	698	343	568	0	0	0	0	0	0	2,328	943
2051	6,643	698	343	574	0	0	0	0	0	0	2,337	967
2052	6,744	698	343	580	0	0	0	0	0	0	2,304	1,036
2053	6,849	698	343	586	0	0	0	0	0	0	2,284	1,086
2054	6,959	698	343	592	0	0	0	0	0	0	2,295	1,111
2055	7,067	698	343	598	0	0	0	0	0	0	2,305	1,137
2056	7,174	698	343	604	0	0	0	0	0	0	2,318	1,162
2057	7,280	698	343	611	0	0	0	0	0	0	2,323	1,187
2058	7,383	698	343	617	0	0	0	0	0	0	2,333	1,212
2059	7,486	698	343	623	0	0	0	0	0	0	2,342	1,236
2060	7,586	698	343	629	0	0	0	0	0	0	2,355	1,261

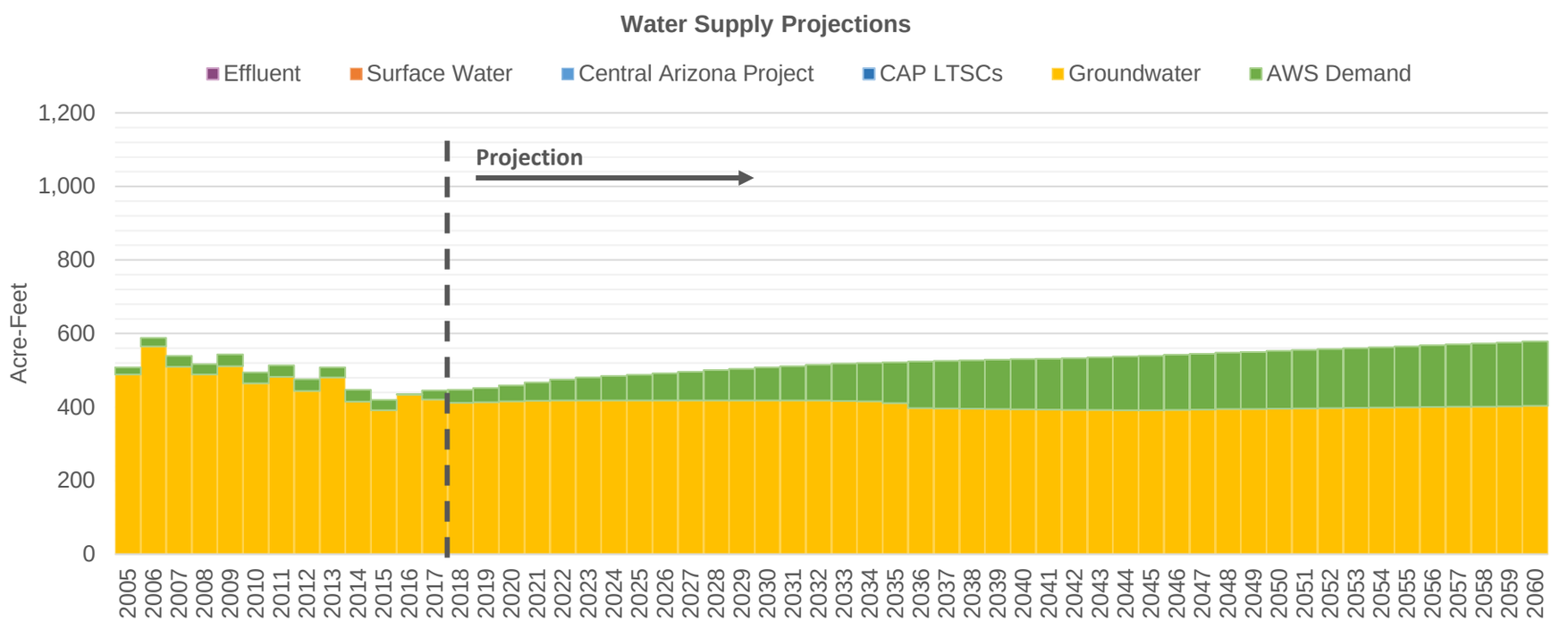
Central Arizona Project Service Area Model

LasQuintas

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

LasQuintas

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions

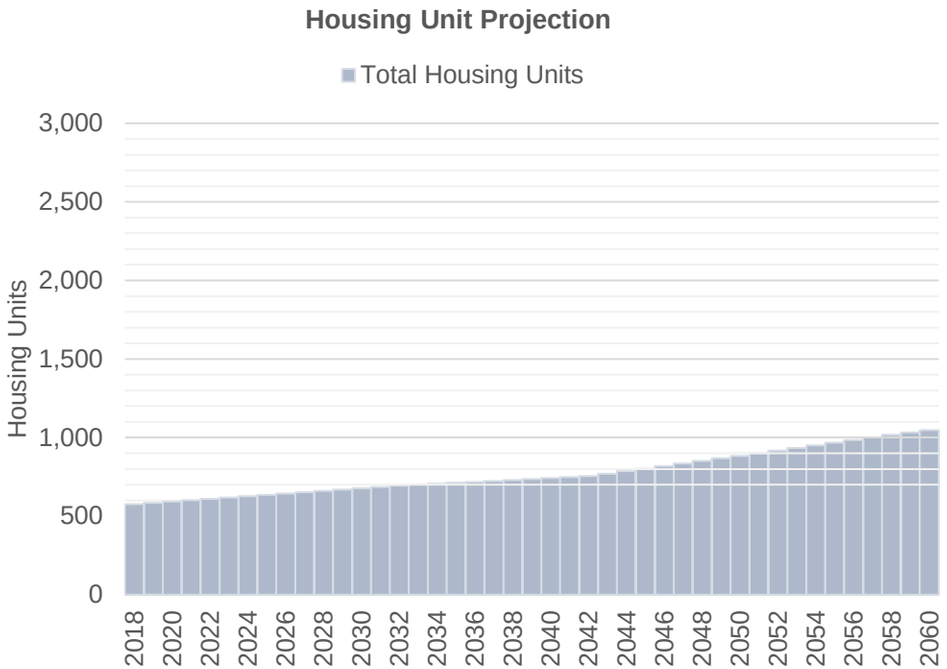
Water Supply Projections (Acre-Feet)

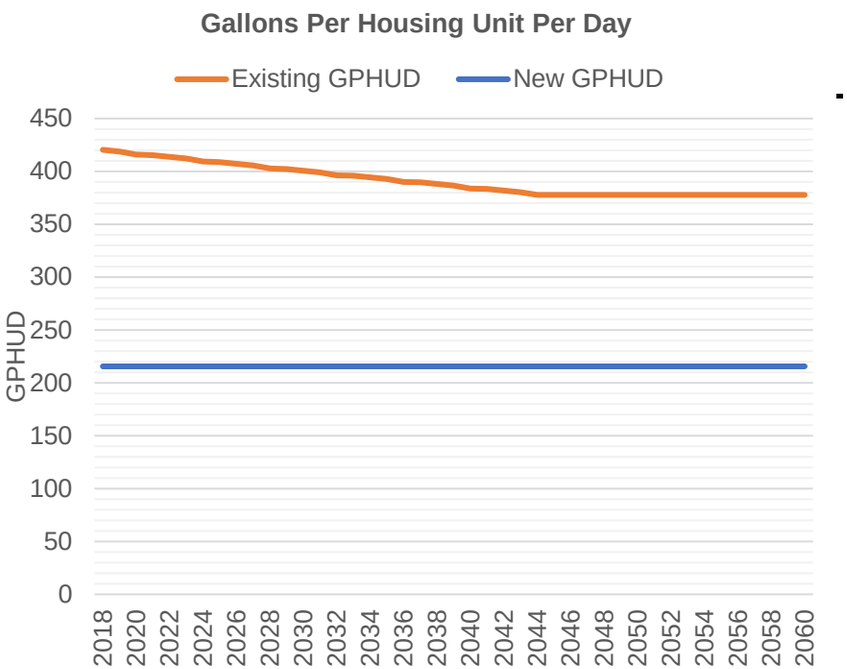
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,093	367	325	0	0	0	0	0	0	0	411	36
2019	1,117	366	325	0	0	0	0	0	0	0	414	38
2020	1,143	364	325	0	0	0	0	0	0	0	415	44
2021	1,171	363	325	0	0	0	0	0	0	0	417	50
2022	1,195	362	325	0	0	0	0	0	0	0	418	57
2023	1,211	360	325	0	0	0	0	0	0	0	418	63
2024	1,226	358	325	0	0	0	0	0	0	0	418	67
2025	1,241	357	325	0	0	0	0	0	0	0	418	70
2026	1,257	356	325	0	0	0	0	0	0	0	418	74
2027	1,273	354	325	0	0	0	0	0	0	0	418	78
2028	1,288	352	325	0	0	0	0	0	0	0	418	82
2029	1,303	352	325	0	0	0	0	0	0	0	418	86
2030	1,318	350	325	0	0	0	0	0	0	0	418	90
2031	1,333	349	325	0	0	0	0	0	0	0	418	94
2032	1.348	346	325	0	0	0	0	0	0	0	418	98
2033	1,358	346	325	0	0	0	0	0	0	0	417	102
2034	1,368	345	325	0	0	0	0	0	0	0	416	104
2035	1,377	343	325	0	0	0	0	0	0	0	411	111
2036	1,387	341	325	0	0	0	0	0	0	0	397	127
2037	1,396	341	325	0	0	0	0	0	0	0	396	129
2038	1,405	339	325	0	0	0	0	0	0	0	396	132
2039	1,413	338	325	0	0	0	0	0	0	0	395	134
2040	1,421	336	325	0	0	0	0	0	0	0	394	136
2041	1,430	335	325	0	0	0	0	0	0	0	393	138
2042	1,438	334	325	0	0	0	0	0	0	0	392	140
2043	1,451	332	325	0	0	0	0	0	0	0	393	142
2044	1,459	331	325	0	0	0	0	0	0	0	392	146
2045	1,466	331	325	0	0	0	0	0	0	0	392	148
2046	1,474	331	325	0	0	0	0	0	0	0	393	150
2047	1,481	331	325	0	0	0	0	0	0	0	393	152
2048	1,488	331	325	0	0	0	0	0	0	0	395	153
2049	1,495	331	325	0	0	0	0	0	0	0	395	155
2050	1,502	331	325	0	0	0	0	0	0	0	396	157
2051	1,508	331	325	0	0	0	0	0	0	0	396	159
2052	1,515	331	325	0	0	0	0	0	0	0	397	160
2053	1,522	331	325	0	0	0	0	0	0	0	398	162
2054	1,529	331	325	0	0	0	0	0	0	0	399	164
2055	1,536	331	325	0	0	0	0	0	0	0	399	166
2056	1,544	331	325	0	0	0	0	0	0	0	401	168
2057	1,551	331	325	0	0	0	0	0	0	0	401	170
2058	1,557	331	325	0	0	0	0	0	0	0	402	171
2059	1,564	331	325	0	0	0	0	0	0	0	402	173
2060	1,571	331	325	0	0	0	0	0	0	0	404	175

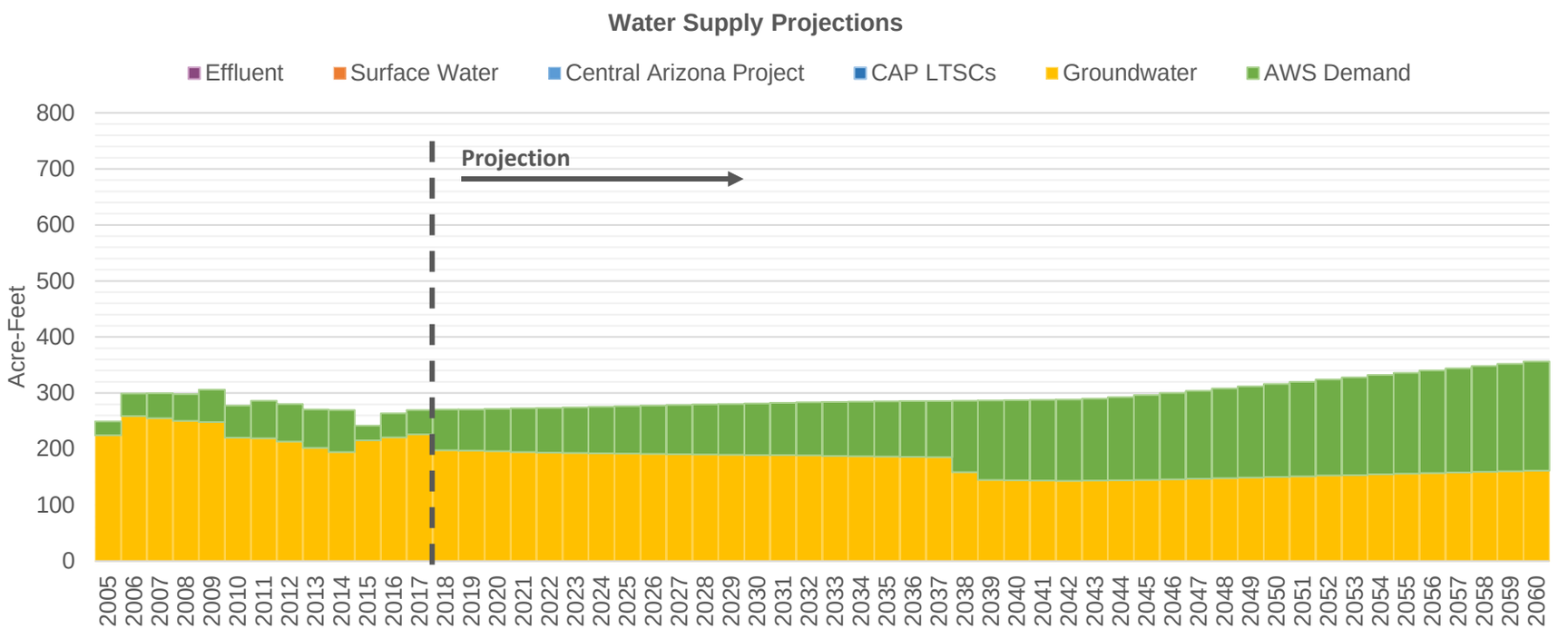
Central Arizona Project Service Area Model

LosCerros

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

LosCerros

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Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	577	420	216	0	0	0	0	0	0	0	198	73
2019	585	419	216	0	0	0	0	0	0	0	197	74
2020	593	416	216	0	0	0	0	0	0	0	196	76
2021	602	415	216	0	0	0	0	0	0	0	195	78
2022	610	414	216	0	0	0	0	0	0	0	194	80
2023	619	412	216	0	0	0	0	0	0	0	193	82
2024	627	409	216	0	0	0	0	0	0	0	192	83
2025	635	409	216	0	0	0	0	0	0	0	192	85
2026	644	407	216	0	0	0	0	0	0	0	191	86
2027	652	406	216	0	0	0	0	0	0	0	191	88
2028	661	403	216	0	0	0	0	0	0	0	191	89
2029	669	402	216	0	0	0	0	0	0	0	190	91
2030	677	401	216	0	0	0	0	0	0	0	189	92
2031	686	399	216	0	0	0	0	0	0	0	189	93
2032	694	396	216	0	0	0	0	0	0	0	189	95
2033	700	396	216	0	0	0	0	0	0	0	188	96
2034	706	394	216	0	0	0	0	0	0	0	187	97
2035	712	393	216	0	0	0	0	0	0	0	187	98
2036	718	390	216	0	0	0	0	0	0	0	186	99
2037	724	390	216	0	0	0	0	0	0	0	185	100
2038	730	388	216	0	0	0	0	0	0	0	159	128
2039	736	387	216	0	0	0	0	0	0	0	145	142
2040	742	384	216	0	0	0	0	0	0	0	145	143
2041	748	383	216	0	0	0	0	0	0	0	144	144
2042	754	382	216	0	0	0	0	0	0	0	143	145
2043	769	380	216	0	0	0	0	0	0	0	144	146
2044	786	378	216	0	0	0	0	0	0	0	144	149
2045	802	378	216	0	0	0	0	0	0	0	145	151
2046	818	378	216	0	0	0	0	0	0	0	146	154
2047	834	378	216	0	0	0	0	0	0	0	147	157
2048	851	378	216	0	0	0	0	0	0	0	148	160
2049	868	378	216	0	0	0	0	0	0	0	149	163
2050	884	378	216	0	0	0	0	0	0	0	150	166
2051	901	378	216	0	0	0	0	0	0	0	152	169
2052	917	378	216	0	0	0	0	0	0	0	153	172
2053	933	378	216	0	0	0	0	0	0	0	154	174
2054	951	378	216	0	0	0	0	0	0	0	155	177
2055	967	378	216	0	0	0	0	0	0	0	156	180
2056	984	378	216	0	0	0	0	0	0	0	157	183
2057	1,000	378	216	0	0	0	0	0	0	0	158	186
2058	1,017	378	216	0	0	0	0	0	0	0	159	189
2059	1,033	378	216	0	0	0	0	0	0	0	160	192
2060	1,048	378	216	0	0	0	0	0	0	0	162	194

Central Arizona Project Service Area Model

Marana

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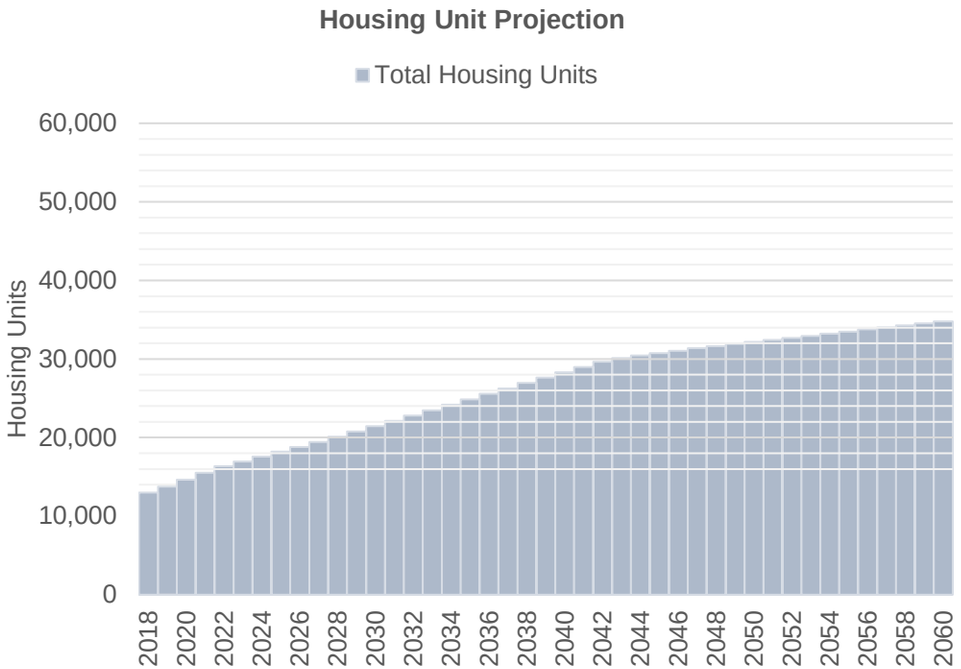

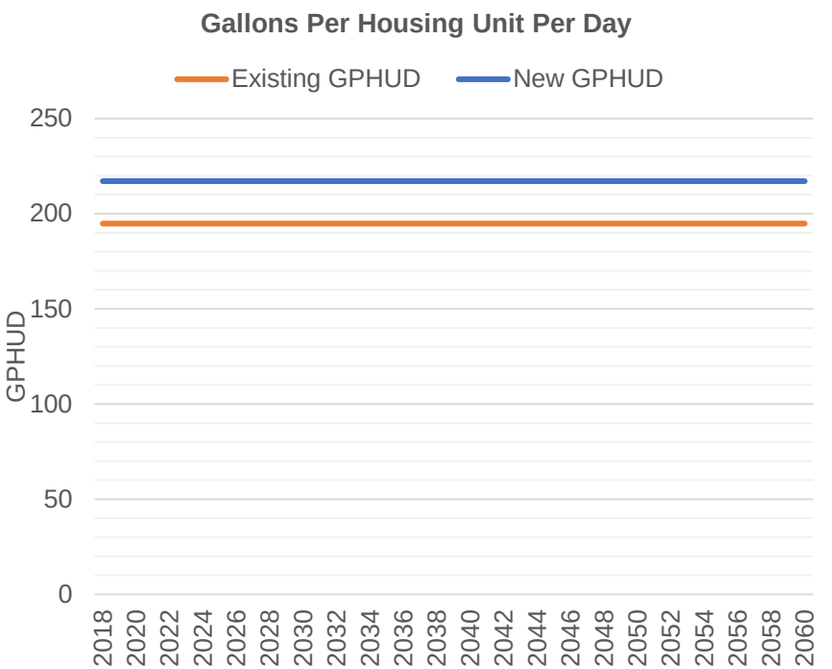

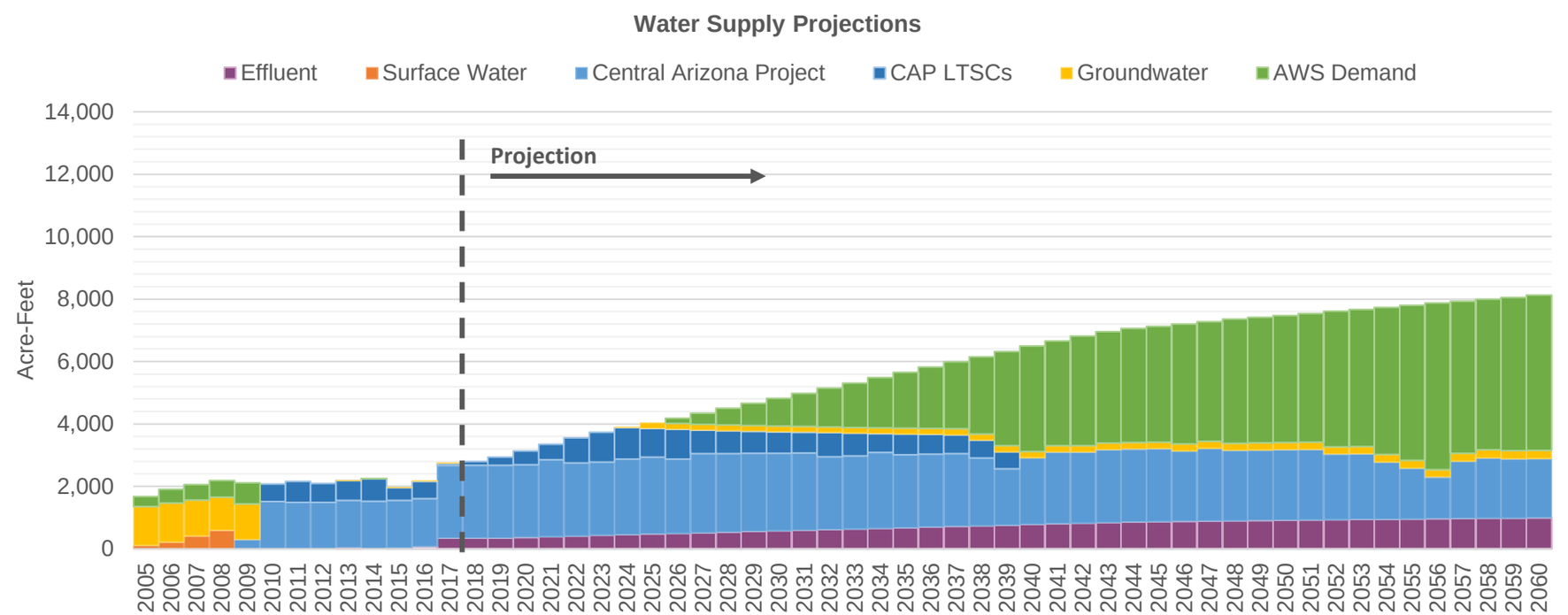

Central Arizona Project Service Area Model

Marana

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Demand Assumptions

Water Supply Projections (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	12,985	195	217	345	0	0	0	2,336	0	115	0	0
2019	13,761	195	217	345	0	0	0	2,336	0	257	0	0
2020	14,619	195	217	362	0	0	0	2,336	0	439	0	0
2021	15,522	195	217	387	0	0	0	2,463	0	500	0	0
2022	16,350	195	217	413	0	0	0	2,339	0	809	0	0
2023	16,964	195	217	439	0	0	0	2,336	0	961	0	0
2024	17,582	195	217	461	0	0	0	2,408	0	1,019	1	0
2025	18,201	195	217	480	0	0	0	2,456	0	920	181	0
2026	18,822	195	217	498	0	0	0	2,376	0	954	188	172
2027	19,451	195	217	516	0	0	0	2,536	0	746	186	354
2028	20,117	195	217	535	0	0	0	2,520	0	725	185	536
2029	20,785	195	217	555	0	0	0	2,505	0	704	185	710
2030	21,454	195	217	574	0	0	0	2,489	0	684	185	889
2031	22,123	195	217	594	0	0	0	2,474	0	665	185	1,066
2032	22,793	195	217	615	0	0	0	2,336	0	770	185	1,248
2033	23,489	195	217	635	0	0	0	2,342	0	726	186	1,425
2034	24,183	195	217	655	0	0	0	2,431	0	600	187	1,609
2035	24,877	195	217	676	0	0	0	2,336	0	665	188	1,785
2036	25,569	195	217	697	0	0	0	2,336	0	632	190	1,973
2037	26,260	195	217	719	0	0	0	2,336	0	601	191	2,141
2038	26,948	195	217	738	0	0	0	2,177	0	570	194	2,477
2039	27,634	195	217	759	0	0	0	1,808	0	539	196	3,021
2040	28,317	195	217	780	0	0	0	2,137	0	0	198	3,384
2041	28,996	195	217	801	0	0	0	2,300	0	0	201	3,353
2042	29,672	195	217	821	0	0	0	2,279	0	0	204	3,516
2043	30,123	195	217	841	0	0	0	2,336	0	0	207	3,572
2044	30,435	195	217	858	0	0	0	2,336	0	0	210	3,657
2045	30,746	195	217	871	0	0	0	2,336	0	0	214	3,704
2046	31,053	195	217	879	0	0	0	2,261	0	0	217	3,844
2047	31,359	195	217	888	0	0	0	2,336	0	0	221	3,830
2048	31,641	195	217	897	0	0	0	2,261	0	0	224	3,977
2049	31,906	195	217	907	0	0	0	2,261	0	0	227	4,018
2050	32,168	195	217	914	0	0	0	2,261	0	0	231	4,071
2051	32,427	195	217	922	0	0	0	2,261	0	0	234	4,123
2052	32,683	195	217	930	0	0	0	2,098	0	0	237	4,350
2053	32,949	195	217	939	0	0	0	2,098	0	0	240	4,388
2054	33,224	195	217	945	0	0	0	1,835	0	0	244	4,708
2055	33,496	195	217	953	0	0	0	1,633	0	0	247	4,966
2056	33,765	195	217	962	0	0	0	1,329	0	0	250	5,338
2057	34,029	195	217	971	0	0	0	1,835	0	0	253	4,870
2058	34,290	195	217	978	0	0	0	1,936	0	0	256	4,823
2059	34,546	195	217	986	0	0	0	1,896	0	0	259	4,915
2060	34,798	195	217	993	0	0	0	1,896	0	0	262	4,981

Central Arizona Project Service Area Model

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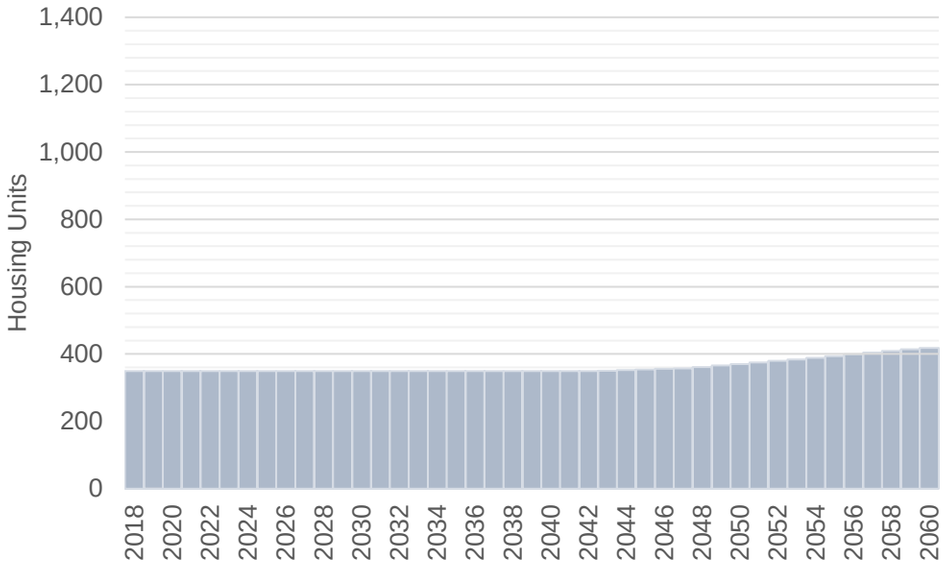
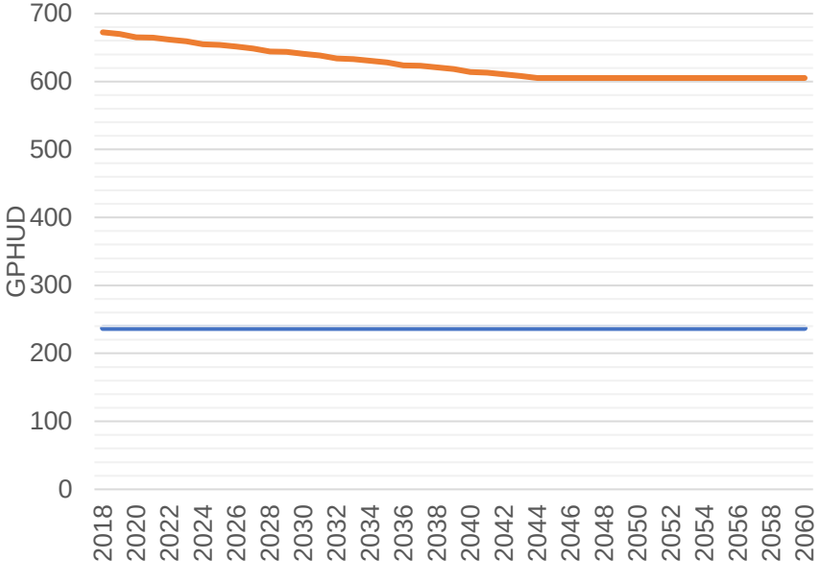
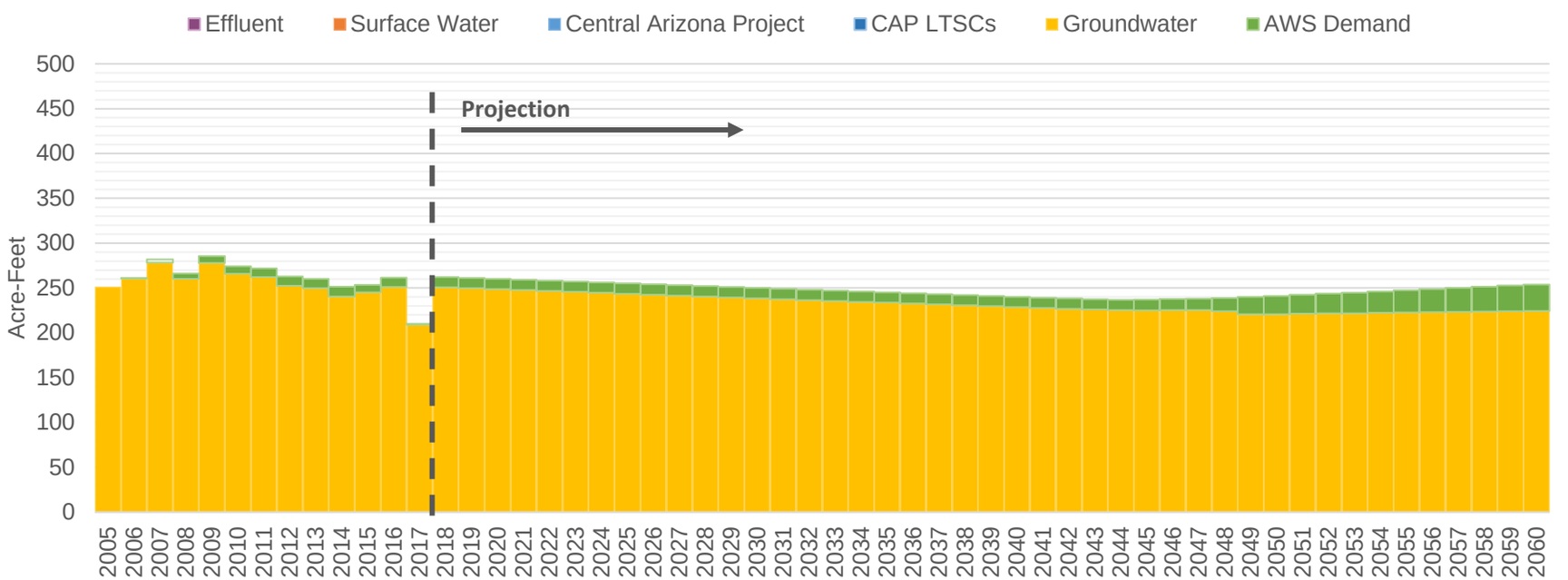
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

MaranaDomesti

E. Official, Very Dry [LSCRBS]

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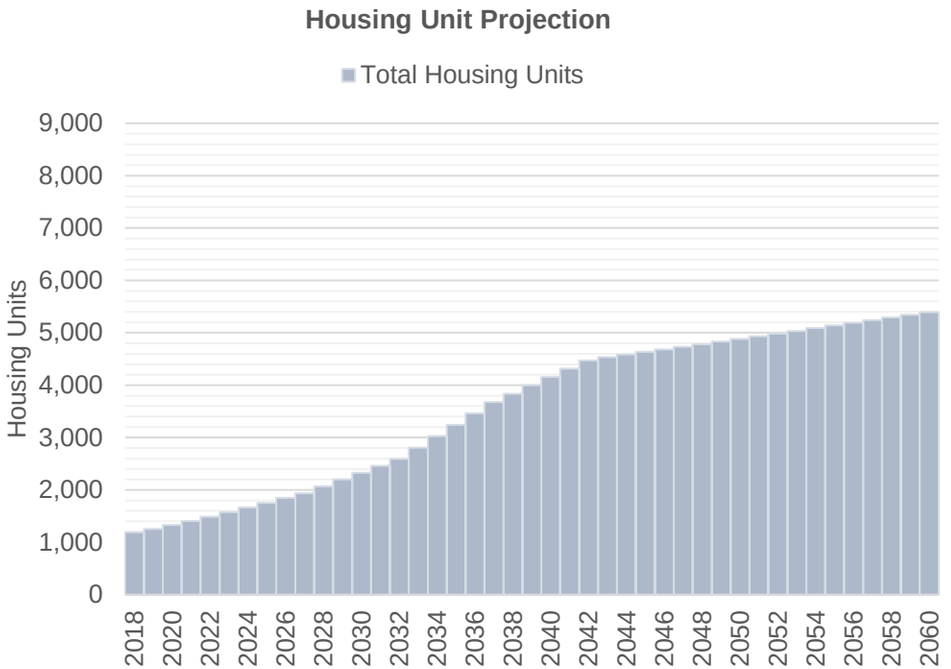
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

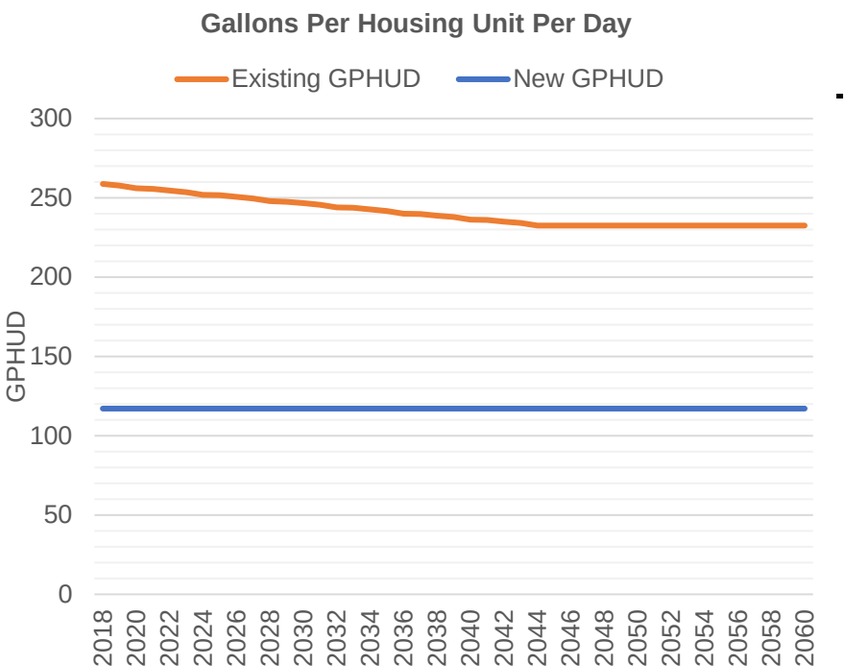
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	349	672	237	0	0	0	0	0	0	0	251	11
2019	349	670	237	0	0	0	0	0	0	0	250	11
2020	349	665	237	0	0	0	0	0	0	0	249	11
2021	349	664	237	0	0	0	0	0	0	0	248	11
2022	349	662	237	0	0	0	0	0	0	0	247	11
2023	349	659	237	0	0	0	0	0	0	0	246	11
2024	349	655	237	0	0	0	0	0	0	0	245	11
2025	349	654	237	0	0	0	0	0	0	0	244	11
2026	349	651	237	0	0	0	0	0	0	0	243	11
2027	349	649	237	0	0	0	0	0	0	0	242	11
2028	349	644	237	0	0	0	0	0	0	0	241	11
2029	349	643	237	0	0	0	0	0	0	0	240	11
2030	349	641	237	0	0	0	0	0	0	0	239	11
2031	349	638	237	0	0	0	0	0	0	0	238	11
2032	349	634	237	0	0	0	0	0	0	0	237	11
2033	349	633	237	0	0	0	0	0	0	0	236	11
2034	349	631	237	0	0	0	0	0	0	0	235	11
2035	349	628	237	0	0	0	0	0	0	0	234	11
2036	349	624	237	0	0	0	0	0	0	0	233	11
2037	349	623	237	0	0	0	0	0	0	0	232	11
2038	349	621	237	0	0	0	0	0	0	0	231	11
2039	349	618	237	0	0	0	0	0	0	0	230	11
2040	349	614	237	0	0	0	0	0	0	0	229	11
2041	349	613	237	0	0	0	0	0	0	0	228	11
2042	349	611	237	0	0	0	0	0	0	0	227	11
2043	350	608	237	0	0	0	0	0	0	0	226	11
2044	352	605	237	0	0	0	0	0	0	0	225	12
2045	354	605	237	0	0	0	0	0	0	0	225	12
2046	356	605	237	0	0	0	0	0	0	0	225	12
2047	357	605	237	0	0	0	0	0	0	0	225	13
2048	361	605	237	0	0	0	0	0	0	0	224	15
2049	366	605	237	0	0	0	0	0	0	0	221	19
2050	370	605	237	0	0	0	0	0	0	0	221	20
2051	375	605	237	0	0	0	0	0	0	0	221	21
2052	380	605	237	0	0	0	0	0	0	0	222	22
2053	384	605	237	0	0	0	0	0	0	0	222	23
2054	389	605	237	0	0	0	0	0	0	0	222	24
2055	394	605	237	0	0	0	0	0	0	0	223	25
2056	399	605	237	0	0	0	0	0	0	0	223	26
2057	404	605	237	0	0	0	0	0	0	0	223	27
2058	409	605	237	0	0	0	0	0	0	0	224	28
2059	414	605	237	0	0	0	0	0	0	0	224	29
2060	418	605	237	0	0	0	0	0	0	0	224	30

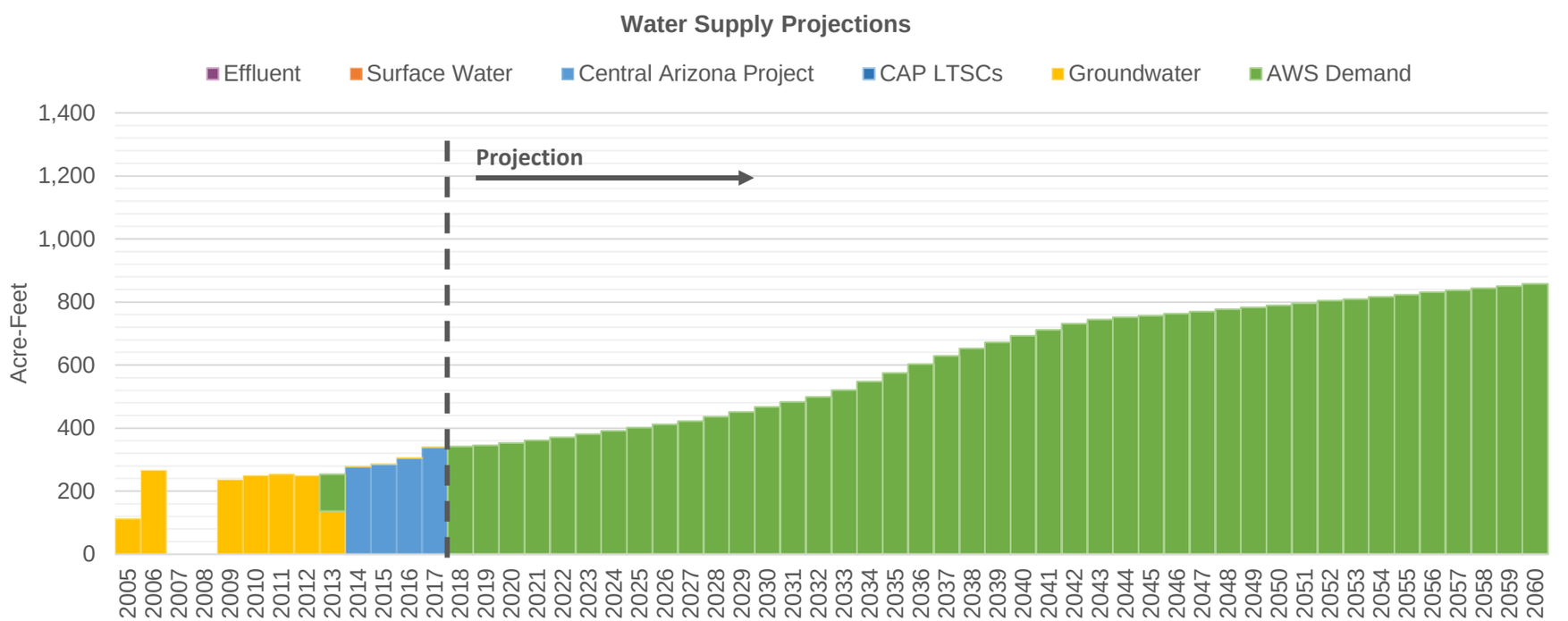
Central Arizona Project Service Area Model

MetroDiablo

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

MetroDiablo

E. Official, Very Dry [LSCRBS]

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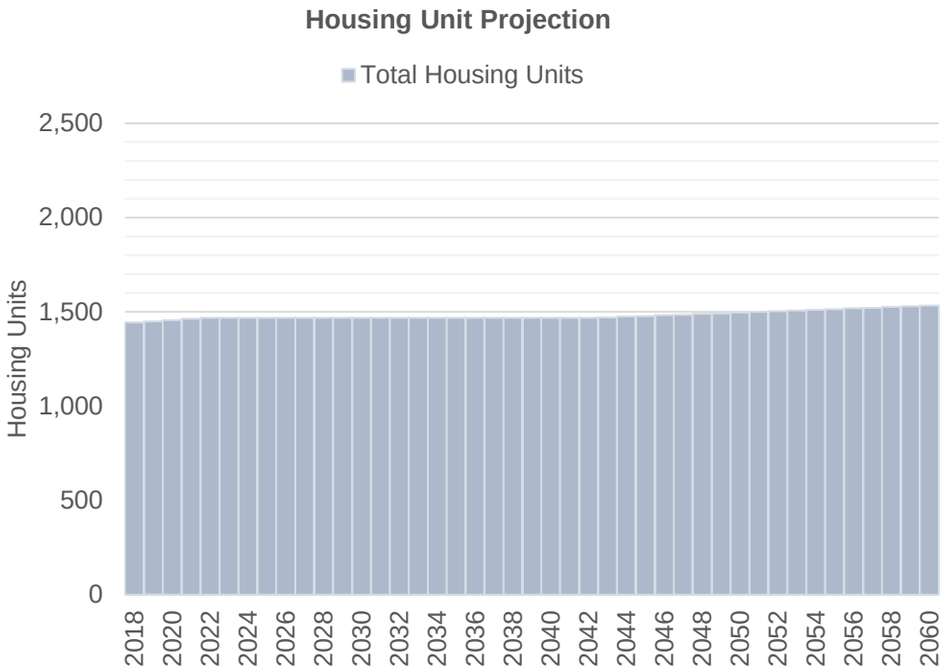
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

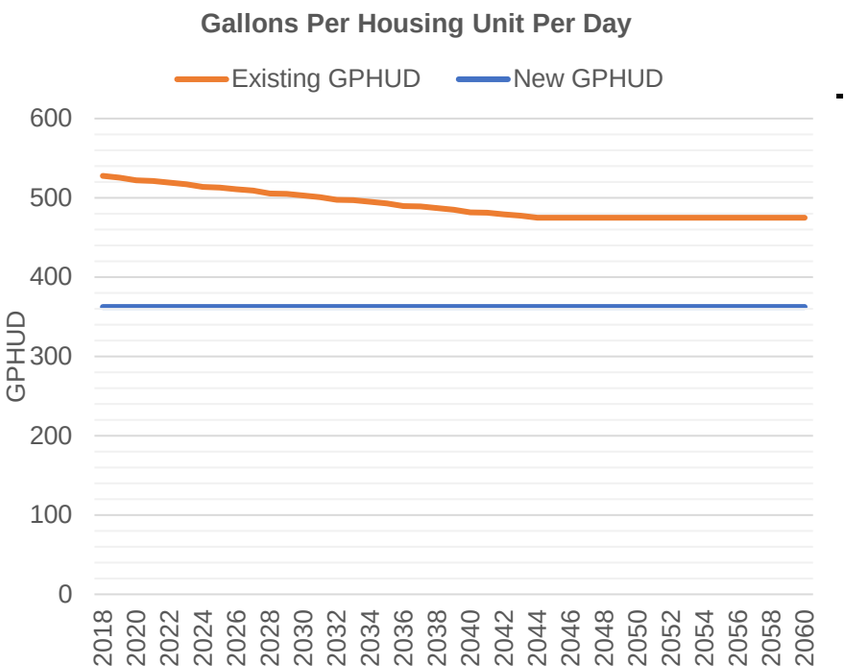
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,192	259	117	0	0	0	0	0	0	0	0	341
2019	1,254	258	117	0	0	0	0	0	0	0	0	345
2020	1,329	256	117	0	0	0	0	0	0	0	0	353
2021	1,409	256	117	0	0	0	0	0	0	0	0	362
2022	1,492	255	117	0	0	0	0	0	0	0	0	371
2023	1,580	254	117	0	0	0	0	0	0	0	0	381
2024	1,668	252	117	0	0	0	0	0	0	0	0	391
2025	1,757	252	117	0	0	0	0	0	0	0	0	401
2026	1,846	251	117	0	0	0	0	0	0	0	0	412
2027	1,940	250	117	0	0	0	0	0	0	0	0	422
2028	2,070	248	117	0	0	0	0	0	0	0	0	436
2029	2,199	248	117	0	0	0	0	0	0	0	0	451
2030	2,328	247	117	0	0	0	0	0	0	0	0	467
2031	2,458	246	117	0	0	0	0	0	0	0	0	483
2032	2.591	244	117	0	0	0	0	0	0	0	0	499
2033	2,809	244	117	0	0	0	0	0	0	0	0	520
2034	3,027	243	117	0	0	0	0	0	0	0	0	548
2035	3,245	242	117	0	0	0	0	0	0	0	0	575
2036	3,462	240	117	0	0	0	0	0	0	0	0	603
2037	3,678	240	117	0	0	0	0	0	0	0	0	630
2038	3,838	239	117	0	0	0	0	0	0	0	0	653
2039	3,997	238	117	0	0	0	0	0	0	0	0	673
2040	4,156	236	117	0	0	0	0	0	0	0	0	693
2041	4,313	236	117	0	0	0	0	0	0	0	0	712
2042	4,470	235	117	0	0	0	0	0	0	0	0	731
2043	4,534	234	117	0	0	0	0	0	0	0	0	744
2044	4,584	233	117	0	0	0	0	0	0	0	0	752
2045	4,634	233	117	0	0	0	0	0	0	0	0	757
2046	4,683	233	117	0	0	0	0	0	0	0	0	763
2047	4,731	233	117	0	0	0	0	0	0	0	0	770
2048	4,782	233	117	0	0	0	0	0	0	0	0	777
2049	4,833	233	117	0	0	0	0	0	0	0	0	783
2050	4,884	233	117	0	0	0	0	0	0	0	0	790
2051	4,934	233	117	0	0	0	0	0	0	0	0	796
2052	4,984	233	117	0	0	0	0	0	0	0	0	804
2053	5,035	233	117	0	0	0	0	0	0	0	0	809
2054	5,089	233	117	0	0	0	0	0	0	0	0	816
2055	5,142	233	117	0	0	0	0	0	0	0	0	823
2056	5,193	233	117	0	0	0	0	0	0	0	0	831
2057	5,245	233	117	0	0	0	0	0	0	0	0	837
2058	5,295	233	117	0	0	0	0	0	0	0	0	843
2059	5,345	233	117	0	0	0	0	0	0	0	0	850
2060	5,394	233	117	0	0	0	0	0	0	0	0	858

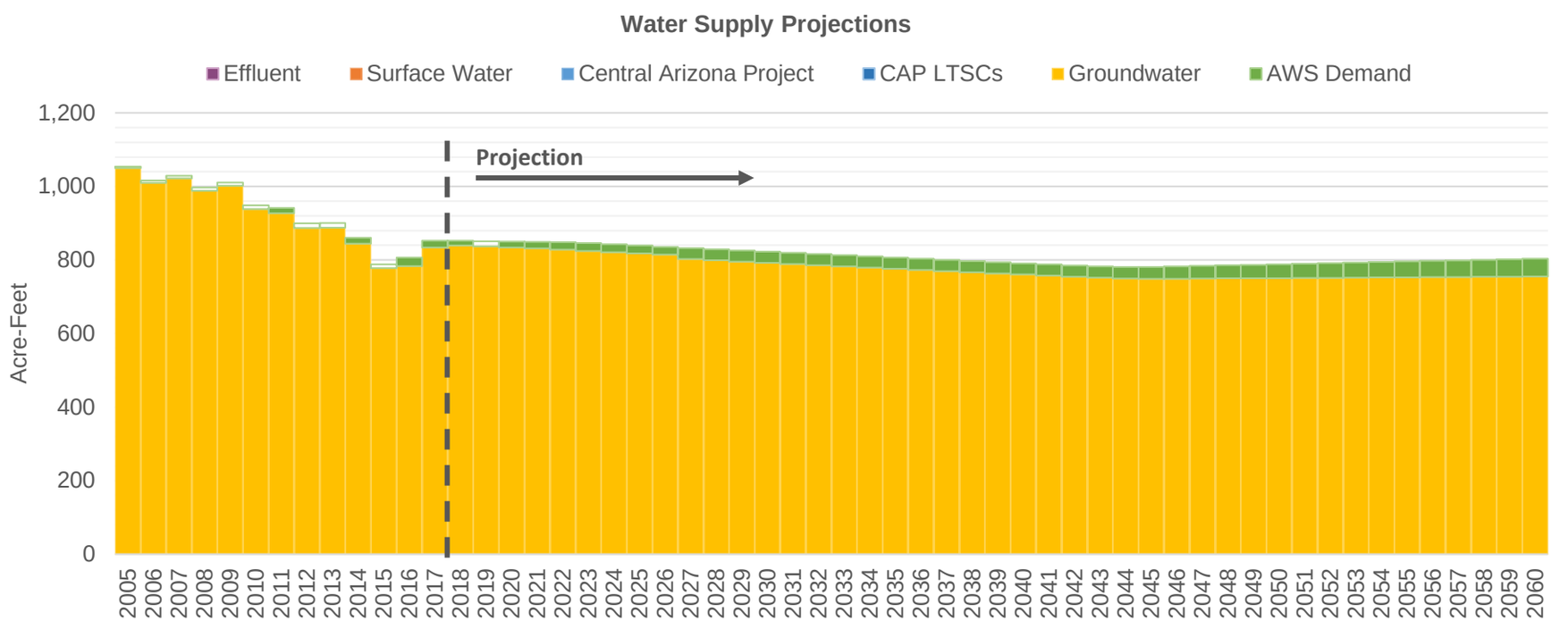
Central Arizona Project Service Area Model

MetroHub

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

MetroHub

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Demand Assumptions

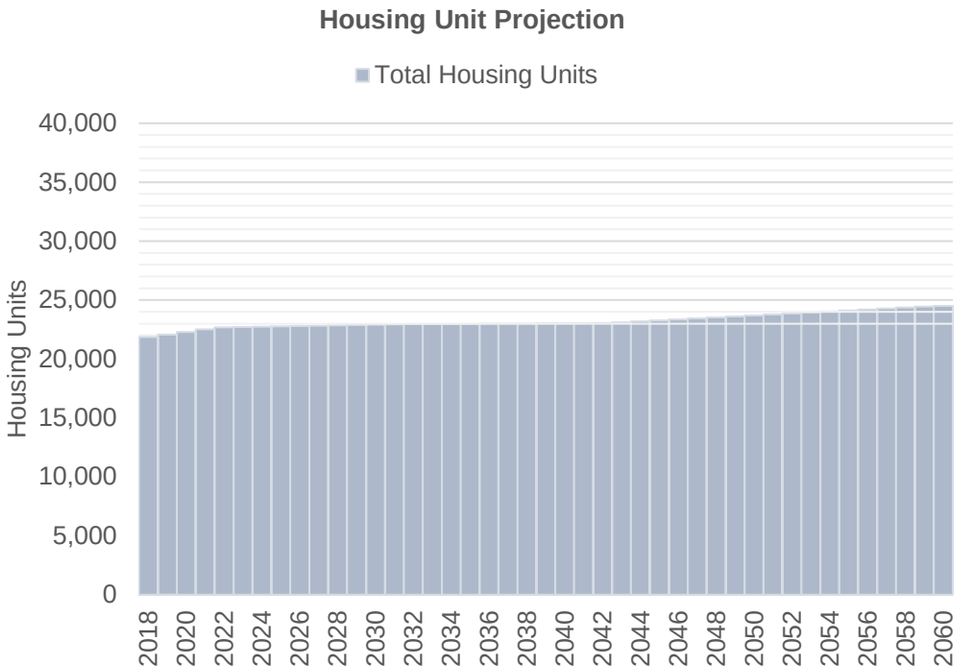
Water Supply Projections (Acre-Feet)

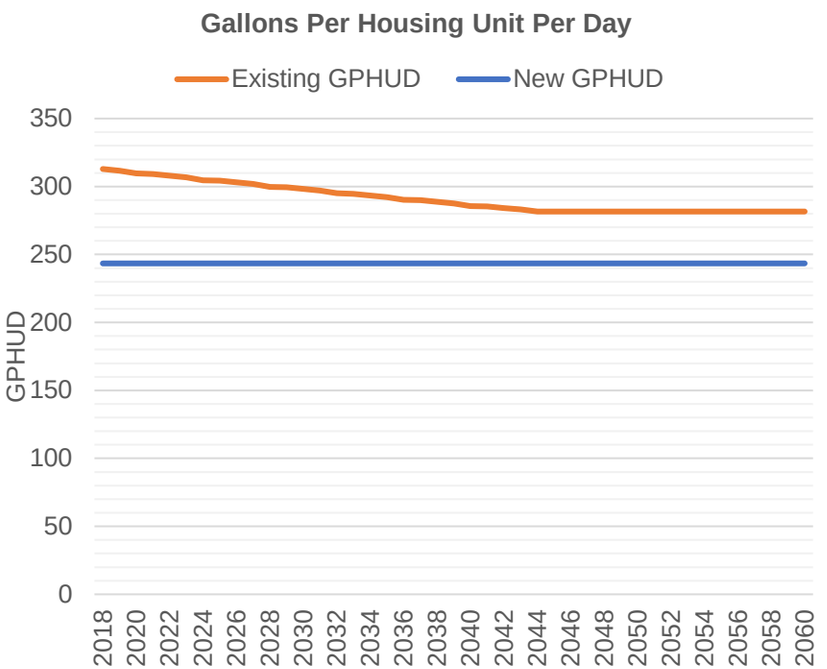
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,444	528	362	0	0	0	0	0	0	0	839	13
2019	1,450	526	362	0	0	0	0	0	0	0	837	14
2020	1,457	522	362	0	0	0	0	0	0	0	834	16
2021	1,463	521	362	0	0	0	0	0	0	0	831	18
2022	1,468	519	362	0	0	0	0	0	0	0	828	20
2023	1,468	517	362	0	0	0	0	0	0	0	825	21
2024	1,468	514	362	0	0	0	0	0	0	0	821	21
2025	1,468	513	362	0	0	0	0	0	0	0	818	21
2026	1,468	511	362	0	0	0	0	0	0	0	815	21
2027	1,468	509	362	0	0	0	0	0	0	0	803	30
2028	1,468	506	362	0	0	0	0	0	0	0	799	30
2029	1,468	505	362	0	0	0	0	0	0	0	796	30
2030	1,468	503	362	0	0	0	0	0	0	0	792	30
2031	1,468	501	362	0	0	0	0	0	0	0	789	30
2032	1,468	498	362	0	0	0	0	0	0	0	786	30
2033	1,468	497	362	0	0	0	0	0	0	0	783	30
2034	1,468	495	362	0	0	0	0	0	0	0	780	30
2035	1,468	493	362	0	0	0	0	0	0	0	776	30
2036	1,468	490	362	0	0	0	0	0	0	0	773	30
2037	1,468	489	362	0	0	0	0	0	0	0	770	30
2038	1,468	487	362	0	0	0	0	0	0	0	767	30
2039	1,468	485	362	0	0	0	0	0	0	0	764	30
2040	1,468	482	362	0	0	0	0	0	0	0	761	30
2041	1,468	481	362	0	0	0	0	0	0	0	757	30
2042	1,468	479	362	0	0	0	0	0	0	0	754	30
2043	1,471	477	362	0	0	0	0	0	0	0	752	30
2044	1,475	475	362	0	0	0	0	0	0	0	749	31
2045	1,478	475	362	0	0	0	0	0	0	0	749	32
2046	1,482	475	362	0	0	0	0	0	0	0	749	33
2047	1,485	475	362	0	0	0	0	0	0	0	749	34
2048	1,489	475	362	0	0	0	0	0	0	0	750	35
2049	1,492	475	362	0	0	0	0	0	0	0	750	36
2050	1,496	475	362	0	0	0	0	0	0	0	751	37
2051	1,500	475	362	0	0	0	0	0	0	0	751	39
2052	1,503	475	362	0	0	0	0	0	0	0	752	40
2053	1,507	475	362	0	0	0	0	0	0	0	752	41
2054	1,511	475	362	0	0	0	0	0	0	0	753	42
2055	1,515	475	362	0	0	0	0	0	0	0	753	43
2056	1,519	475	362	0	0	0	0	0	0	0	754	44
2057	1,522	475	362	0	0	0	0	0	0	0	754	45
2058	1,526	475	362	0	0	0	0	0	0	0	754	46
2059	1,530	475	362	0	0	0	0	0	0	0	755	47
2060	1,533	475	362	0	0	0	0	0	0	0	755	48

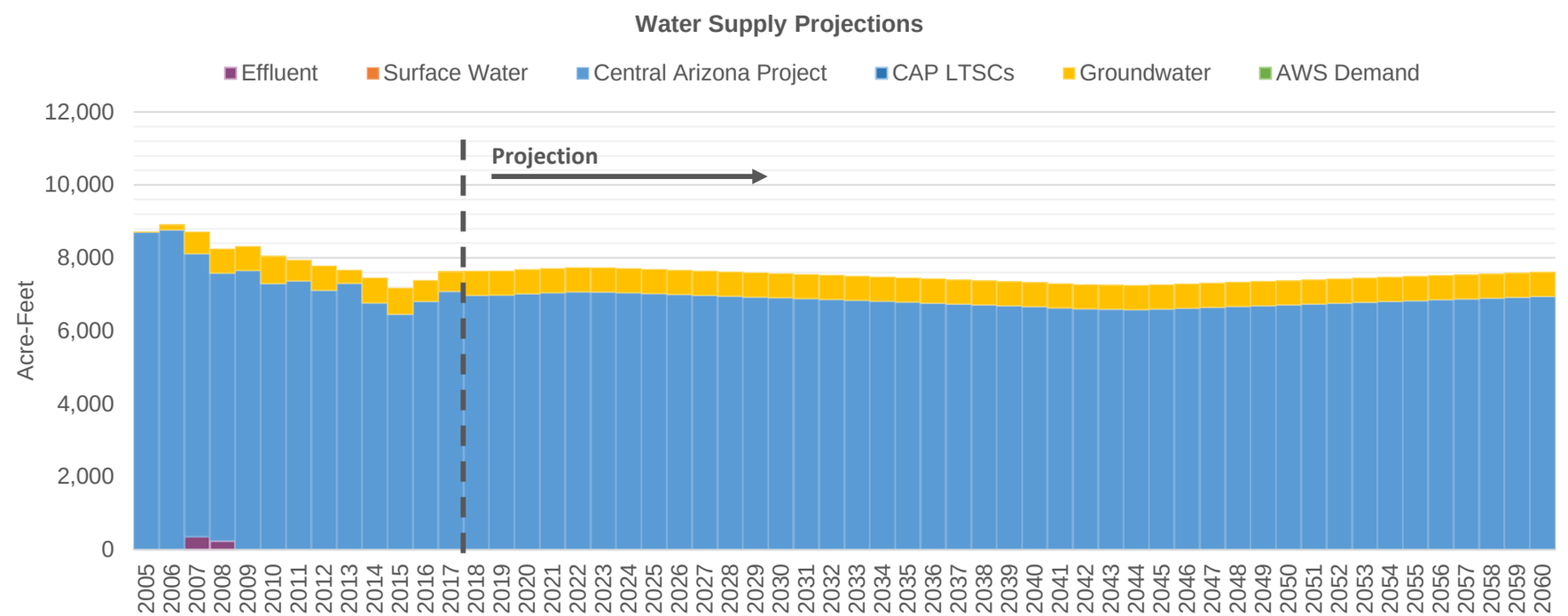
Central Arizona Project Service Area Model

MetroMain

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

MetroMain

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

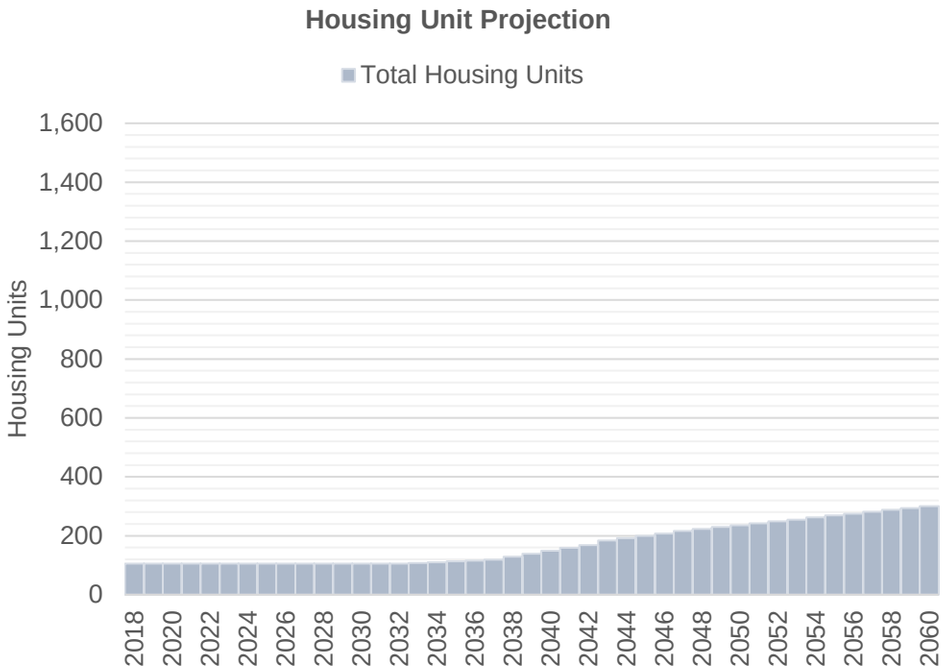
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

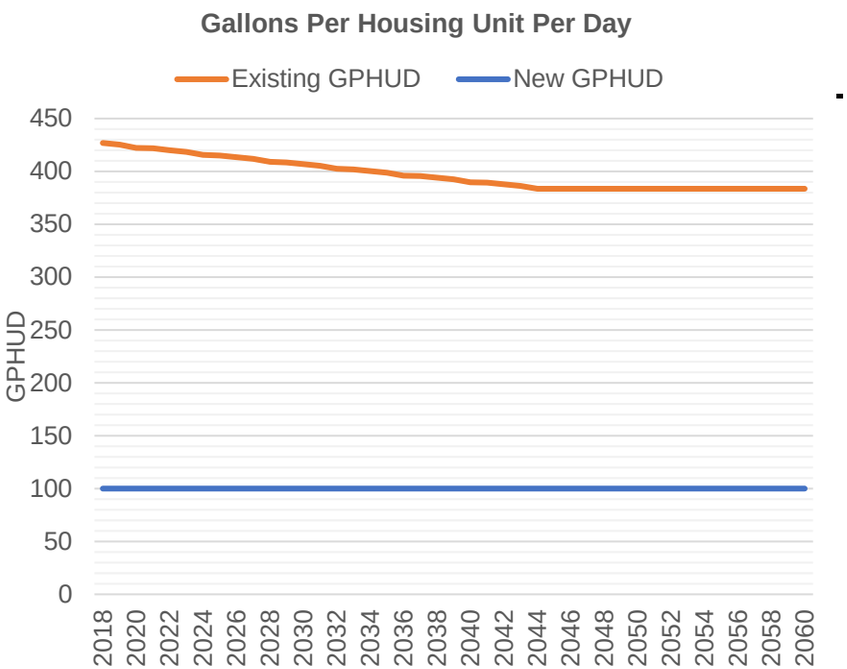
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	21,865	313	243	0	0	0	0	6,974	6,486	0	668	0
2019	22,066	312	243	0	0	0	0	6,985	6,475	0	668	0
2020	22,287	310	243	0	0	0	0	7,012	6,448	0	668	0
2021	22,520	309	243	0	0	0	0	7,043	6,417	0	668	0
2022	22,693	308	243	0	0	0	0	7,069	6,391	0	668	0
2023	22,718	307	243	0	0	0	0	7,066	6,394	0	668	0
2024	22,743	305	243	0	0	0	0	7,043	6,417	0	668	0
2025	22,768	304	243	0	0	0	0	7,020	6,440	0	668	0
2026	22,794	303	243	0	0	0	0	6,997	6,463	0	668	0
2027	22,819	302	243	0	0	0	0	6,974	6,486	0	668	0
2028	22,846	300	243	0	0	0	0	6,953	6,507	0	668	0
2029	22,872	299	243	0	0	0	0	6,930	6,530	0	668	0
2030	22,899	298	243	0	0	0	0	6,908	6,552	0	668	0
2031	22,925	297	243	0	0	0	0	6,886	6,574	0	668	0
2032	22,951	295	243	0	0	0	0	6,865	6,595	0	668	0
2033	22,959	295	243	0	0	0	0	6,840	6,620	0	668	0
2034	22,968	293	243	0	0	0	0	6,814	6,646	0	668	0
2035	22,976	292	243	0	0	0	0	6,787	6,673	0	668	0
2036	22,984	290	243	0	0	0	0	6,762	6,698	0	668	0
2037	22,993	290	243	0	0	0	0	6,735	6,725	0	668	0
2038	23,002	289	243	0	0	0	0	6,709	5,832	0	668	0
2039	23,011	288	243	0	0	0	0	6,683	3,733	0	668	0
2040	23,020	286	243	0	0	0	0	6,659	5,654	0	668	0
2041	23,029	285	243	0	0	0	0	6,632	6,617	0	668	0
2042	23,038	284	243	0	0	0	0	6,607	6,523	0	668	0
2043	23,111	283	243	0	0	0	0	6,590	6,870	0	668	0
2044	23,194	282	243	0	0	0	0	6,585	6,875	0	668	0
2045	23,276	282	243	0	0	0	0	6,599	6,861	0	668	0
2046	23,358	282	243	0	0	0	0	6,621	6,404	0	668	0
2047	23,439	282	243	0	0	0	0	6,643	6,817	0	668	0
2048	23,522	282	243	0	0	0	0	6,667	6,358	0	668	0
2049	23,606	282	243	0	0	0	0	6,688	6,337	0	668	0
2050	23,690	282	243	0	0	0	0	6,711	6,314	0	668	0
2051	23,773	282	243	0	0	0	0	6,734	6,291	0	668	0
2052	23,855	282	243	0	0	0	0	6,758	5,333	0	668	0
2053	23,939	282	243	0	0	0	0	6,779	5,312	0	668	0
2054	24,025	282	243	0	0	0	0	6,802	3,772	0	668	0
2055	24,110	282	243	0	0	0	0	6,826	2,581	0	668	0
2056	24,194	282	243	0	0	0	0	6,850	805	0	668	0
2057	24,277	282	243	0	0	0	0	6,871	3,702	0	668	0
2058	24,358	282	243	0	0	0	0	6,894	4,264	0	668	0
2059	24,439	282	243	0	0	0	0	6,916	4,008	0	668	0
2060	24,518	282	243	0	0	0	0	6,940	3,984	0	668	0

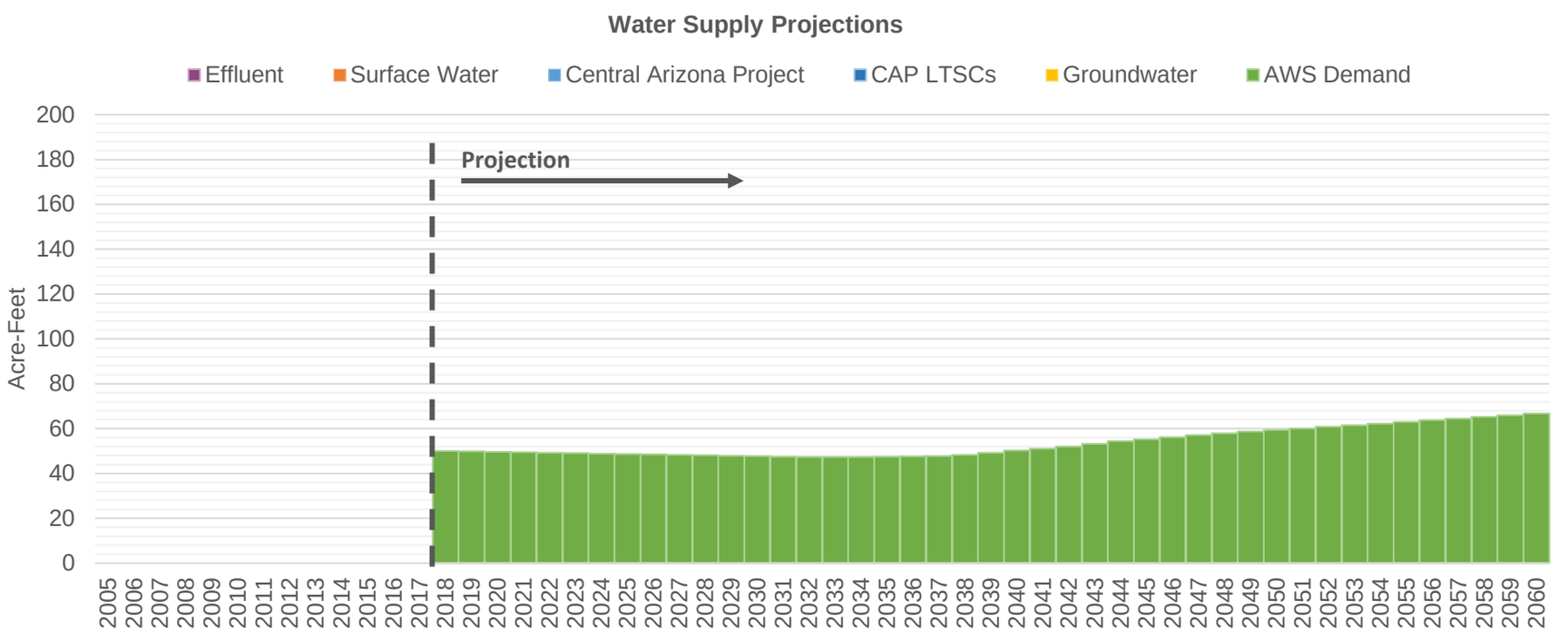
Central Arizona Project Service Area Model

MetroWest

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

MetroWest

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

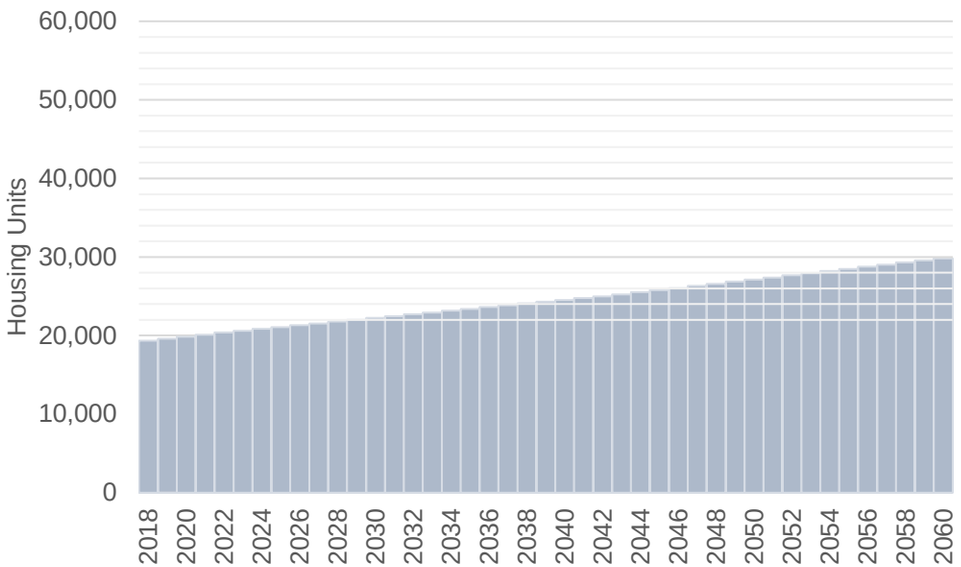
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	105	427	100	0	0	0	0	0	0	0	0	50
2019	105	425	100	0	0	0	0	0	0	0	0	50
2020	105	422	100	0	0	0	0	0	0	0	0	50
2021	105	422	100	0	0	0	0	0	0	0	0	49
2022	105	420	100	0	0	0	0	0	0	0	0	49
2023	105	418	100	0	0	0	0	0	0	0	0	49
2024	105	416	100	0	0	0	0	0	0	0	0	49
2025	105	415	100	0	0	0	0	0	0	0	0	49
2026	105	413	100	0	0	0	0	0	0	0	0	48
2027	105	412	100	0	0	0	0	0	0	0	0	48
2028	105	409	100	0	0	0	0	0	0	0	0	48
2029	105	408	100	0	0	0	0	0	0	0	0	48
2030	105	407	100	0	0	0	0	0	0	0	0	48
2031	105	405	100	0	0	0	0	0	0	0	0	48
2032	105	403	100	0	0	0	0	0	0	0	0	47
2033	108	402	100	0	0	0	0	0	0	0	0	47
2034	110	400	100	0	0	0	0	0	0	0	0	47
2035	113	399	100	0	0	0	0	0	0	0	0	47
2036	116	396	100	0	0	0	0	0	0	0	0	48
2037	119	396	100	0	0	0	0	0	0	0	0	48
2038	129	394	100	0	0	0	0	0	0	0	0	48
2039	139	392	100	0	0	0	0	0	0	0	0	49
2040	149	390	100	0	0	0	0	0	0	0	0	50
2041	159	389	100	0	0	0	0	0	0	0	0	51
2042	168	388	100	0	0	0	0	0	0	0	0	52
2043	184	386	100	0	0	0	0	0	0	0	0	53
2044	192	384	100	0	0	0	0	0	0	0	0	54
2045	200	384	100	0	0	0	0	0	0	0	0	55
2046	208	384	100	0	0	0	0	0	0	0	0	56
2047	216	384	100	0	0	0	0	0	0	0	0	57
2048	223	384	100	0	0	0	0	0	0	0	0	58
2049	230	384	100	0	0	0	0	0	0	0	0	59
2050	236	384	100	0	0	0	0	0	0	0	0	59
2051	242	384	100	0	0	0	0	0	0	0	0	60
2052	249	384	100	0	0	0	0	0	0	0	0	61
2053	255	384	100	0	0	0	0	0	0	0	0	62
2054	262	384	100	0	0	0	0	0	0	0	0	62
2055	269	384	100	0	0	0	0	0	0	0	0	63
2056	275	384	100	0	0	0	0	0	0	0	0	64
2057	282	384	100	0	0	0	0	0	0	0	0	64
2058	288	384	100	0	0	0	0	0	0	0	0	65
2059	294	384	100	0	0	0	0	0	0	0	0	66
2060	301	384	100	0	0	0	0	0	0	0	0	67

Central Arizona Project Service Area Model

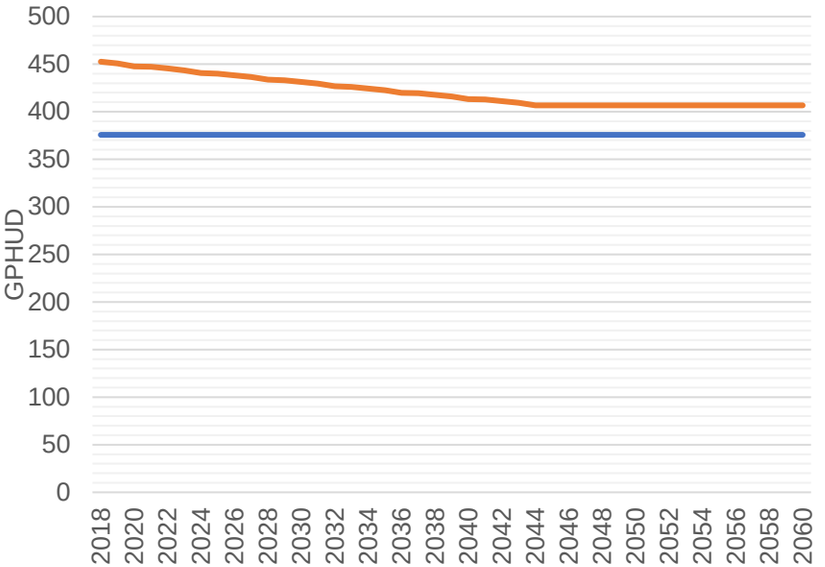
E. Official, Very Dry [LSCRBS]

OroValley

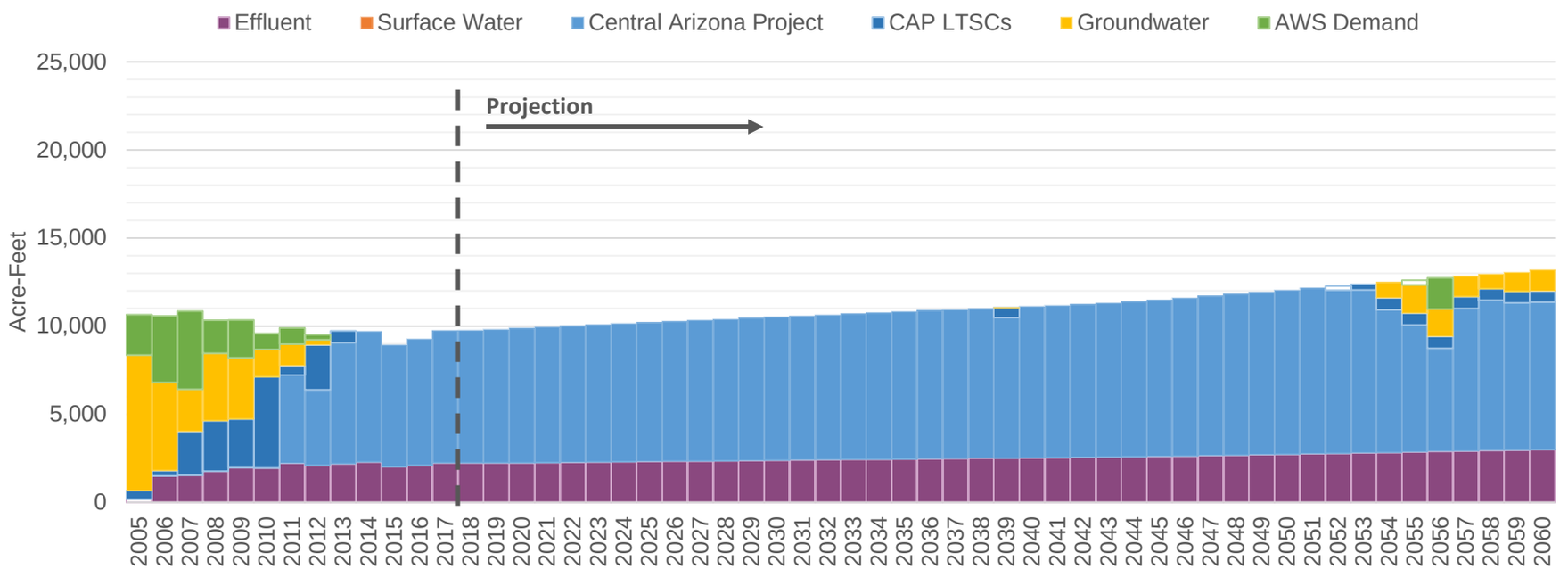
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

OroValley

E. Official, Very Dry [LSCRBS]

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Demand Assumptions

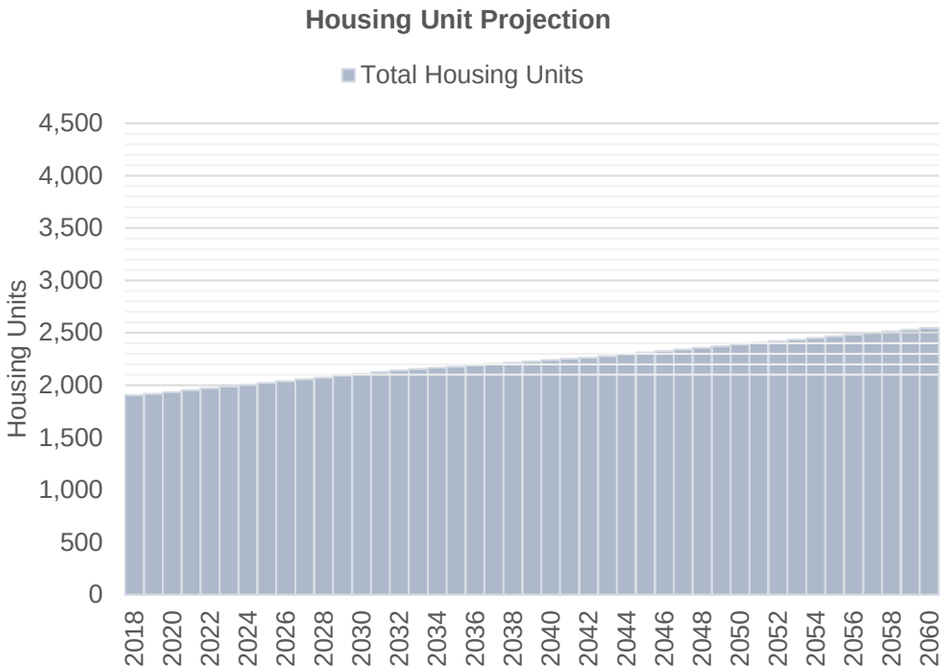
Water Supply Projections (Acre-Feet)

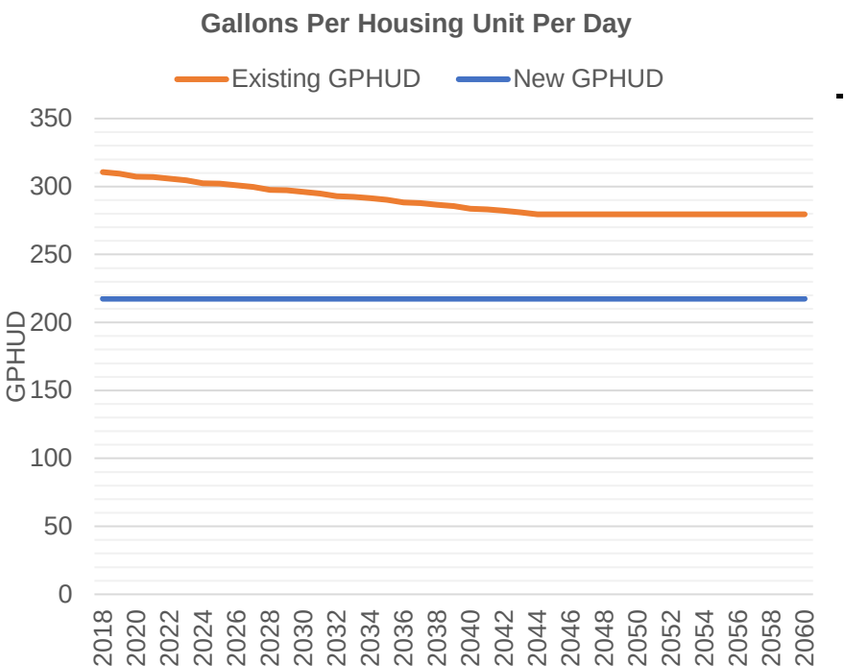
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	19,342	453	376	2,232	0	0	0	7,537	2,768	0	0	0
2019	19,581	451	376	2,232	0	0	0	7,574	2,731	0	0	0
2020	19,843	448	376	2,240	0	0	0	7,633	2,672	0	0	0
2021	20,119	447	376	2,256	0	0	0	7,691	2,614	0	0	0
2022	20,384	445	376	2,273	0	0	0	7,750	2,555	0	0	0
2023	20,613	444	376	2,290	0	0	0	7,798	2,507	0	0	0
2024	20,843	441	376	2,305	0	0	0	7,843	2,462	0	0	0
2025	21,074	440	376	2,319	0	0	0	7,887	2,418	0	0	0
2026	21,306	438	376	2,332	0	0	0	7,933	2,372	0	0	0
2027	21,538	437	376	2,345	0	0	0	7,980	2,325	0	0	0
2028	21,772	434	376	2,359	0	0	0	8,029	2,276	0	0	0
2029	22,007	433	376	2,373	0	0	0	8,074	2,231	0	0	0
2030	22,242	431	376	2,387	0	0	0	8,121	2,184	0	0	0
2031	22,477	430	376	2,401	0	0	0	8,169	2,136	0	0	0
2032	22,712	427	376	2,415	0	0	0	8,221	2,084	0	0	0
2033	22,942	426	376	2,430	0	0	0	8,263	2,042	0	0	0
2034	23,172	424	376	2,443	0	0	0	8,310	1,995	0	0	0
2035	23,401	423	376	2,457	0	0	0	8,356	1,949	0	0	0
2036	23,630	420	376	2,471	0	0	0	8,407	1,898	0	0	0
2037	23,858	419	376	2,485	0	0	0	8,448	1,857	0	0	0
2038	24,086	418	376	2,498	0	0	0	8,495	1,107	0	0	0
2039	24,313	416	376	2,512	0	0	0	7,975	0	564	2	0
2040	24,539	413	376	2,525	0	0	0	8,593	834	0	0	0
2041	24,764	413	376	2,540	0	0	0	8,631	1,513	0	0	0
2042	24,988	411	376	2,552	0	0	0	8,678	1,374	0	0	0
2043	25,251	409	376	2,566	0	0	0	8,731	1,574	0	0	0
2044	25,520	407	376	2,581	0	0	0	8,800	1,505	0	0	0
2045	25,787	407	376	2,600	0	0	0	8,876	1,429	0	0	0
2046	26,052	407	376	2,622	0	0	0	8,966	1,006	0	0	0
2047	26,314	407	376	2,648	0	0	0	9,052	1,253	0	0	0
2048	26,584	407	376	2,673	0	0	0	9,147	826	0	0	0
2049	26,858	407	376	2,701	0	0	0	9,225	747	0	0	0
2050	27,129	407	376	2,725	0	0	0	9,316	656	0	0	0
2051	27,398	407	376	2,751	0	0	0	9,403	569	0	0	0
2052	27,663	407	376	2,777	0	0	0	9,257	0	242	0	0
2053	27,936	407	376	2,805	0	0	0	9,257	0	318	0	0
2054	28,215	407	376	2,828	0	0	0	8,095	0	679	893	0
2055	28,491	407	376	2,855	0	0	0	7,202	0	672	1,615	268
2056	28,763	407	376	2,882	0	0	0	5,861	0	665	1,559	1,771
2057	29,032	407	376	2,911	0	0	0	8,095	0	659	1,177	0
2058	29,296	407	376	2,934	0	0	0	8,542	0	652	825	0
2059	29,556	407	376	2,960	0	0	0	8,363	0	646	1,095	0
2060	29,812	407	376	2,985	0	0	0	8,363	0	639	1,197	0

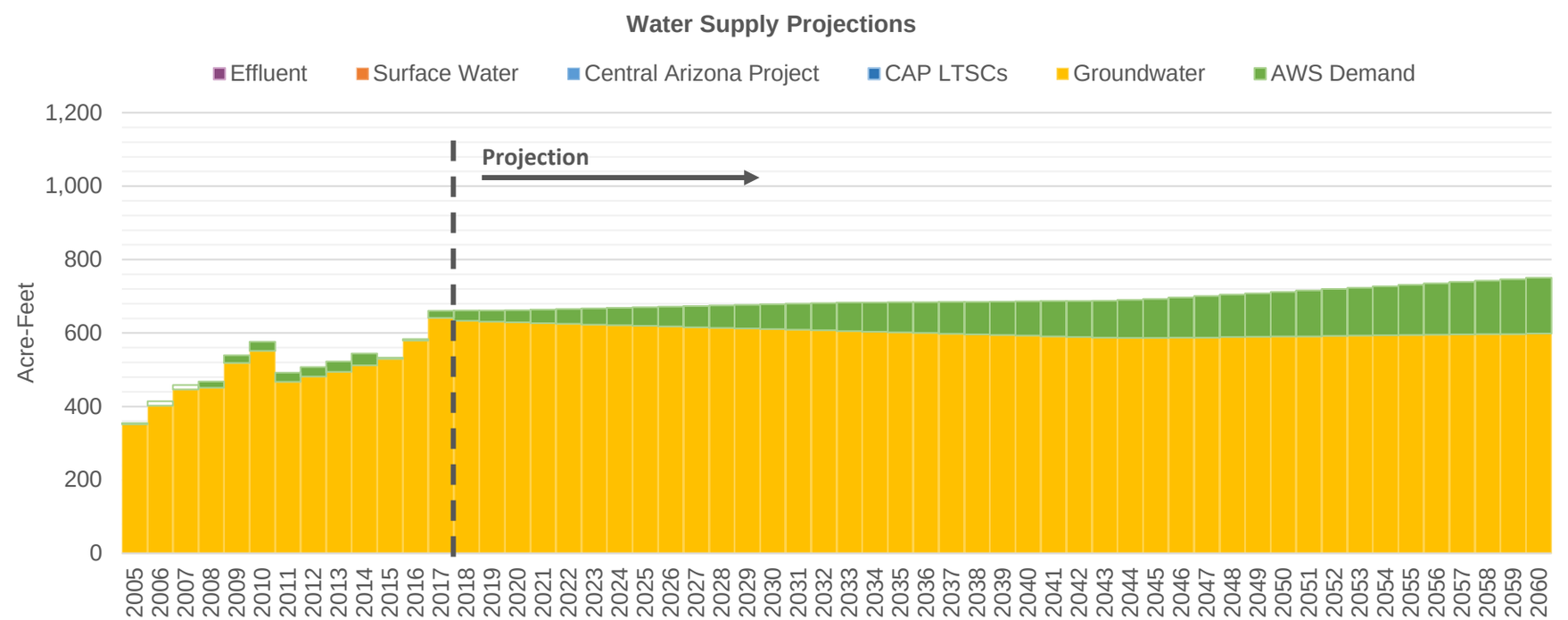
Central Arizona Project Service Area Model

QuailCreek

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

QuailCreek

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions

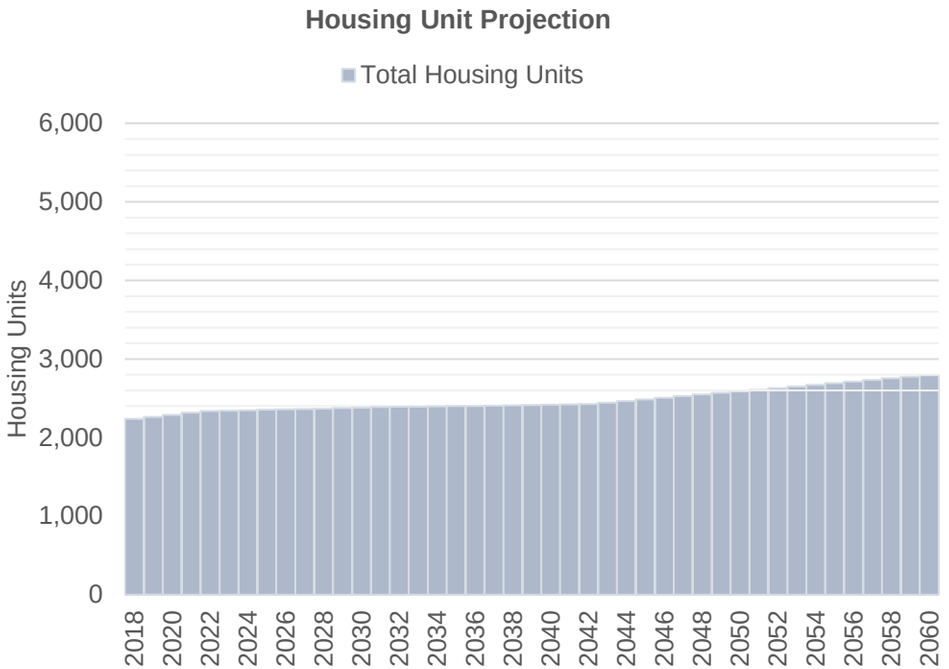
Water Supply Projections (Acre-Feet)

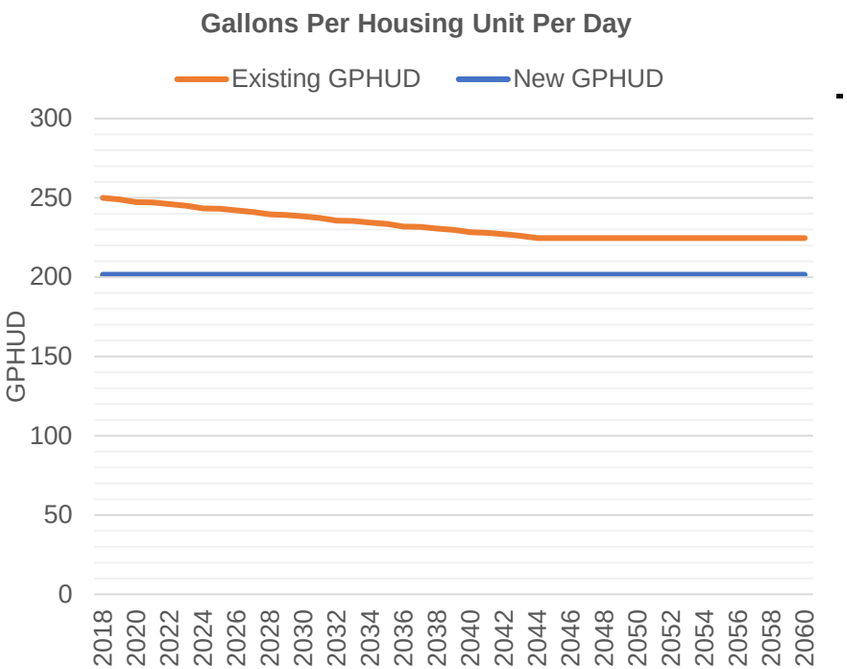
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,905	311	217	0	0	0	0	0	0	0	633	28
2019	1,919	309	217	0	0	0	0	0	0	0	631	30
2020	1,935	307	217	0	0	0	0	0	0	0	629	33
2021	1,952	307	217	0	0	0	0	0	0	0	627	37
2022	1,970	306	217	0	0	0	0	0	0	0	625	40
2023	1,987	304	217	0	0	0	0	0	0	0	623	44
2024	2,004	302	217	0	0	0	0	0	0	0	621	47
2025	2,021	302	217	0	0	0	0	0	0	0	619	51
2026	2,039	301	217	0	0	0	0	0	0	0	618	54
2027	2,056	300	217	0	0	0	0	0	0	0	616	57
2028	2,073	298	217	0	0	0	0	0	0	0	614	61
2029	2,090	297	217	0	0	0	0	0	0	0	613	64
2030	2,108	296	217	0	0	0	0	0	0	0	611	67
2031	2,125	295	217	0	0	0	0	0	0	0	609	71
2032	2,142	293	217	0	0	0	0	0	0	0	608	74
2033	2,154	292	217	0	0	0	0	0	0	0	605	77
2034	2,166	291	217	0	0	0	0	0	0	0	604	79
2035	2,178	290	217	0	0	0	0	0	0	0	602	82
2036	2,190	288	217	0	0	0	0	0	0	0	600	84
2037	2,202	288	217	0	0	0	0	0	0	0	598	86
2038	2,214	287	217	0	0	0	0	0	0	0	596	89
2039	2,227	286	217	0	0	0	0	0	0	0	595	91
2040	2,239	284	217	0	0	0	0	0	0	0	593	93
2041	2,251	283	217	0	0	0	0	0	0	0	591	96
2042	2,263	282	217	0	0	0	0	0	0	0	589	98
2043	2,279	281	217	0	0	0	0	0	0	0	588	100
2044	2,295	280	217	0	0	0	0	0	0	0	587	103
2045	2,311	280	217	0	0	0	0	0	0	0	586	107
2046	2,326	280	217	0	0	0	0	0	0	0	587	110
2047	2,341	280	217	0	0	0	0	0	0	0	588	112
2048	2,357	280	217	0	0	0	0	0	0	0	589	115
2049	2,373	280	217	0	0	0	0	0	0	0	590	118
2050	2,389	280	217	0	0	0	0	0	0	0	590	122
2051	2,404	280	217	0	0	0	0	0	0	0	591	125
2052	2,420	280	217	0	0	0	0	0	0	0	592	128
2053	2,436	280	217	0	0	0	0	0	0	0	593	131
2054	2,452	280	217	0	0	0	0	0	0	0	594	134
2055	2,468	280	217	0	0	0	0	0	0	0	594	137
2056	2,484	280	217	0	0	0	0	0	0	0	596	140
2057	2,499	280	217	0	0	0	0	0	0	0	596	143
2058	2,515	280	217	0	0	0	0	0	0	0	597	146
2059	2,530	280	217	0	0	0	0	0	0	0	598	149
2060	2,545	280	217	0	0	0	0	0	0	0	599	152

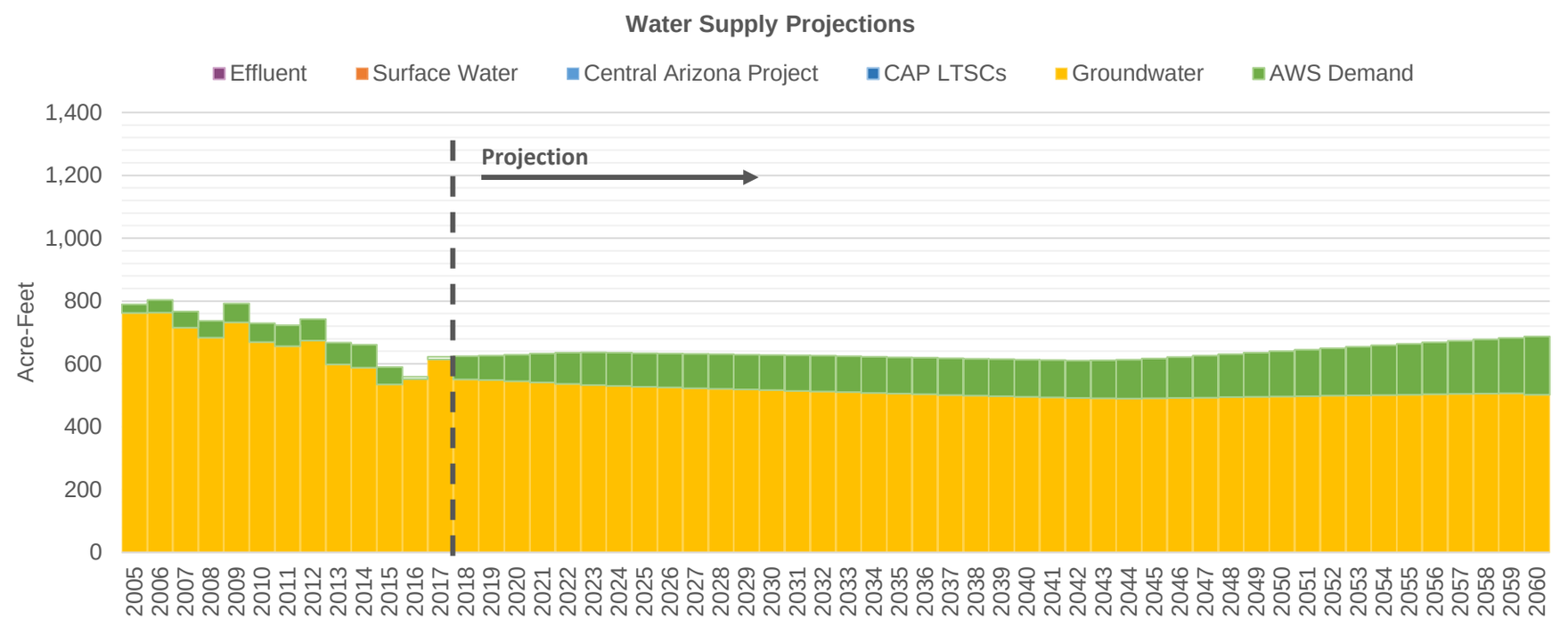
Central Arizona Project Service Area Model

RayWC

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

RayWC

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions

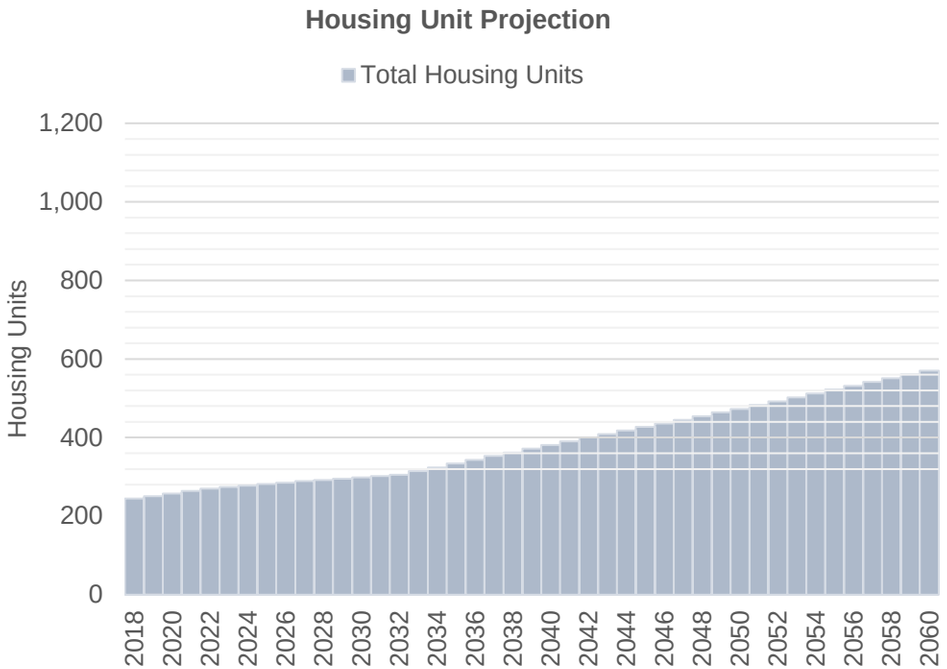
Water Supply Projections (Acre-Feet)

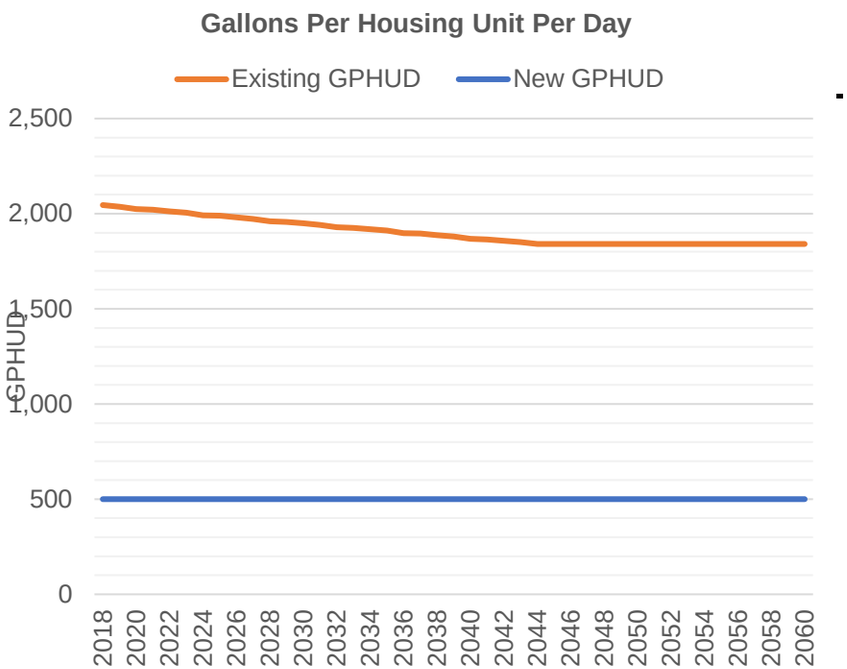
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,238	250	202	0	0	0	0	0	0	0	551	74
2019	2,263	249	202	0	0	0	0	0	0	0	548	78
2020	2,289	247	202	0	0	0	0	0	0	0	545	85
2021	2,316	247	202	0	0	0	0	0	0	0	541	92
2022	2,337	246	202	0	0	0	0	0	0	0	537	99
2023	2,343	245	202	0	0	0	0	0	0	0	532	104
2024	2,348	243	202	0	0	0	0	0	0	0	530	106
2025	2,354	243	202	0	0	0	0	0	0	0	527	107
2026	2,359	242	202	0	0	0	0	0	0	0	525	108
2027	2,365	241	202	0	0	0	0	0	0	0	523	109
2028	2,370	240	202	0	0	0	0	0	0	0	521	110
2029	2,376	239	202	0	0	0	0	0	0	0	519	111
2030	2,381	238	202	0	0	0	0	0	0	0	516	112
2031	2,387	237	202	0	0	0	0	0	0	0	514	113
2032	2,392	236	202	0	0	0	0	0	0	0	512	114
2033	2,395	235	202	0	0	0	0	0	0	0	510	115
2034	2,397	234	202	0	0	0	0	0	0	0	508	115
2035	2,400	234	202	0	0	0	0	0	0	0	506	116
2036	2,403	232	202	0	0	0	0	0	0	0	504	116
2037	2,405	232	202	0	0	0	0	0	0	0	501	117
2038	2,409	231	202	0	0	0	0	0	0	0	499	117
2039	2,413	230	202	0	0	0	0	0	0	0	497	118
2040	2,418	228	202	0	0	0	0	0	0	0	495	118
2041	2,422	228	202	0	0	0	0	0	0	0	493	119
2042	2,426	227	202	0	0	0	0	0	0	0	491	120
2043	2,445	226	202	0	0	0	0	0	0	0	491	120
2044	2,466	225	202	0	0	0	0	0	0	0	490	124
2045	2,486	225	202	0	0	0	0	0	0	0	490	127
2046	2,506	225	202	0	0	0	0	0	0	0	491	130
2047	2,526	225	202	0	0	0	0	0	0	0	493	134
2048	2,547	225	202	0	0	0	0	0	0	0	494	137
2049	2,568	225	202	0	0	0	0	0	0	0	495	141
2050	2,588	225	202	0	0	0	0	0	0	0	496	144
2051	2,609	225	202	0	0	0	0	0	0	0	497	148
2052	2,629	225	202	0	0	0	0	0	0	0	499	151
2053	2,650	225	202	0	0	0	0	0	0	0	500	154
2054	2,671	225	202	0	0	0	0	0	0	0	501	158
2055	2,692	225	202	0	0	0	0	0	0	0	502	162
2056	2,713	225	202	0	0	0	0	0	0	0	504	165
2057	2,734	225	202	0	0	0	0	0	0	0	505	169
2058	2,754	225	202	0	0	0	0	0	0	0	506	172
2059	2,774	225	202	0	0	0	0	0	0	0	507	176
2060	2,793	225	202	0	0	0	0	0	0	0	501	186

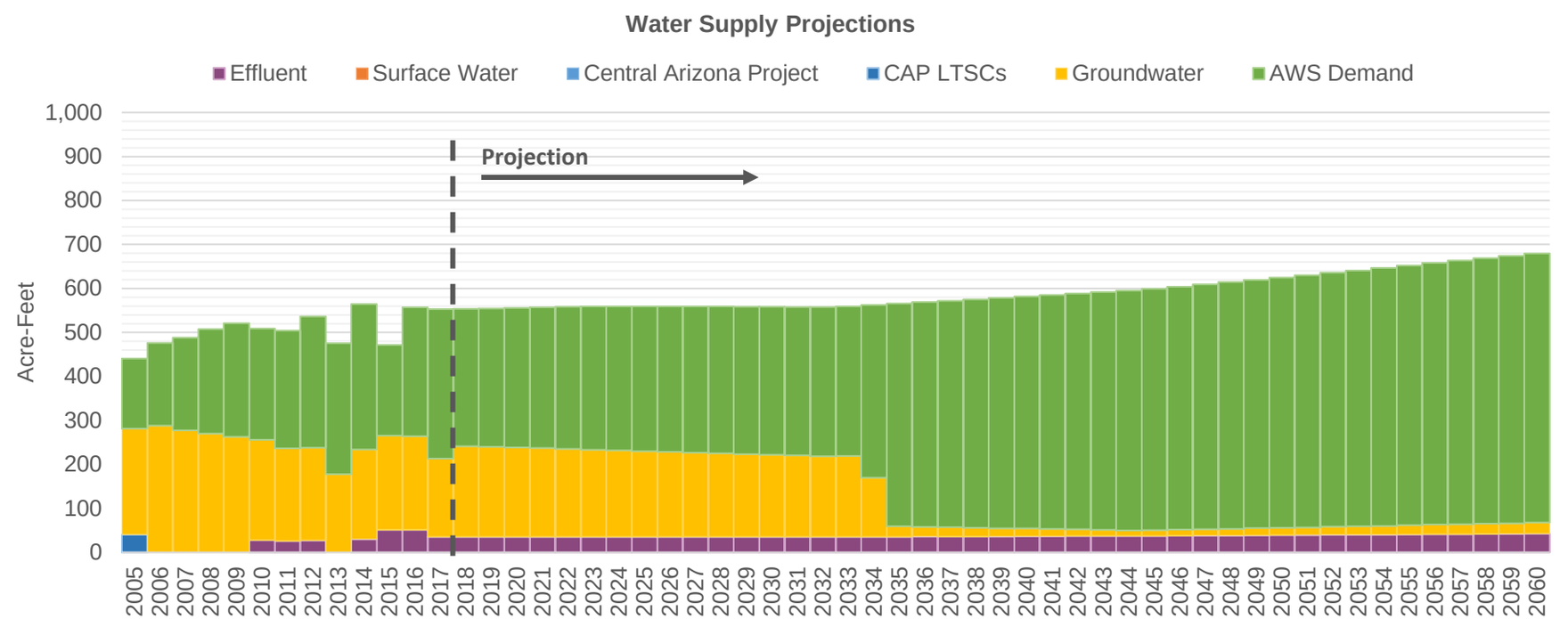
Central Arizona Project Service Area Model

RidgeView

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

RidgeView

E. Official, Very Dry [LSCRBS]

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Demand Assumptions

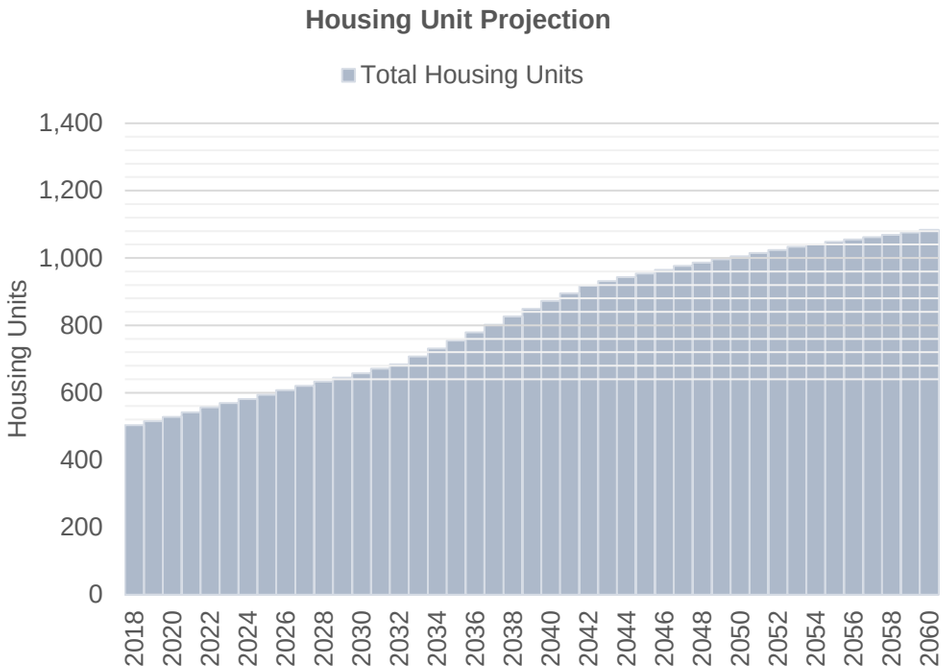
Water Supply Projections (Acre-Feet)

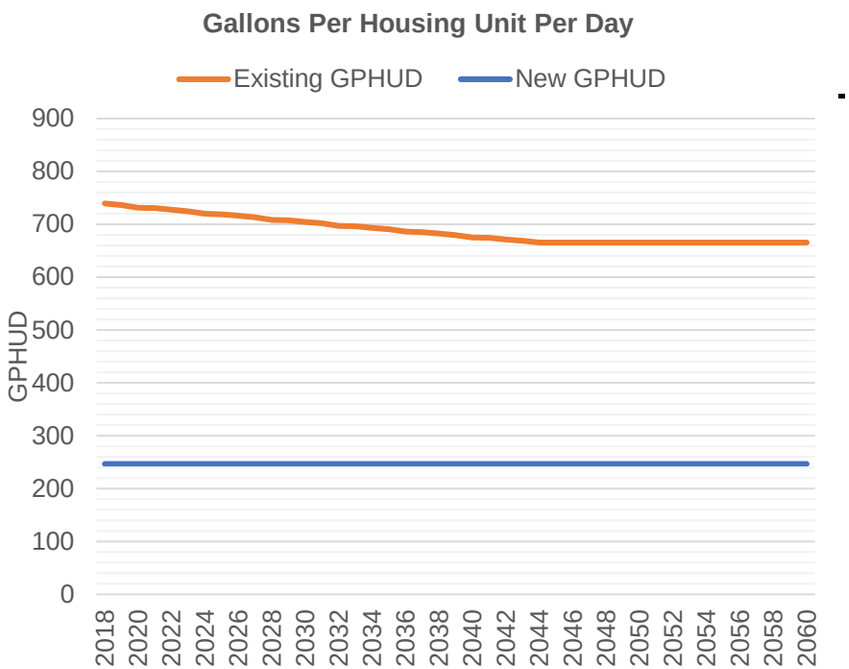
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	245	2,045	500	35	0	0	0	0	0	0	206	313
2019	251	2,037	500	35	0	0	0	0	0	0	205	315
2020	257	2,024	500	35	0	0	0	0	0	0	203	317
2021	264	2,021	500	35	0	0	0	0	0	0	202	320
2022	270	2,013	500	35	0	0	0	0	0	0	200	323
2023	274	2,005	500	35	0	0	0	0	0	0	198	326
2024	278	1,991	500	35	0	0	0	0	0	0	197	328
2025	282	1,989	500	35	0	0	0	0	0	0	195	329
2026	285	1,981	500	35	0	0	0	0	0	0	193	331
2027	289	1,973	500	35	0	0	0	0	0	0	192	332
2028	292	1,960	500	35	0	0	0	0	0	0	190	334
2029	295	1,957	500	35	0	0	0	0	0	0	188	335
2030	299	1,949	500	35	0	0	0	0	0	0	187	336
2031	302	1,942	500	35	0	0	0	0	0	0	185	338
2032	305	1,929	500	35	0	0	0	0	0	0	184	339
2033	315	1,926	500	35	0	0	0	0	0	0	184	340
2034	324	1,918	500	35	0	0	0	0	0	0	135	393
2035	334	1,911	500	36	0	0	0	0	0	0	24	507
2036	343	1,898	500	36	0	0	0	0	0	0	22	511
2037	353	1,895	500	36	0	0	0	0	0	0	21	515
2038	362	1,888	500	36	0	0	0	0	0	0	20	520
2039	372	1,880	500	36	0	0	0	0	0	0	19	524
2040	381	1,868	500	37	0	0	0	0	0	0	18	528
2041	390	1,865	500	37	0	0	0	0	0	0	16	532
2042	400	1,858	500	37	0	0	0	0	0	0	15	536
2043	409	1,850	500	37	0	0	0	0	0	0	14	540
2044	418	1,841	500	37	0	0	0	0	0	0	13	545
2045	427	1,841	500	38	0	0	0	0	0	0	13	548
2046	436	1,841	500	38	0	0	0	0	0	0	14	552
2047	445	1,841	500	38	0	0	0	0	0	0	15	557
2048	454	1,841	500	38	0	0	0	0	0	0	16	561
2049	464	1,841	500	39	0	0	0	0	0	0	16	564
2050	473	1,841	500	39	0	0	0	0	0	0	17	569
2051	483	1,841	500	39	0	0	0	0	0	0	18	573
2052	492	1,841	500	40	0	0	0	0	0	0	19	577
2053	502	1,841	500	40	0	0	0	0	0	0	19	581
2054	512	1,841	500	40	0	0	0	0	0	0	20	586
2055	522	1,841	500	41	0	0	0	0	0	0	21	590
2056	532	1,841	500	41	0	0	0	0	0	0	22	595
2057	542	1,841	500	42	0	0	0	0	0	0	23	599
2058	551	1,841	500	42	0	0	0	0	0	0	23	604
2059	561	1,841	500	42	0	0	0	0	0	0	24	608
2060	570	1,841	500	43	0	0	0	0	0	0	25	612

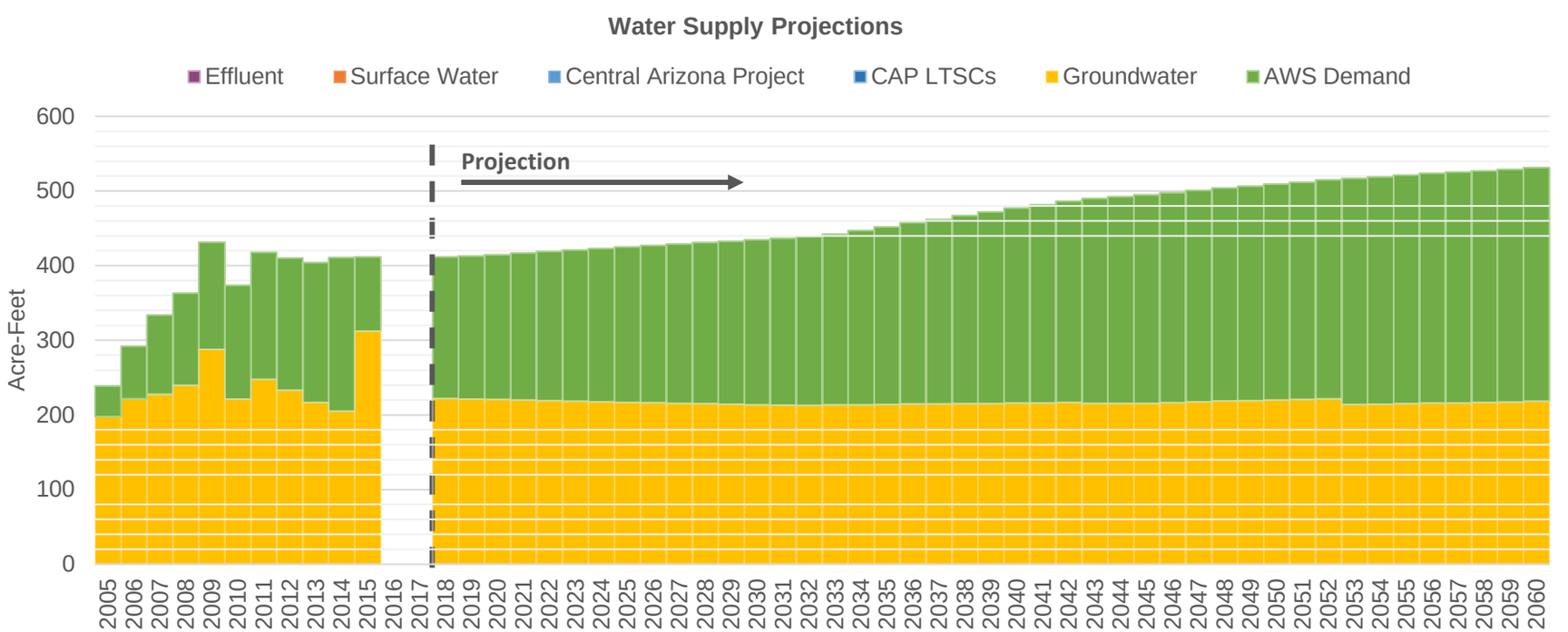
Central Arizona Project Service Area Model

Saguaro

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

Saguaro

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

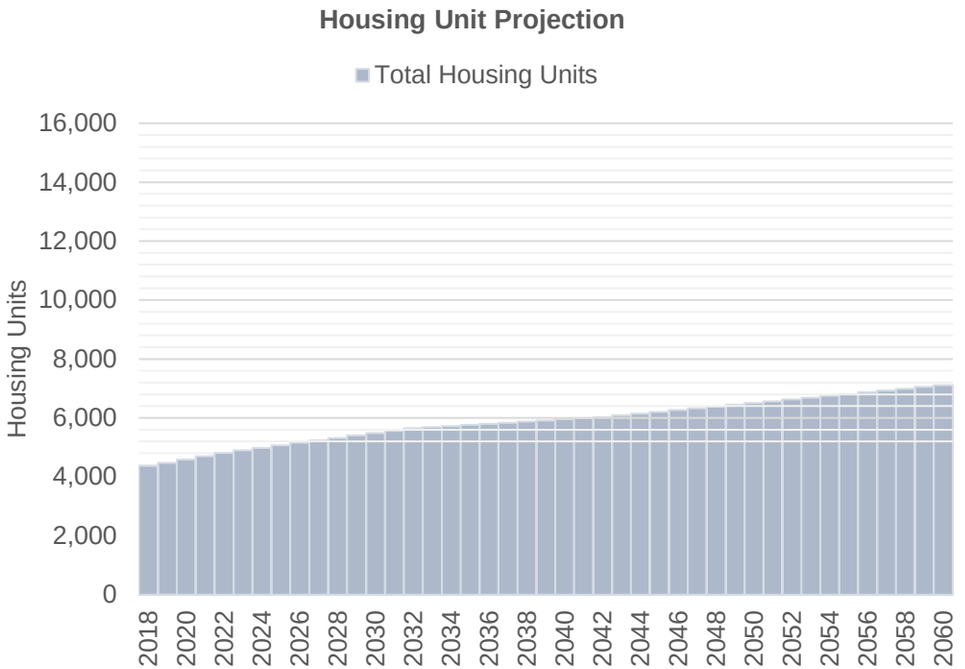
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

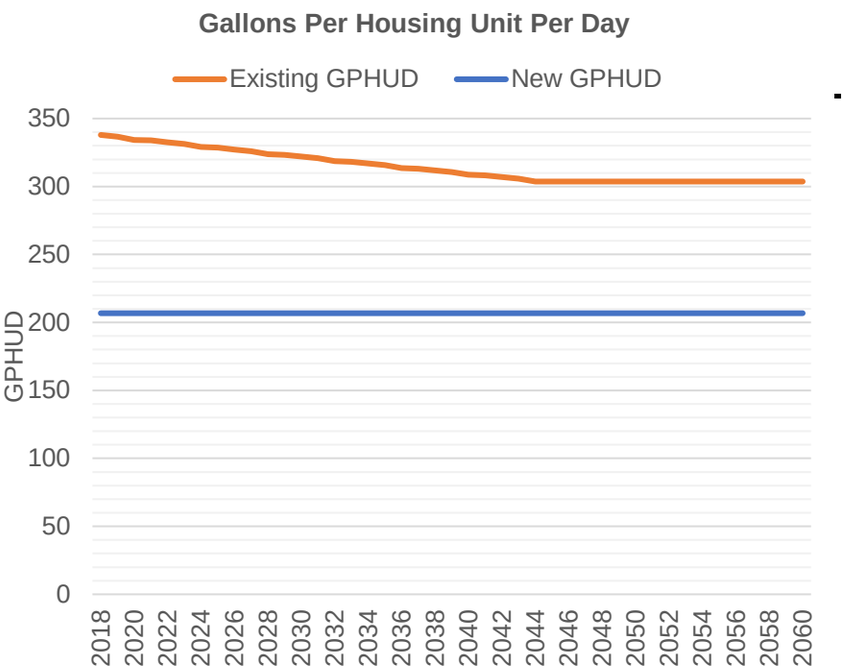
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	503	739	247	0	0	0	0	0	0	0	222	190
2019	515	736	247	0	0	0	0	0	0	0	221	192
2020	528	731	247	0	0	0	0	0	0	0	221	194
2021	542	731	247	0	0	0	0	0	0	0	220	197
2022	556	728	247	0	0	0	0	0	0	0	219	200
2023	569	725	247	0	0	0	0	0	0	0	218	203
2024	581	720	247	0	0	0	0	0	0	0	217	206
2025	594	719	247	0	0	0	0	0	0	0	217	208
2026	607	716	247	0	0	0	0	0	0	0	216	211
2027	620	713	247	0	0	0	0	0	0	0	215	213
2028	633	708	247	0	0	0	0	0	0	0	215	216
2029	645	708	247	0	0	0	0	0	0	0	214	219
2030	658	705	247	0	0	0	0	0	0	0	214	221
2031	671	702	247	0	0	0	0	0	0	0	213	224
2032	684	697	247	0	0	0	0	0	0	0	213	226
2033	708	696	247	0	0	0	0	0	0	0	213	229
2034	731	693	247	0	0	0	0	0	0	0	214	233
2035	755	691	247	0	0	0	0	0	0	0	214	238
2036	779	686	247	0	0	0	0	0	0	0	215	243
2037	802	685	247	0	0	0	0	0	0	0	215	248
2038	826	682	247	0	0	0	0	0	0	0	215	252
2039	849	680	247	0	0	0	0	0	0	0	215	257
2040	872	675	247	0	0	0	0	0	0	0	216	261
2041	895	674	247	0	0	0	0	0	0	0	216	266
2042	918	672	247	0	0	0	0	0	0	0	216	270
2043	931	669	247	0	0	0	0	0	0	0	216	275
2044	943	665	247	0	0	0	0	0	0	0	215	277
2045	954	665	247	0	0	0	0	0	0	0	215	279
2046	965	665	247	0	0	0	0	0	0	0	216	281
2047	976	665	247	0	0	0	0	0	0	0	217	284
2048	986	665	247	0	0	0	0	0	0	0	219	286
2049	996	665	247	0	0	0	0	0	0	0	219	288
2050	1,005	665	247	0	0	0	0	0	0	0	220	289
2051	1,015	665	247	0	0	0	0	0	0	0	221	291
2052	1,024	665	247	0	0	0	0	0	0	0	222	293
2053	1,033	665	247	0	0	0	0	0	0	0	214	303
2054	1,040	665	247	0	0	0	0	0	0	0	214	305
2055	1,048	665	247	0	0	0	0	0	0	0	215	306
2056	1,055	665	247	0	0	0	0	0	0	0	216	308
2057	1,062	665	247	0	0	0	0	0	0	0	216	309
2058	1,069	665	247	0	0	0	0	0	0	0	217	311
2059	1,076	665	247	0	0	0	0	0	0	0	217	312
2060	1,083	665	247	0	0	0	0	0	0	0	218	313

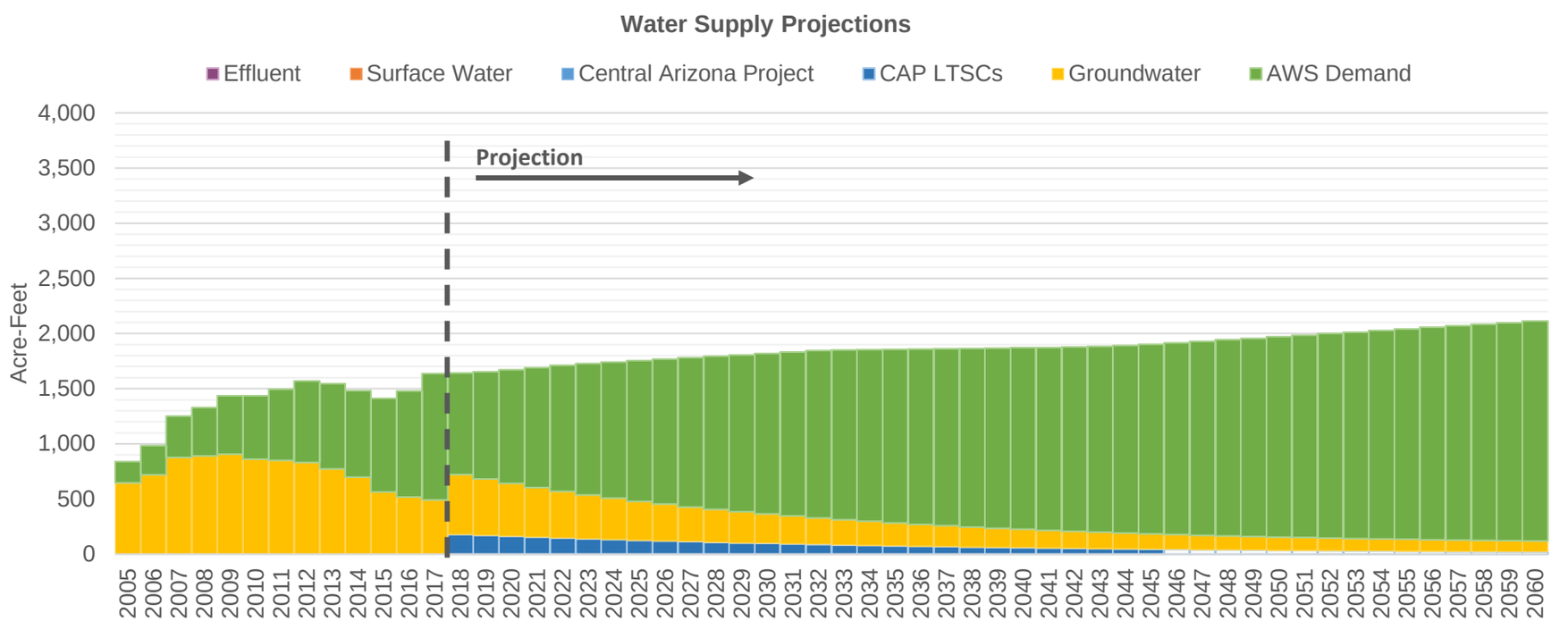
Central Arizona Project Service Area Model

Sahuarita

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

Sahuarita

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7/14/20 9:06 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,376	338	207	0	0	0	0	0	0	179	544	919
2019	4,478	337	207	0	0	0	0	0	0	171	510	973
2020	4,589	334	207	0	0	0	0	0	0	162	479	1,031
2021	4,705	334	207	0	0	0	0	0	0	154	450	1,088
2022	4,814	333	207	0	0	0	0	0	0	146	423	1,142
2023	4,898	331	207	0	0	0	0	0	0	139	398	1,190
2024	4,983	329	207	0	0	0	0	0	0	132	375	1,234
2025	5,069	329	207	0	0	0	0	0	0	125	354	1,275
2026	5,154	327	207	0	0	0	0	0	0	119	334	1,314
2027	5,239	326	207	0	0	0	0	0	0	113	316	1,352
2028	5,321	324	207	0	0	0	0	0	0	107	298	1,388
2029	5,403	323	207	0	0	0	0	0	0	102	283	1,422
2030	5,485	322	207	0	0	0	0	0	0	97	268	1,454
2031	5,567	321	207	0	0	0	0	0	0	92	254	1,486
2032	5.648	319	207	0	0	0	0	0	0	88	241	1.516
2033	5,685	318	207	0	0	0	0	0	0	83	230	1,539
2034	5,723	317	207	0	0	0	0	0	0	79	219	1,557
2035	5,760	316	207	0	0	0	0	0	0	75	209	1,574
2036	5,797	314	207	0	0	0	0	0	0	71	199	1,590
2037	5,834	313	207	0	0	0	0	0	0	68	190	1,604
2038	5,873	312	207	0	0	0	0	0	0	64	182	1,618
2039	5,912	311	207	0	0	0	0	0	0	61	175	1,632
2040	5,951	309	207	0	0	0	0	0	0	58	168	1,646
2041	5,990	308	207	0	0	0	0	0	0	55	161	1,657
2042	6,028	307	207	0	0	0	0	0	0	52	155	1,669
2043	6,089	306	207	0	0	0	0	0	0	50	150	1,683
2044	6,148	304	207	0	0	0	0	0	0	47	144	1,700
2045	6,206	304	207	0	0	0	0	0	0	45	140	1,718
2046	6,265	304	207	0	0	0	0	0	0	43	135	1,738
2047	6,322	304	207	0	0	0	0	0	0	41	131	1,758
2048	6,382	304	207	0	0	0	0	0	0	39	127	1,778
2049	6,444	304	207	0	0	0	0	0	0	37	124	1,797
2050	6,505	304	207	0	0	0	0	0	0	35	120	1,816
2051	6,565	304	207	0	0	0	0	0	0	33	117	1,835
2052	6,625	304	207	0	0	0	0	0	0	31	115	1,854
2053	6,686	304	207	0	0	0	0	0	0	30	112	1,871
2054	6,749	304	207	0	0	0	0	0	0	28	110	1,889
2055	6,812	304	207	0	0	0	0	0	0	27	108	1,907
2056	6,873	304	207	0	0	0	0	0	0	26	106	1,926
2057	6,934	304	207	0	0	0	0	0	0	24	104	1,942
2058	6,993	304	207	0	0	0	0	0	0	23	103	1,958
2059	7,052	304	207	0	0	0	0	0	0	22	101	1,975
2060	7,110	304	207	0	0	0	0	0	0	21	100	1,992

Central Arizona Project Service Area Model

SpanishTrailWC

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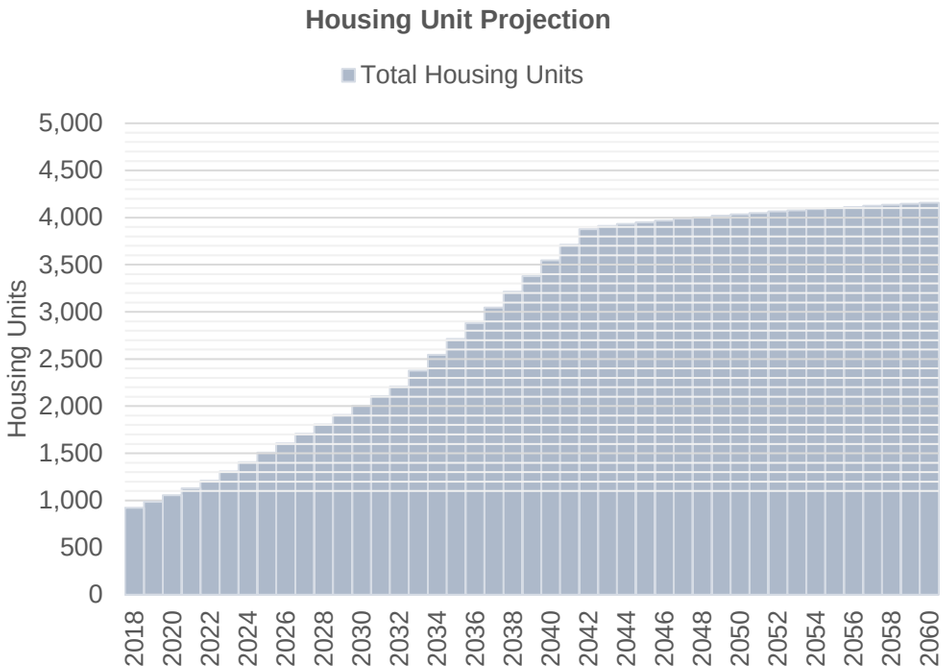

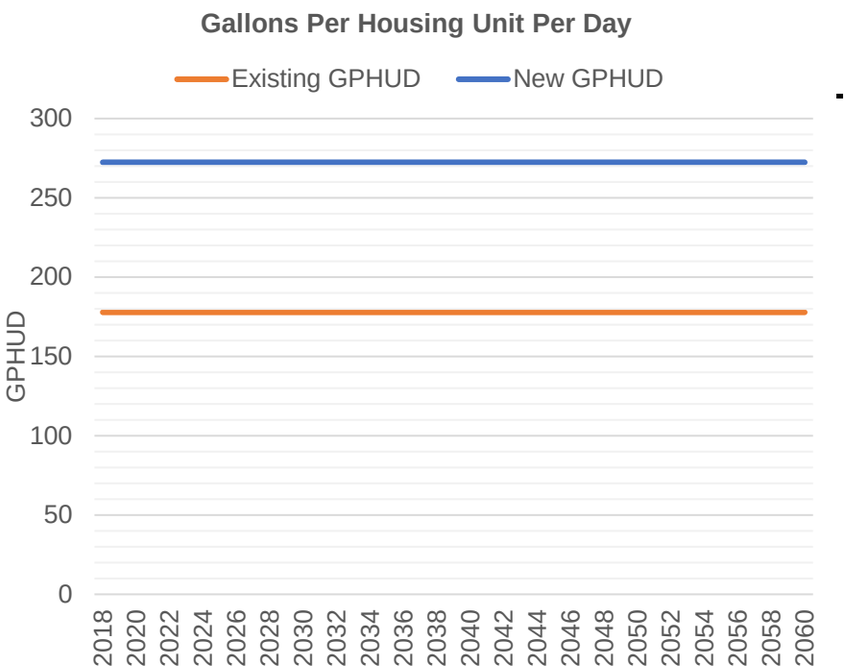

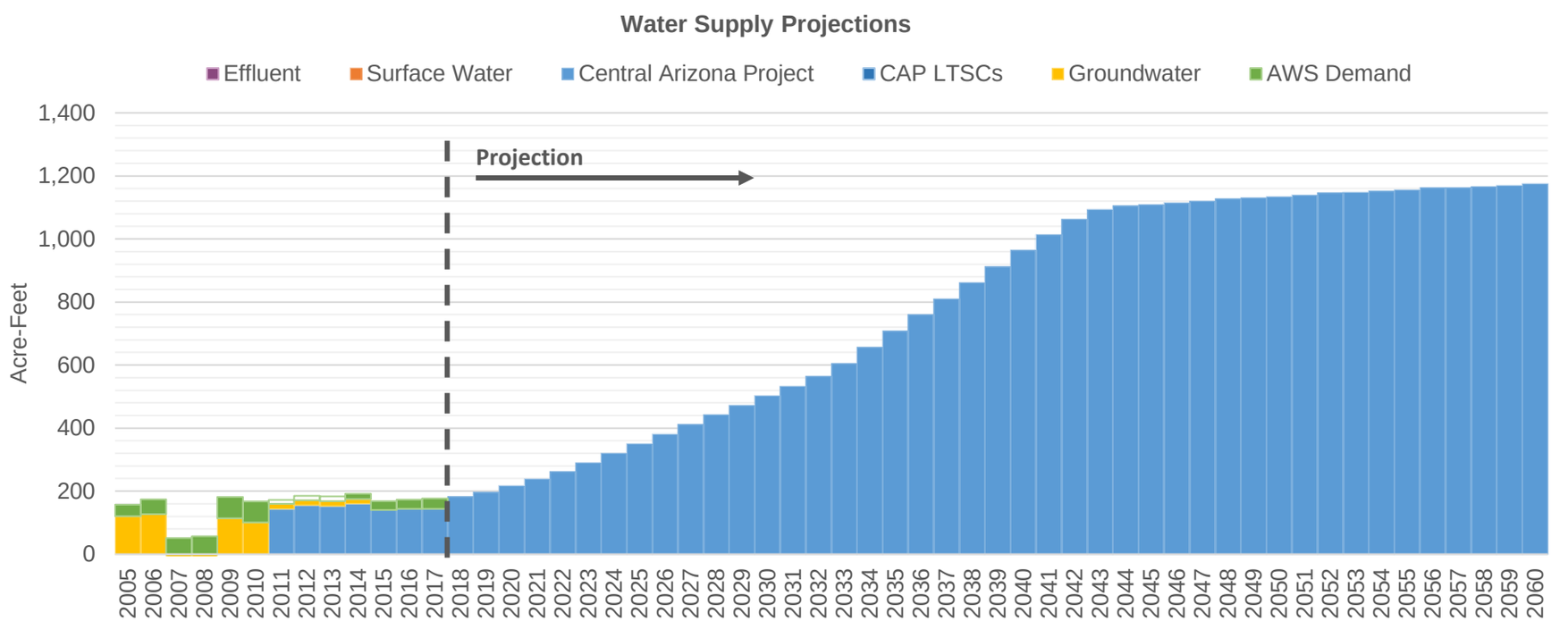

Central Arizona Project Service Area Model

SpanishTrailWC

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7/14/20 9:06 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	921	178	272	0	0	0	0	182	2,855	0	0	0
2019	984	178	272	0	0	0	0	197	2,840	0	0	0
2020	1,054	178	272	0	0	0	0	217	2,820	0	0	0
2021	1,127	178	272	0	0	0	0	239	2,798	0	0	0
2022	1,209	178	272	0	0	0	0	262	2,775	0	0	0
2023	1,307	178	272	0	0	0	0	290	2,747	0	0	0
2024	1,407	178	272	0	0	0	0	320	2,717	0	0	0
2025	1,507	178	272	0	0	0	0	350	2,687	0	0	0
2026	1,607	178	272	0	0	0	0	381	2,656	0	0	0
2027	1,707	178	272	0	0	0	0	411	2,626	0	0	0
2028	1,806	178	272	0	0	0	0	443	2,594	0	0	0
2029	1,906	178	272	0	0	0	0	472	2,565	0	0	0
2030	2,005	178	272	0	0	0	0	503	2,534	0	0	0
2031	2,105	178	272	0	0	0	0	533	2,504	0	0	0
2032	2,207	178	272	0	0	0	0	565	2,472	0	0	0
2033	2,376	178	272	0	0	0	0	605	2,432	0	0	0
2034	2,544	178	272	0	0	0	0	657	2,380	0	0	0
2035	2,712	178	272	0	0	0	0	708	2,329	0	0	0
2036	2,880	178	272	0	0	0	0	761	2,276	0	0	0
2037	3,047	178	272	0	0	0	0	810	2,227	0	0	0
2038	3,214	178	272	0	0	0	0	861	1,969	0	0	0
2039	3,380	178	272	0	0	0	0	912	1,438	0	0	0
2040	3,546	178	272	0	0	0	0	965	1,813	0	0	0
2041	3,711	178	272	0	0	0	0	1,013	1,977	0	0	0
2042	3,875	178	272	0	0	0	0	1,063	1,899	0	0	0
2043	3,913	178	272	0	0	0	0	1,094	1,943	0	0	0
2044	3,932	178	272	0	0	0	0	1,105	1,932	0	0	0
2045	3,951	178	272	0	0	0	0	1,109	1,928	0	0	0
2046	3,969	178	272	0	0	0	0	1,114	1,825	0	0	0
2047	3,987	178	272	0	0	0	0	1,120	1,917	0	0	0
2048	4,004	178	272	0	0	0	0	1,128	1,811	0	0	0
2049	4,019	178	272	0	0	0	0	1,130	1,809	0	0	0
2050	4,034	178	272	0	0	0	0	1,134	1,804	0	0	0
2051	4,049	178	272	0	0	0	0	1,139	1,800	0	0	0
2052	4,064	178	272	0	0	0	0	1,146	1,582	0	0	0
2053	4,077	178	272	0	0	0	0	1,148	1,580	0	0	0
2054	4,089	178	272	0	0	0	0	1,152	1,234	0	0	0
2055	4,101	178	272	0	0	0	0	1,155	967	0	0	0
2056	4,113	178	272	0	0	0	0	1,162	566	0	0	0
2057	4,124	178	272	0	0	0	0	1,163	1,223	0	0	0
2058	4,135	178	272	0	0	0	0	1,166	1,352	0	0	0
2059	4,147	178	272	0	0	0	0	1,169	1,295	0	0	0
2060	4,157	178	272	0	0	0	0	1,176	1,289	0	0	0

Central Arizona Project Service Area Model

Tucson

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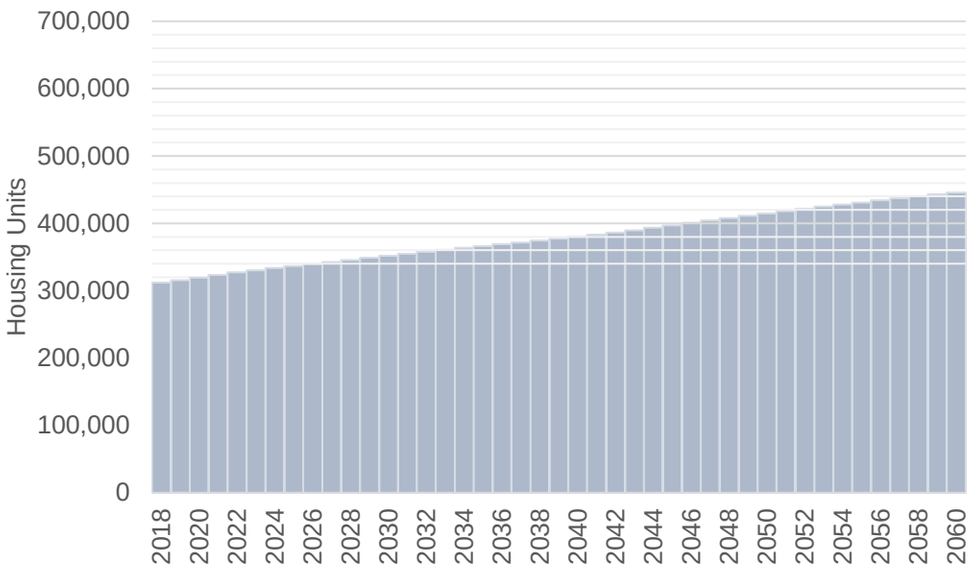
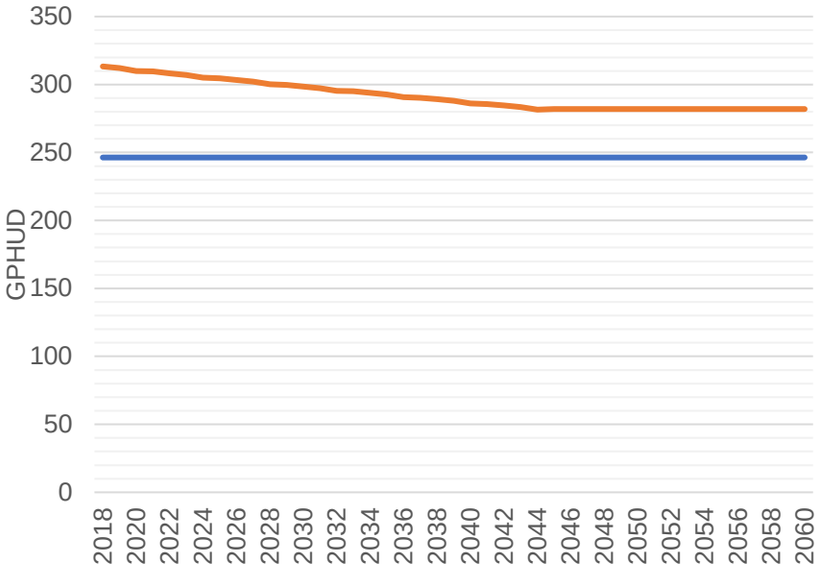
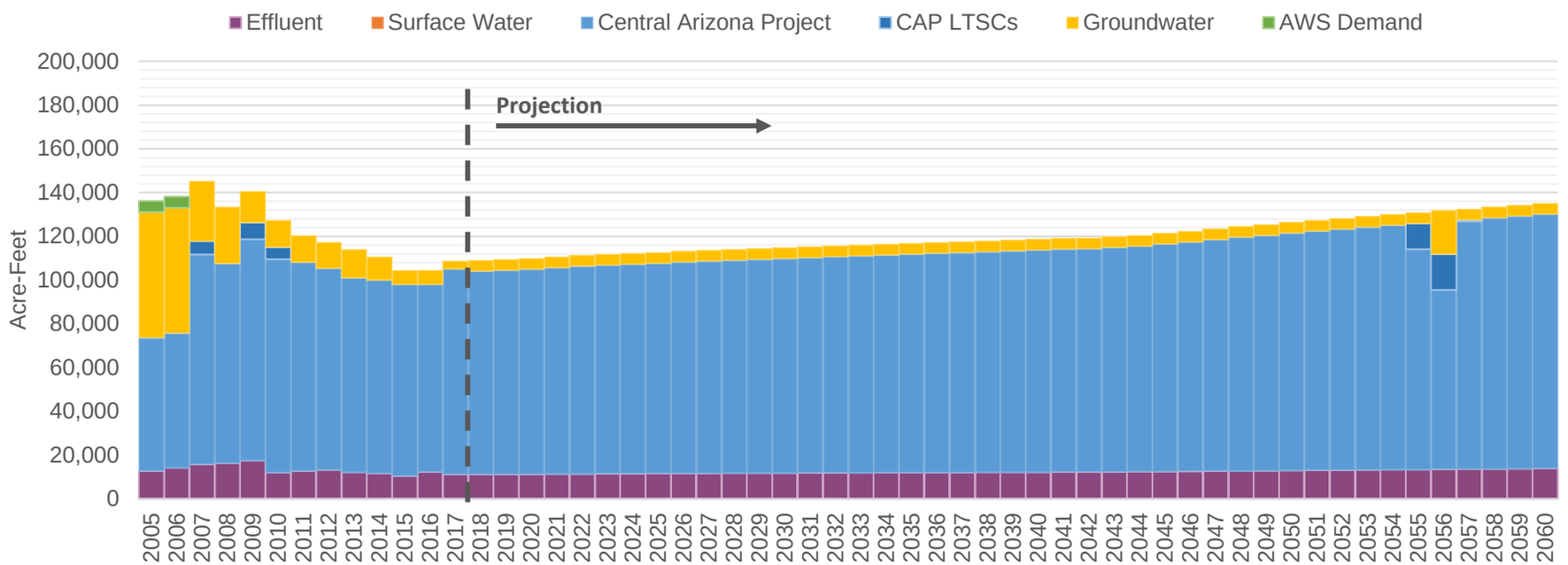
Housing Unit Projection



Gallons Per Housing Unit Per Day



Water Supply Projections



Central Arizona Project Service Area Model

Tucson

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	Demand Assumptions			Water Supply Projections (Acre-Feet)								
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	311,886	313	246	11,236	0	0	0	92,867	51,305	0	4,951	0
2019	315,484	312	246	11,236	0	0	0	93,188	50,984	0	4,951	0
2020	319,407	310	246	11,269	0	0	0	93,765	50,407	0	4,951	0
2021	323,534	310	246	11,332	0	0	0	94,375	49,797	0	4,951	0
2022	327,386	308	246	11,401	0	0	0	94,977	49,195	0	4,951	0
2023	330,416	307	246	11,470	0	0	0	95,429	48,743	0	4,951	0
2024	333,467	305	246	11,524	0	0	0	95,804	48,368	0	4,951	0
2025	336,525	305	246	11,568	0	0	0	96,161	48,011	0	4,951	0
2026	339,590	303	246	11,610	0	0	0	96,541	47,631	0	4,951	0
2027	342,656	302	246	11,653	0	0	0	96,922	47,250	0	4,951	0
2028	345,692	300	246	11,697	0	0	0	97,326	46,846	0	4,951	0
2029	348,735	300	246	11,743	0	0	0	97,675	46,497	0	4,951	0
2030	351,781	299	246	11,784	0	0	0	98,058	46,114	0	4,951	0
2031	354,829	297	246	11,827	0	0	0	98,440	45,732	0	4,951	0
2032	357,867	295	246	11,871	0	0	0	98,858	45,314	0	4,951	0
2033	360,641	295	246	11,919	0	0	0	99,166	45,007	0	4,951	0
2034	363,412	294	246	11,955	0	0	0	99,484	44,688	0	4,951	0
2035	366,179	293	246	11,992	0	0	0	99,803	44,369	0	4,951	0
2036	368,939	291	246	12,029	0	0	0	100,166	44,006	0	4,951	0
2037	371,692	290	246	12,070	0	0	0	100,437	43,735	0	4,951	0
2038	374,572	289	246	12,102	0	0	0	100,779	33,555	0	4,951	0
2039	377,442	288	246	12,140	0	0	0	101,132	10,438	0	4,951	0
2040	380,298	286	246	12,181	0	0	0	101,534	30,348	0	4,951	0
2041	383,141	286	246	12,226	0	0	0	101,824	40,096	0	4,951	0
2042	385,967	285	246	12,261	0	0	0	102,174	38,465	0	4,951	0
2043	389,602	283	246	12,301	0	0	0	102,631	41,541	0	4,951	0
2044	393,326	282	246	12,352	0	0	0	103,263	40,909	0	4,951	0
2045	397,022	282	246	12,422	0	0	0	104,042	40,130	0	4,951	0
2046	400,689	282	246	12,510	0	0	0	104,970	34,544	0	4,951	0
2047	404,325	282	246	12,614	0	0	0	105,873	38,299	0	4,951	0
2048	407,872	282	246	12,718	0	0	0	106,832	32,681	0	4,951	0
2049	411,341	282	246	12,828	0	0	0	107,618	31,895	0	4,951	0
2050	414,774	282	246	12,920	0	0	0	108,478	31,036	0	4,951	0
2051	418,170	282	246	13,018	0	0	0	109,322	30,192	0	4,951	0
2052	421,527	282	246	13,115	0	0	0	110,240	19,272	0	4,951	0
2053	424,770	282	246	13,220	0	0	0	110,963	18,549	0	4,951	0
2054	427,898	282	246	13,305	0	0	0	111,756	1,502	0	4,951	0
2055	430,986	282	246	13,395	0	0	0	100,756	0	11,768	4,951	0
2056	434,031	282	246	13,484	0	0	0	82,002	0	16,392	19,930	0
2057	437,032	282	246	13,580	0	0	0	113,258	0	760	4,951	0
2058	439,989	282	246	13,657	0	0	0	114,764	4,746	0	4,951	0
2059	442,901	282	246	13,742	0	0	0	115,489	1,520	0	4,951	0
2060	445,766	282	246	13,825	0	0	0	116,304	705	0	4,951	0

Central Arizona Project Service Area Model

UniversityofAZ

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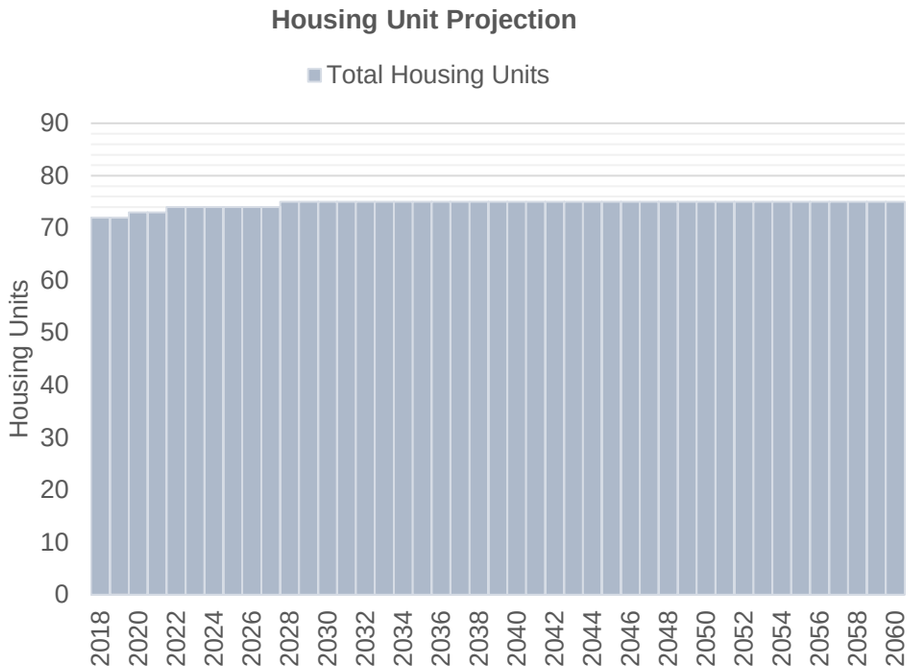

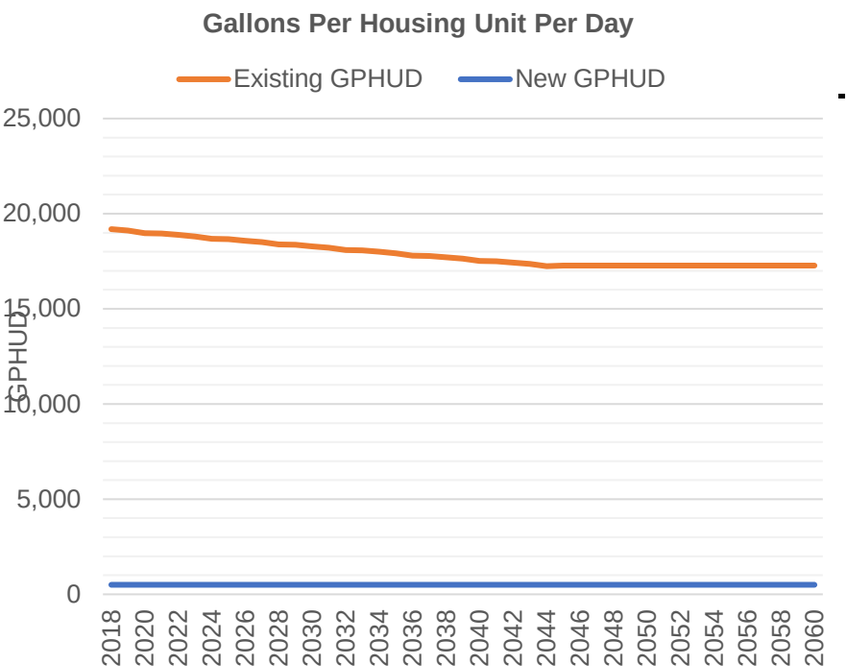

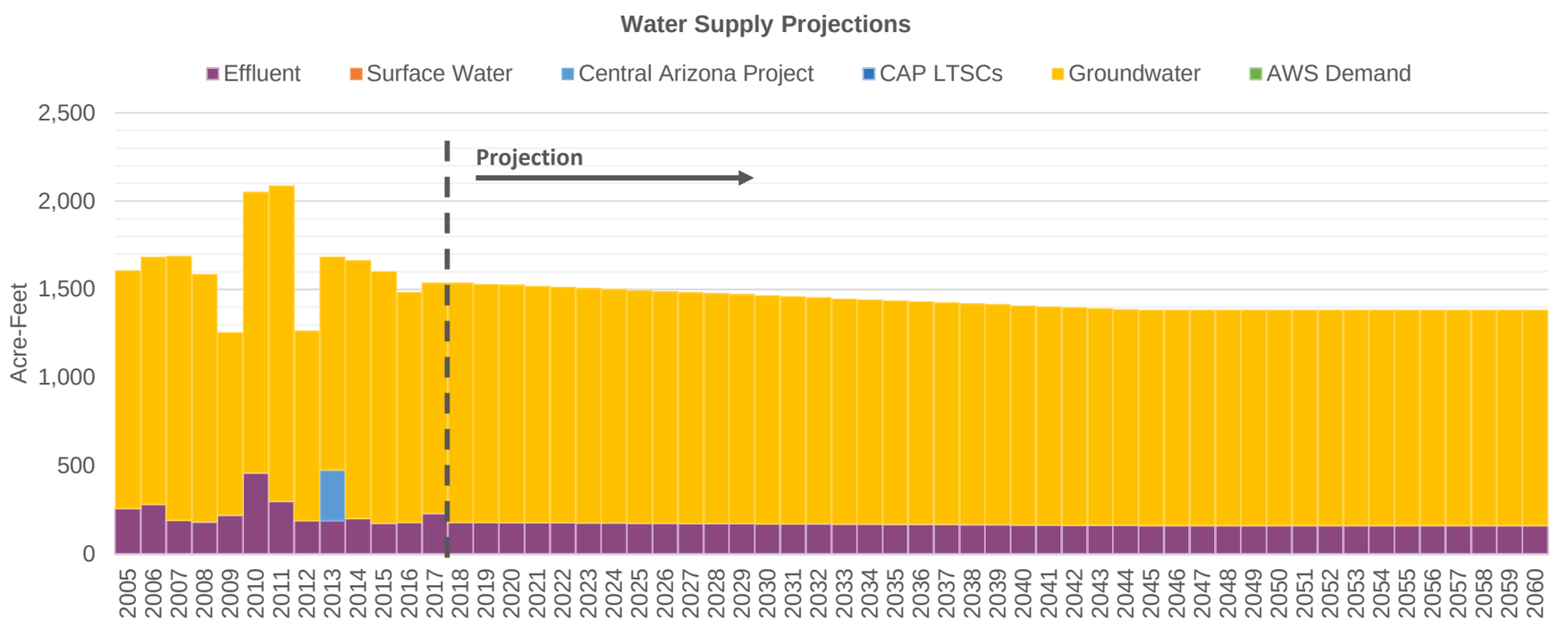

Central Arizona Project Service Area Model

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Demand Assumptions

Water Supply Projections (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	72	19,189	500	180	0	0	0	0	0	0	1,356	0
2019	72	19,112	500	180	0	0	0	0	0	0	1,350	0
2020	73	18,983	500	179	0	0	0	0	0	0	1,345	0
2021	73	18,959	500	179	0	0	0	0	0	0	1,340	0
2022	74	18,883	500	178	0	0	0	0	0	0	1,335	0
2023	74	18,808	500	177	0	0	0	0	0	0	1,330	0
2024	74	18,681	500	177	0	0	0	0	0	0	1,324	0
2025	74	18,658	500	176	0	0	0	0	0	0	1,319	0
2026	74	18,583	500	175	0	0	0	0	0	0	1,314	0
2027	74	18,509	500	174	0	0	0	0	0	0	1,309	0
2028	75	18,384	500	174	0	0	0	0	0	0	1,304	0
2029	75	18,361	500	173	0	0	0	0	0	0	1,299	0
2030	75	18,288	500	172	0	0	0	0	0	0	1,294	0
2031	75	18,214	500	172	0	0	0	0	0	0	1,288	0
2032	75	18,092	500	171	0	0	0	0	0	0	1,283	0
2033	75	18,069	500	170	0	0	0	0	0	0	1,278	0
2034	75	17,997	500	170	0	0	0	0	0	0	1,273	0
2035	75	17,925	500	169	0	0	0	0	0	0	1,268	0
2036	75	17,804	500	168	0	0	0	0	0	0	1,263	0
2037	75	17,782	500	168	0	0	0	0	0	0	1,258	0
2038	75	17,710	500	167	0	0	0	0	0	0	1,253	0
2039	75	17,640	500	166	0	0	0	0	0	0	1,248	0
2040	75	17,521	500	166	0	0	0	0	0	0	1,243	0
2041	75	17,499	500	165	0	0	0	0	0	0	1,238	0
2042	75	17,429	500	164	0	0	0	0	0	0	1,233	0
2043	75	17,359	500	164	0	0	0	0	0	0	1,228	0
2044	75	17,242	500	163	0	0	0	0	0	0	1,223	0
2045	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2046	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2047	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2048	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2049	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2050	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2051	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2052	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2053	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2054	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2055	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2056	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2057	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2058	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2059	75	17,270	500	162	0	0	0	0	0	0	1,222	0
2060	75	17,270	500	162	0	0	0	0	0	0	1,222	0

Central Arizona Project Service Area Model

VailWC

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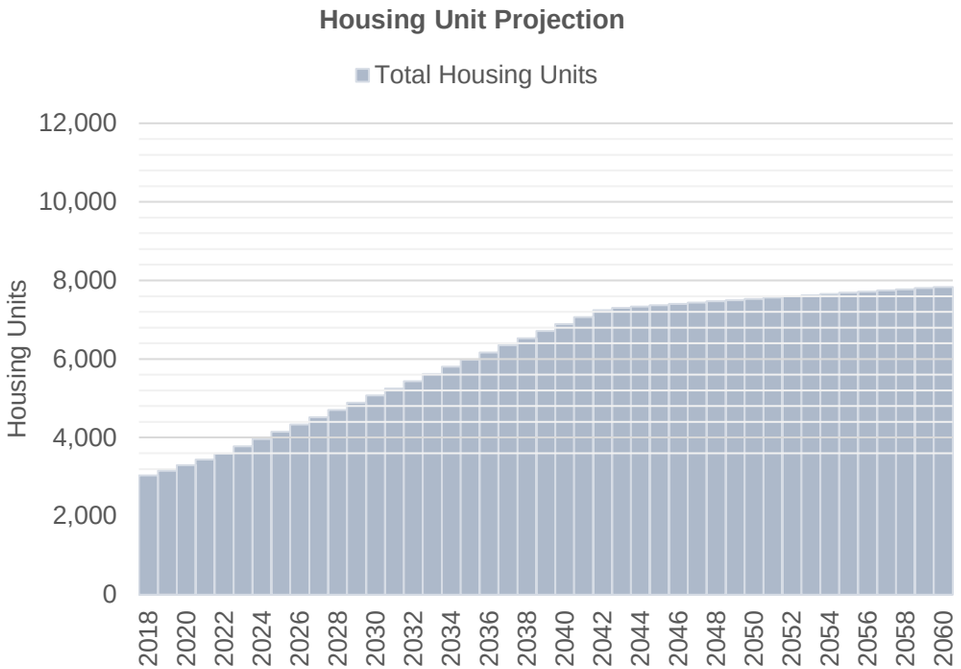

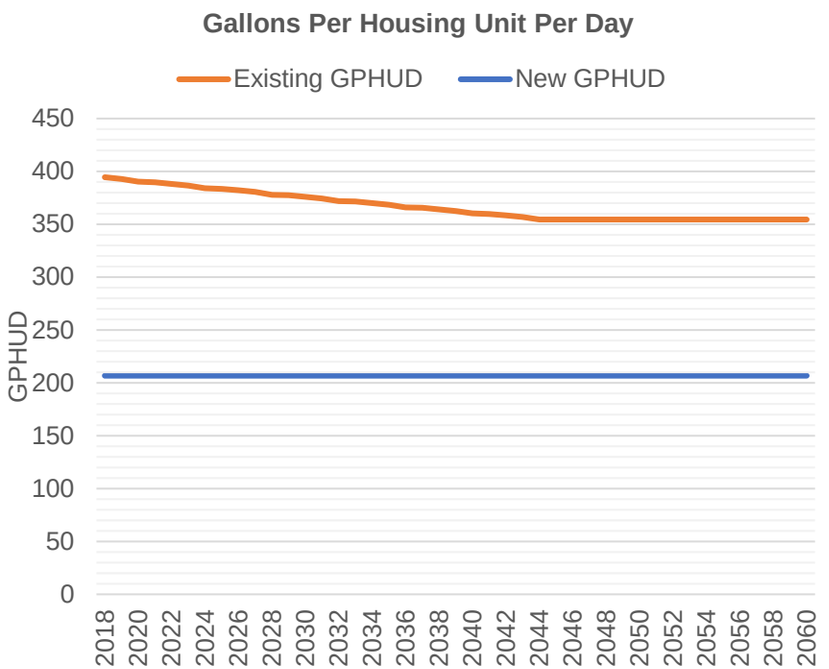

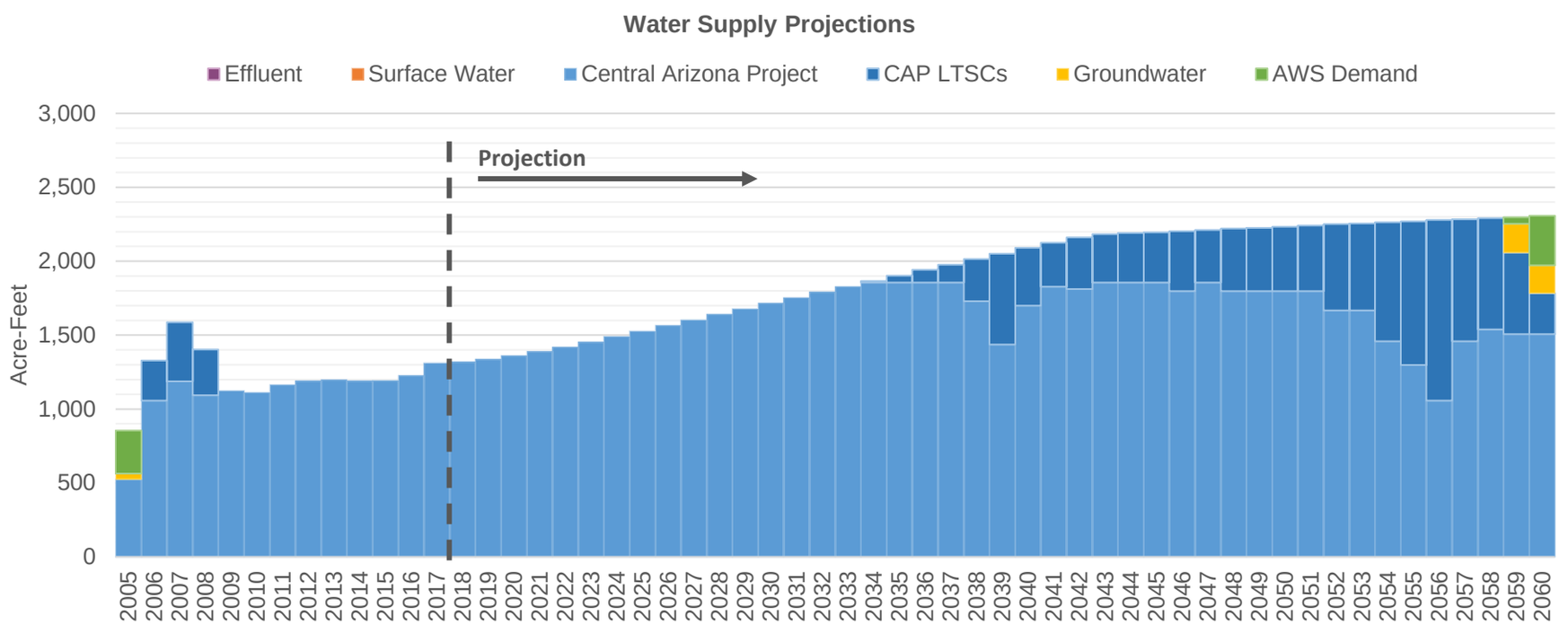

Central Arizona Project Service Area Model

VailWC

E. Official, Very Dry [LSCRBS]

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Demand Assumptions

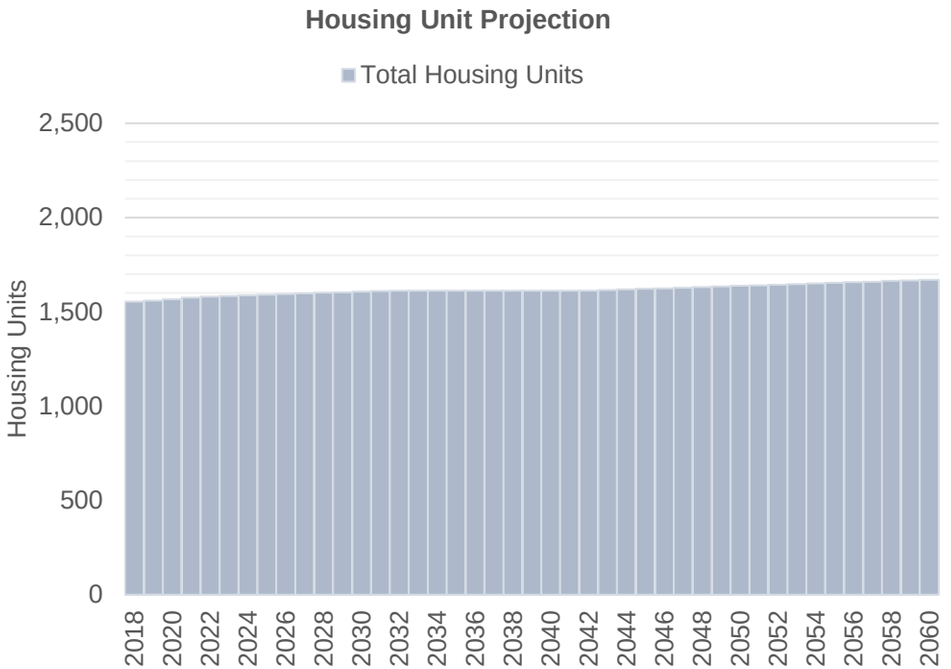
Water Supply Projections (Acre-Feet)

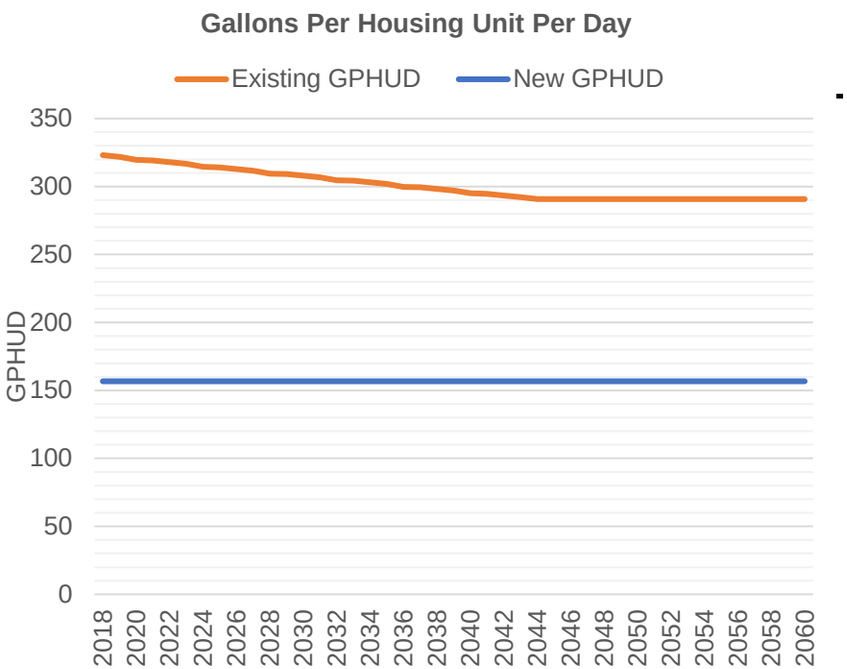
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,033	395	207	0	0	0	0	1,319	538	0	0	0
2019	3,157	393	207	0	0	0	0	1,336	521	0	0	0
2020	3,294	390	207	0	0	0	0	1,361	496	0	0	0
2021	3,438	390	207	0	0	0	0	1,388	469	0	0	0
2022	3,595	388	207	0	0	0	0	1,418	439	0	0	0
2023	3,778	387	207	0	0	0	0	1,452	405	0	0	0
2024	3,963	384	207	0	0	0	0	1,490	367	0	0	0
2025	4,147	384	207	0	0	0	0	1,527	330	0	0	0
2026	4,333	382	207	0	0	0	0	1,565	292	0	0	0
2027	4,518	381	207	0	0	0	0	1,603	254	0	0	0
2028	4,701	378	207	0	0	0	0	1,641	216	0	0	0
2029	4,885	378	207	0	0	0	0	1,678	179	0	0	0
2030	5,069	376	207	0	0	0	0	1,715	142	0	0	0
2031	5,253	374	207	0	0	0	0	1,753	104	0	0	0
2032	5.437	372	207	0	0	0	0	1.792	65	0	0	0
2033	5,620	371	207	0	0	0	0	1,828	29	0	0	0
2034	5,803	370	207	0	0	0	0	1,857	0	9	0	0
2035	5,985	369	207	0	0	0	0	1,857	0	46	0	0
2036	6,167	366	207	0	0	0	0	1,857	0	85	0	0
2037	6,348	366	207	0	0	0	0	1,857	0	120	0	0
2038	6,529	364	207	0	0	0	0	1,730	0	284	0	0
2039	6,709	363	207	0	0	0	0	1,437	0	614	0	0
2040	6,888	360	207	0	0	0	0	1,699	0	392	0	0
2041	7,067	360	207	0	0	0	0	1,828	0	297	0	0
2042	7,244	358	207	0	0	0	0	1,811	0	350	0	0
2043	7,299	357	207	0	0	0	0	1,857	0	326	0	0
2044	7,333	355	207	0	0	0	0	1,857	0	335	0	0
2045	7,367	355	207	0	0	0	0	1,857	0	339	0	0
2046	7,400	355	207	0	0	0	0	1,797	0	406	0	0
2047	7,433	355	207	0	0	0	0	1,857	0	354	0	0
2048	7,466	355	207	0	0	0	0	1,797	0	424	0	0
2049	7,498	355	207	0	0	0	0	1,797	0	429	0	0
2050	7,530	355	207	0	0	0	0	1,797	0	437	0	0
2051	7,561	355	207	0	0	0	0	1,797	0	444	0	0
2052	7,593	355	207	0	0	0	0	1,668	0	583	0	0
2053	7,624	355	207	0	0	0	0	1,668	0	587	0	0
2054	7,655	355	207	0	0	0	0	1,459	0	804	0	0
2055	7,686	355	207	0	0	0	0	1,298	0	972	0	0
2056	7,716	355	207	0	0	0	0	1,056	0	1,224	0	0
2057	7,746	355	207	0	0	0	0	1,459	0	825	0	0
2058	7,776	355	207	0	0	0	0	1,539	0	751	0	0
2059	7,805	355	207	0	0	0	0	1,507	0	552	193	45
2060	7,834	355	207	0	0	0	0	1,507	0	276	188	336

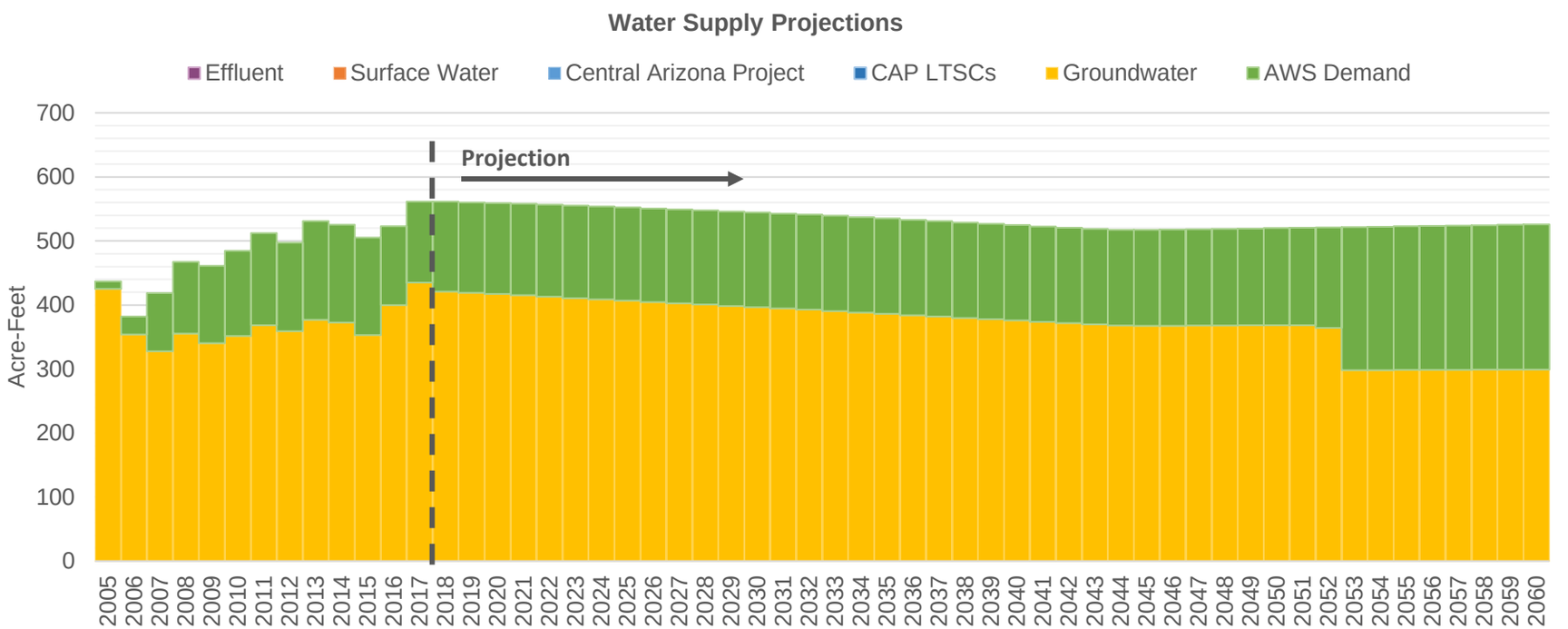
Central Arizona Project Service Area Model

VoyagerWC

E. Official, Very Dry [LSCRBS]







Central Arizona Project Service Area Model

VoyagerWC

E. Official, Very Dry [LSCRBS]

7/14/20 9:06 AM

Demand Assumptions

Water Supply Projections (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,554	323	157	0	0	0	0	0	0	0	421	141
2019	1,560	322	157	0	0	0	0	0	0	0	419	141
2020	1,567	320	157	0	0	0	0	0	0	0	417	142
2021	1,575	319	157	0	0	0	0	0	0	0	415	143
2022	1,581	318	157	0	0	0	0	0	0	0	413	144
2023	1,584	317	157	0	0	0	0	0	0	0	411	145
2024	1,588	315	157	0	0	0	0	0	0	0	409	145
2025	1,591	314	157	0	0	0	0	0	0	0	407	146
2026	1,594	313	157	0	0	0	0	0	0	0	405	146
2027	1,598	312	157	0	0	0	0	0	0	0	403	146
2028	1,601	310	157	0	0	0	0	0	0	0	401	147
2029	1,604	309	157	0	0	0	0	0	0	0	399	147
2030	1,607	308	157	0	0	0	0	0	0	0	397	148
2031	1,610	307	157	0	0	0	0	0	0	0	395	148
2032	1,613	305	157	0	0	0	0	0	0	0	393	149
2033	1,613	304	157	0	0	0	0	0	0	0	390	149
2034	1,613	303	157	0	0	0	0	0	0	0	388	149
2035	1,613	302	157	0	0	0	0	0	0	0	386	149
2036	1,613	300	157	0	0	0	0	0	0	0	384	149
2037	1,613	299	157	0	0	0	0	0	0	0	382	149
2038	1,613	298	157	0	0	0	0	0	0	0	380	149
2039	1,613	297	157	0	0	0	0	0	0	0	378	149
2040	1,613	295	157	0	0	0	0	0	0	0	376	149
2041	1,613	295	157	0	0	0	0	0	0	0	374	149
2042	1,613	293	157	0	0	0	0	0	0	0	372	149
2043	1,615	292	157	0	0	0	0	0	0	0	370	149
2044	1,619	291	157	0	0	0	0	0	0	0	368	149
2045	1,622	291	157	0	0	0	0	0	0	0	368	150
2046	1,625	291	157	0	0	0	0	0	0	0	368	150
2047	1,628	291	157	0	0	0	0	0	0	0	368	150
2048	1,631	291	157	0	0	0	0	0	0	0	368	151
2049	1,635	291	157	0	0	0	0	0	0	0	368	151
2050	1,638	291	157	0	0	0	0	0	0	0	368	152
2051	1,641	291	157	0	0	0	0	0	0	0	368	152
2052	1,644	291	157	0	0	0	0	0	0	0	364	157
2053	1,647	291	157	0	0	0	0	0	0	0	298	223
2054	1,651	291	157	0	0	0	0	0	0	0	298	224
2055	1,654	291	157	0	0	0	0	0	0	0	298	224
2056	1,657	291	157	0	0	0	0	0	0	0	299	225
2057	1,660	291	157	0	0	0	0	0	0	0	299	225
2058	1,664	291	157	0	0	0	0	0	0	0	299	226
2059	1,667	291	157	0	0	0	0	0	0	0	299	226
2060	1,670	291	157	0	0	0	0	0	0	0	299	226

CAP:SAM Supply and Demand Projections by Water Provider

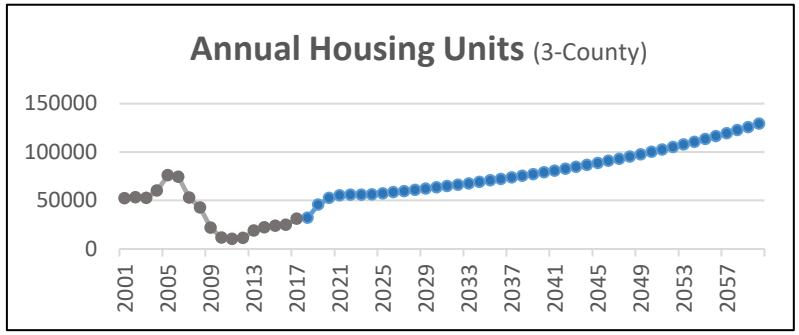
Scenario F

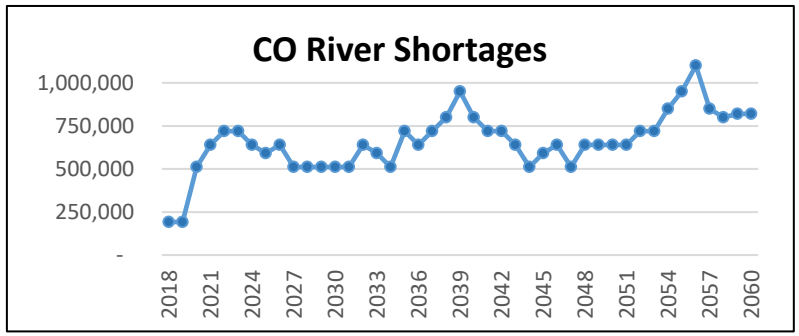
Climate: Worse Case
Growth Rate: Rapid
Growth Pattern: Outward
Relative Risk: High

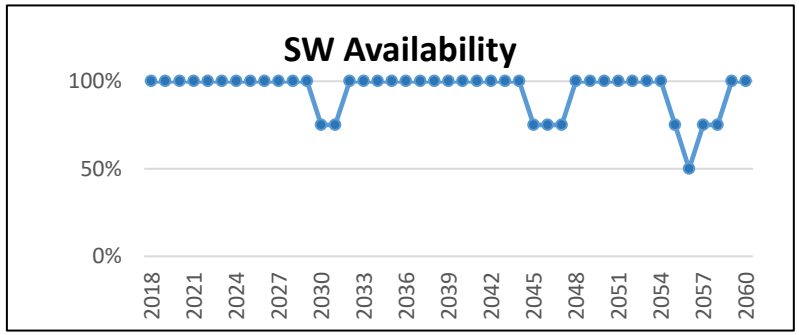
F. Rapid, Outward, Very Dry Climate [LSCRBS **Run Date:** 7/15/2020 **Filename:** CAPServiceArea_v3.50_LSCRBS_AC

Growth rate based on High growth series from the State, and outward growth pattern in CAP-SAM, mining growth w/o

Allow Shortages	Yes	
Select CRSS Array	3	*3=Synthetic*
Use Specific Trace	Yes	
Selected Trace	3	*1=Moderate; 2=Deep; 3=Slight*
AWBA Max M&I	20%	
Surface Water Scenario	3	*1=No Reduction; 2=Occational; 3=Frequent*
Use CAP Buildup	Yes	
CAP Buildup Scenario	2	*1=2035; 2=2045*
HU Growth Pattern	3	*1=Baseline*
HU Forecast	2	*1=Use Curve; 2=Eller Forecast*
HU Curve	1	
HU Growth Start Rate	2%	
HU Ordinary Level	56,000	
HU Rate @ 50 yrs	3%	
GPHUD Change Existing	-0.4%	*per year*
GPHUD Max Change Existing	-10%	
GPHUD Min Existing	200	
GPHUD Scenario New	1	
GPHUD Change New	0.0%	*per year*
Ag Climate Adjustment	0.2	
Ag Efficiency Increase	0.1%	*per year*
Ag Efficiency Goal	80%	
Ag Replace Crop CU	2.66	
Ag Intensity Scenario	2	
Ag Develop on Crops	60%	*Perecent of max on active Ag*
Ag Acres Replace Percent	0%	
Ag Replace Crop Year	2025	



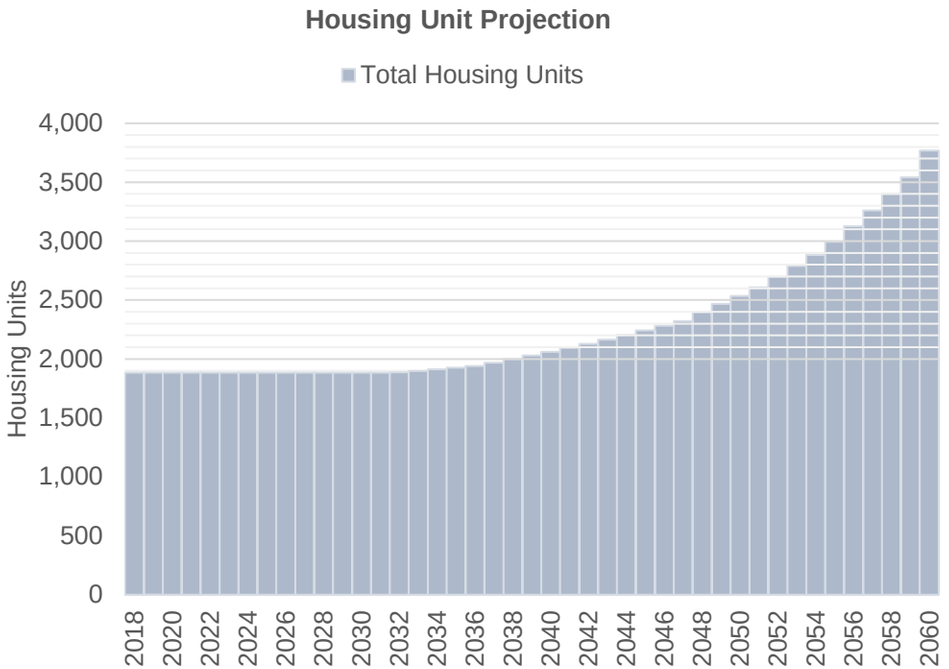


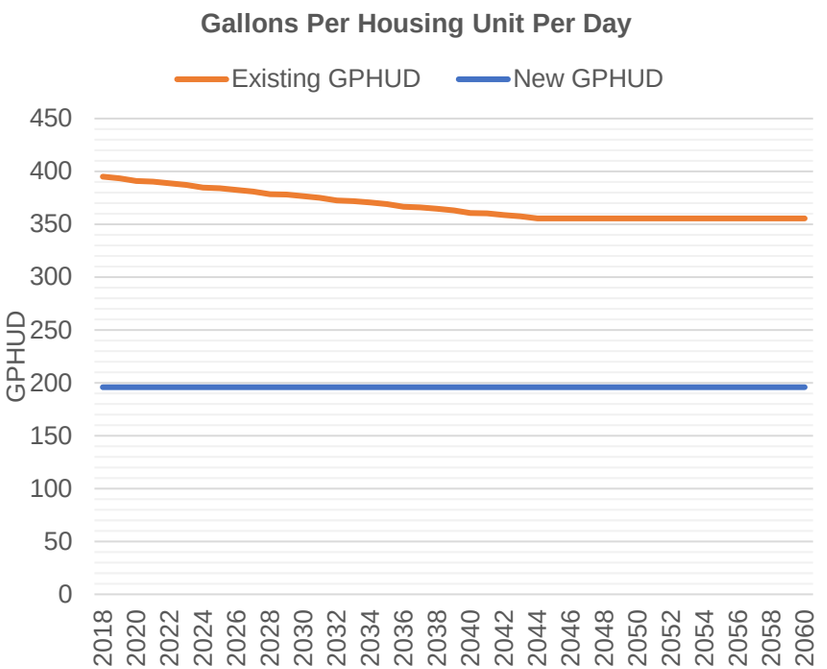


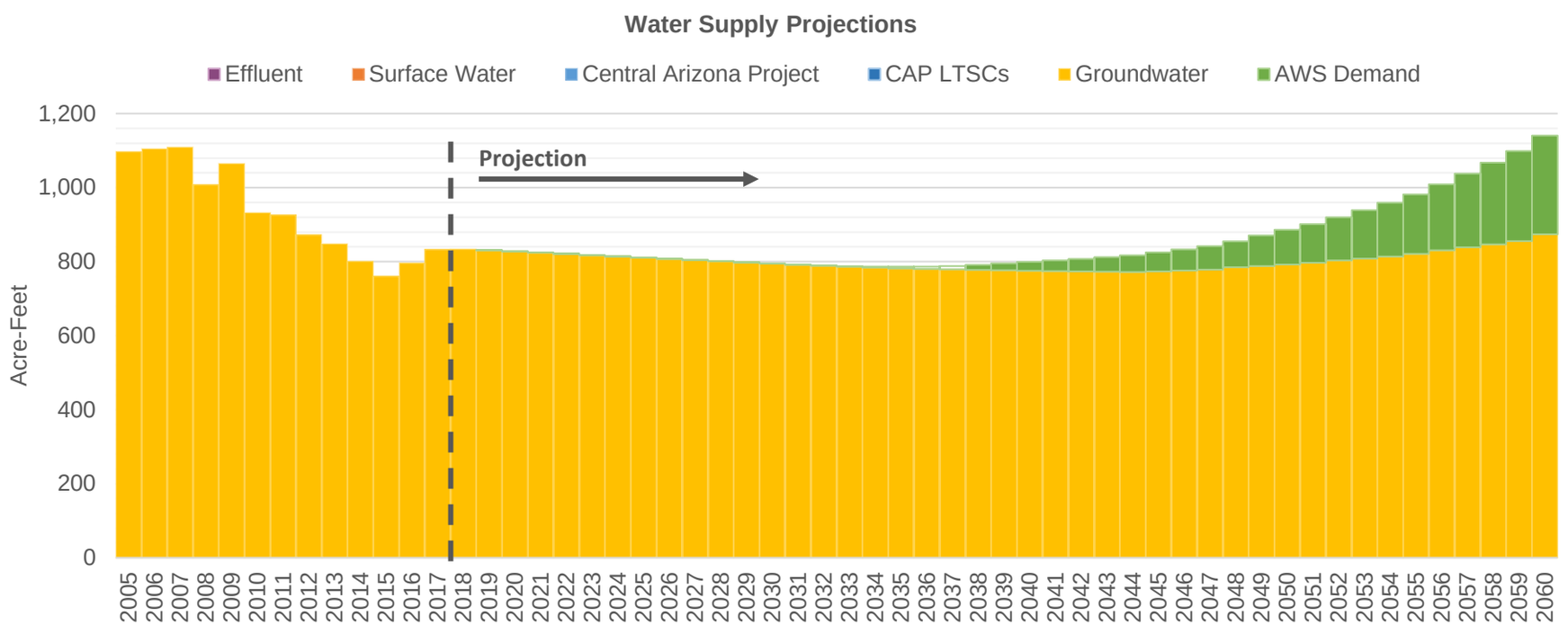
Central Arizona Project Service Area Model

AvraWaterCoop

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

AvraWaterCoop

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

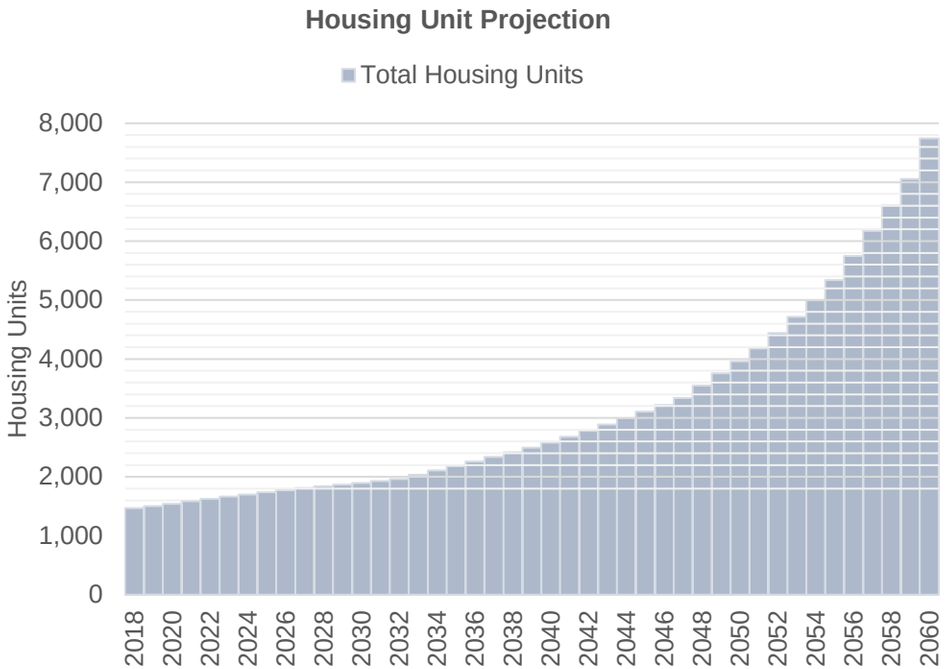
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

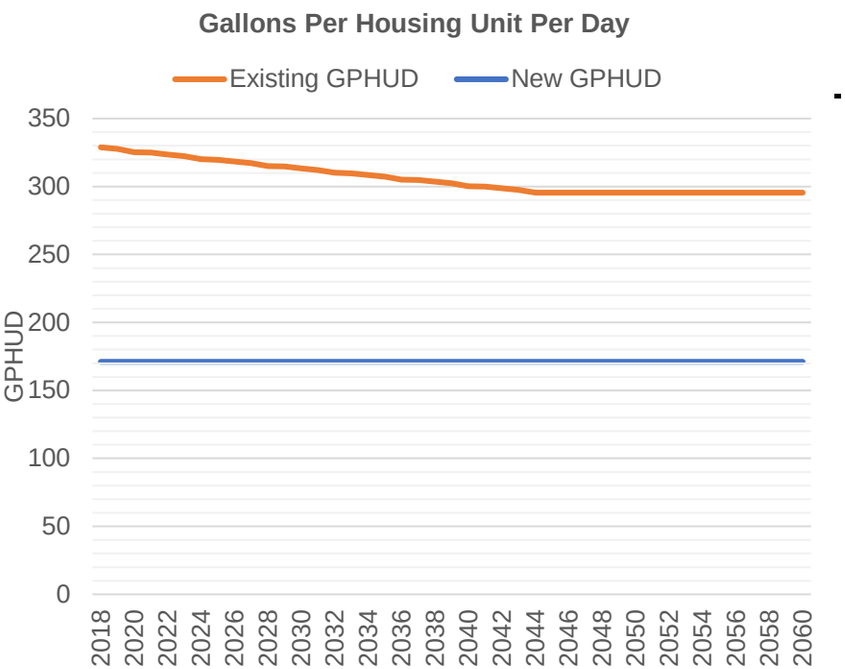
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,885	395	196	0	0	0	0	0	0	0	834	0
2019	1,885	393	196	0	0	0	0	0	0	0	831	0
2020	1,885	391	196	0	0	0	0	0	0	0	827	0
2021	1,885	390	196	0	0	0	0	0	0	0	824	0
2022	1,885	389	196	0	0	0	0	0	0	0	821	0
2023	1,885	387	196	0	0	0	0	0	0	0	817	0
2024	1,885	385	196	0	0	0	0	0	0	0	814	0
2025	1,885	384	196	0	0	0	0	0	0	0	811	0
2026	1,885	383	196	0	0	0	0	0	0	0	808	0
2027	1,885	381	196	0	0	0	0	0	0	0	804	0
2028	1,885	378	196	0	0	0	0	0	0	0	801	0
2029	1,885	378	196	0	0	0	0	0	0	0	798	0
2030	1,885	377	196	0	0	0	0	0	0	0	795	0
2031	1,885	375	196	0	0	0	0	0	0	0	792	0
2032	1,886	372	196	0	0	0	0	0	0	0	789	0
2033	1,899	372	196	0	0	0	0	0	0	0	787	0
2034	1,912	371	196	0	0	0	0	0	0	0	784	2
2035	1,925	369	196	0	0	0	0	0	0	0	782	4
2036	1,939	367	196	0	0	0	0	0	0	0	780	7
2037	1,969	366	196	0	0	0	0	0	0	0	779	9
2038	1,999	365	196	0	0	0	0	0	0	0	778	14
2039	2,030	363	196	0	0	0	0	0	0	0	777	18
2040	2,062	361	196	0	0	0	0	0	0	0	776	23
2041	2,095	360	196	0	0	0	0	0	0	0	775	29
2042	2,129	359	196	0	0	0	0	0	0	0	774	34
2043	2,165	357	196	0	0	0	0	0	0	0	773	39
2044	2,203	356	196	0	0	0	0	0	0	0	772	45
2045	2,242	356	196	0	0	0	0	0	0	0	773	51
2046	2,282	356	196	0	0	0	0	0	0	0	776	58
2047	2,323	356	196	0	0	0	0	0	0	0	778	64
2048	2,397	356	196	0	0	0	0	0	0	0	785	71
2049	2,467	356	196	0	0	0	0	0	0	0	788	82
2050	2,536	356	196	0	0	0	0	0	0	0	792	94
2051	2,609	356	196	0	0	0	0	0	0	0	797	105
2052	2,698	356	196	0	0	0	0	0	0	0	803	117
2053	2,789	356	196	0	0	0	0	0	0	0	808	131
2054	2,883	356	196	0	0	0	0	0	0	0	814	145
2055	2,994	356	196	0	0	0	0	0	0	0	821	160
2056	3,126	356	196	0	0	0	0	0	0	0	831	178
2057	3,261	356	196	0	0	0	0	0	0	0	838	199
2058	3,400	356	196	0	0	0	0	0	0	0	847	221
2059	3,542	356	196	0	0	0	0	0	0	0	856	243
2060	3,769	356	196	0	0	0	0	0	0	0	874	266

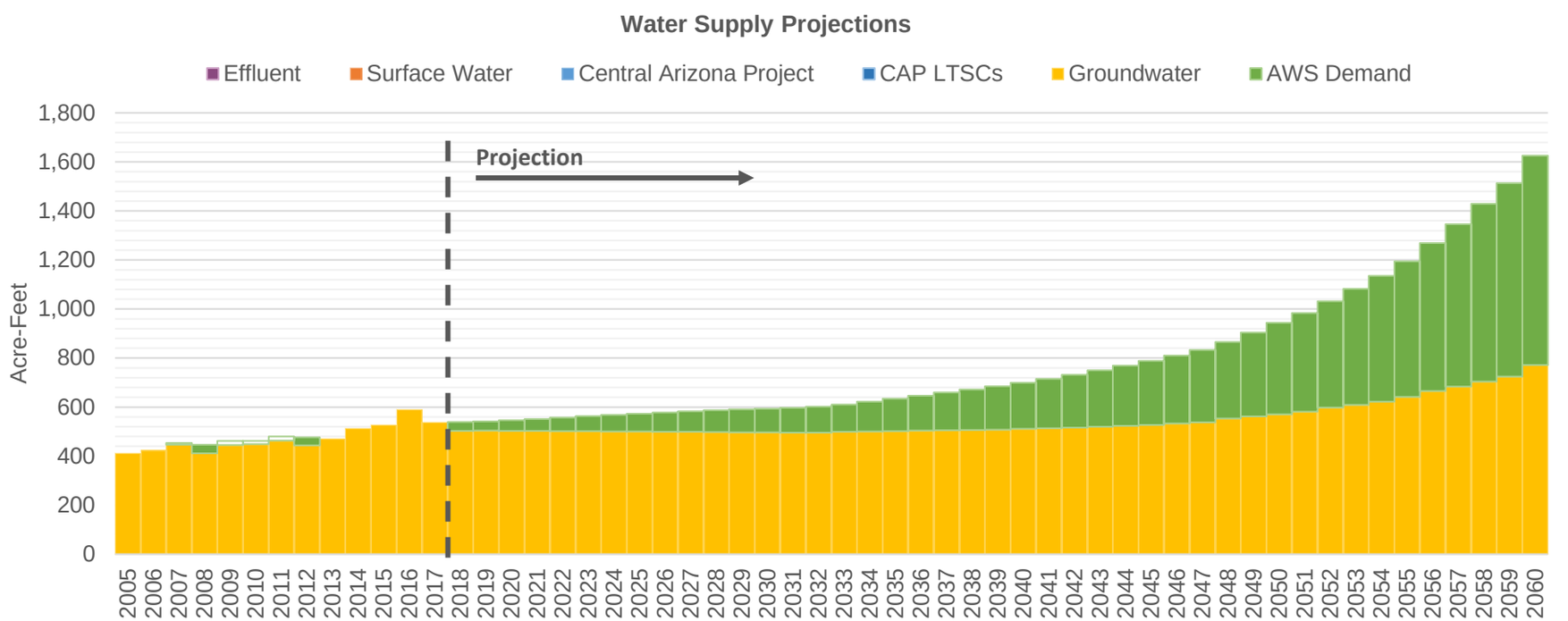
AZWCOracle

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

AZWCOracle

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

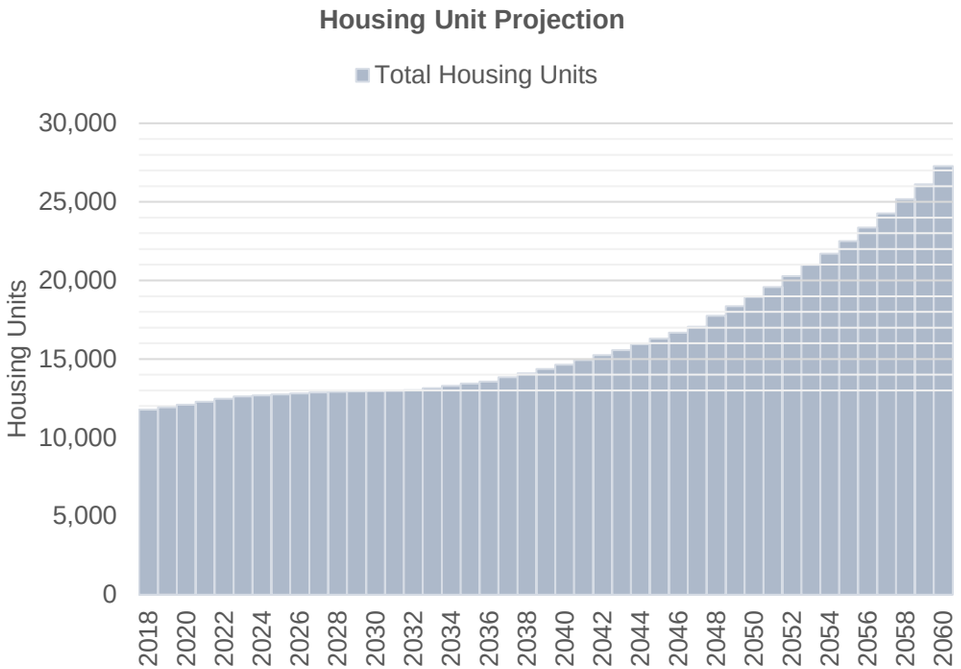
Water Supply Projections (Acre-Feet)

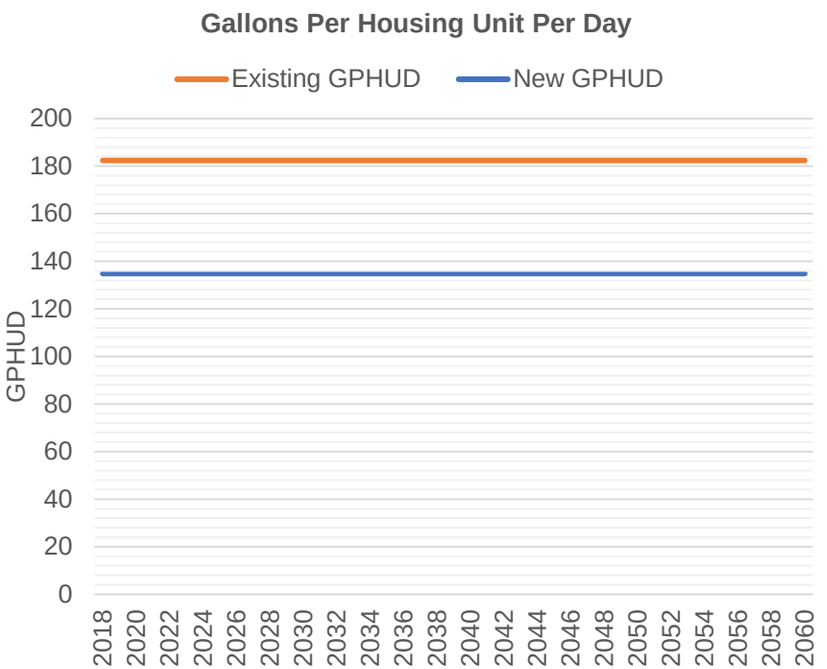
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,471	329	171	0	0	0	0	0	0	0	503	36
2019	1,505	328	171	0	0	0	0	0	0	0	504	37
2020	1,544	325	171	0	0	0	0	0	0	0	503	43
2021	1,585	325	171	0	0	0	0	0	0	0	503	49
2022	1,627	324	171	0	0	0	0	0	0	0	502	55
2023	1,666	322	171	0	0	0	0	0	0	0	501	62
2024	1,701	320	171	0	0	0	0	0	0	0	501	67
2025	1,737	320	171	0	0	0	0	0	0	0	500	73
2026	1,773	318	171	0	0	0	0	0	0	0	500	78
2027	1,810	317	171	0	0	0	0	0	0	0	499	83
2028	1,842	315	171	0	0	0	0	0	0	0	499	89
2029	1,870	315	171	0	0	0	0	0	0	0	497	93
2030	1,898	313	171	0	0	0	0	0	0	0	497	97
2031	1,928	312	171	0	0	0	0	0	0	0	496	101
2032	1.964	310	171	0	0	0	0	0	0	0	496	106
2033	2,036	310	171	0	0	0	0	0	0	0	499	111
2034	2,109	308	171	0	0	0	0	0	0	0	500	122
2035	2,184	307	171	0	0	0	0	0	0	0	502	132
2036	2,260	305	171	0	0	0	0	0	0	0	504	143
2037	2,337	305	171	0	0	0	0	0	0	0	505	154
2038	2,415	304	171	0	0	0	0	0	0	0	507	165
2039	2,496	302	171	0	0	0	0	0	0	0	508	177
2040	2,581	300	171	0	0	0	0	0	0	0	511	189
2041	2,680	300	171	0	0	0	0	0	0	0	514	201
2042	2,782	299	171	0	0	0	0	0	0	0	517	215
2043	2,888	298	171	0	0	0	0	0	0	0	520	230
2044	2,996	296	171	0	0	0	0	0	0	0	524	246
2045	3,107	296	171	0	0	0	0	0	0	0	527	262
2046	3,221	296	171	0	0	0	0	0	0	0	533	278
2047	3,337	296	171	0	0	0	0	0	0	0	538	294
2048	3,552	296	171	0	0	0	0	0	0	0	554	311
2049	3,757	296	171	0	0	0	0	0	0	0	562	343
2050	3,959	296	171	0	0	0	0	0	0	0	571	373
2051	4,176	296	171	0	0	0	0	0	0	0	582	402
2052	4,443	296	171	0	0	0	0	0	0	0	598	434
2053	4,716	296	171	0	0	0	0	0	0	0	609	473
2054	4,997	296	171	0	0	0	0	0	0	0	622	512
2055	5,338	296	171	0	0	0	0	0	0	0	641	553
2056	5,750	296	171	0	0	0	0	0	0	0	666	603
2057	6,173	296	171	0	0	0	0	0	0	0	683	663
2058	6,607	296	171	0	0	0	0	0	0	0	704	725
2059	7,053	296	171	0	0	0	0	0	0	0	725	788
2060	7,747	296	171	0	0	0	0	0	0	0	772	853

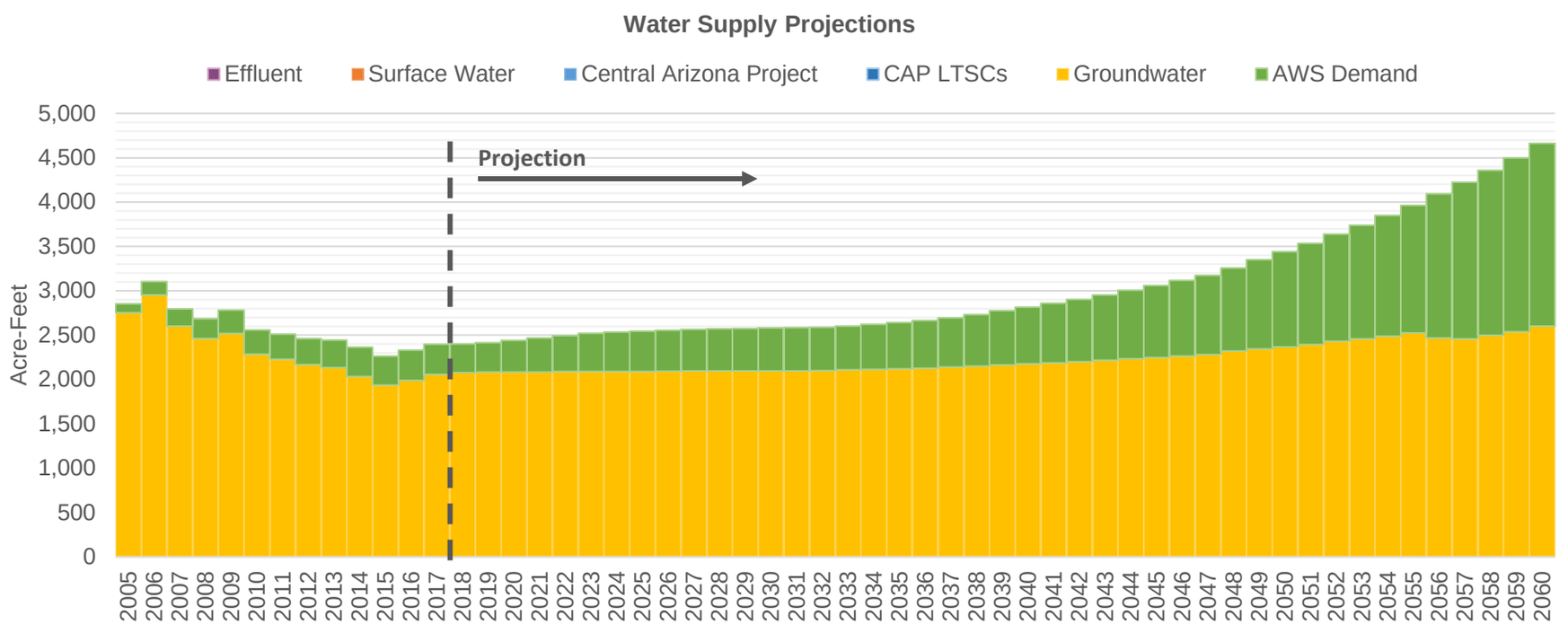
Central Arizona Project Service Area Model

CommWaterGreenVly

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

CommWaterGre

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

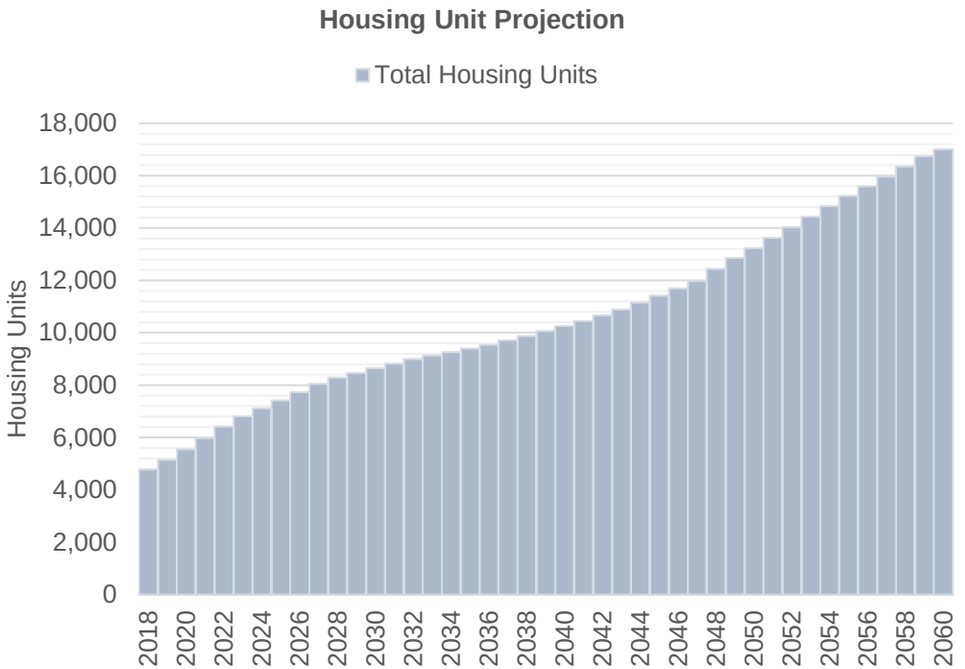
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

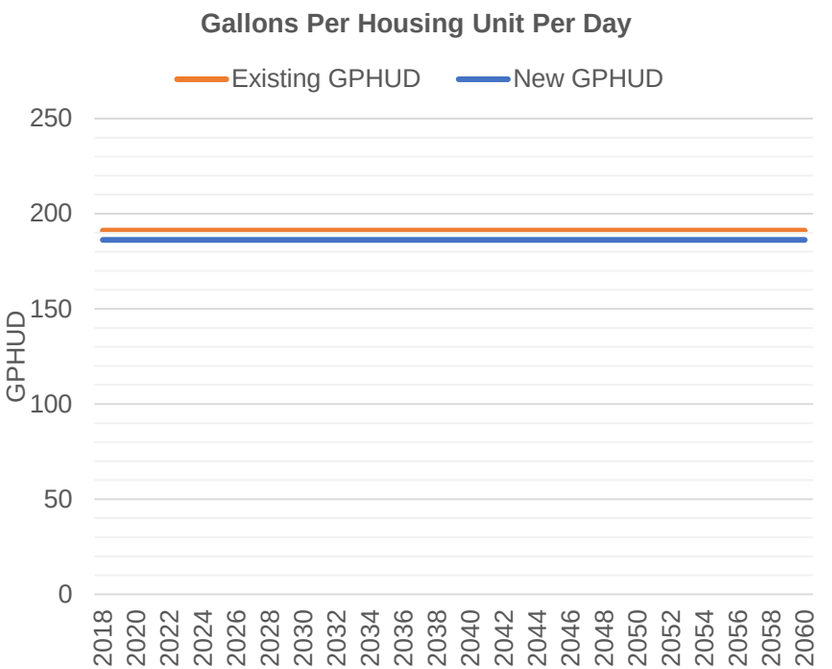
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	11,773	182	135	0	0	0	0	0	0	0	2,078	322
2019	11,925	182	135	0	0	0	0	0	0	0	2,085	330
2020	12,101	182	135	0	0	0	0	0	0	0	2,085	355
2021	12,285	182	135	0	0	0	0	0	0	0	2,085	382
2022	12,472	182	135	0	0	0	0	0	0	0	2,090	405
2023	12,618	182	135	0	0	0	0	0	0	0	2,091	428
2024	12,679	182	135	0	0	0	0	0	0	0	2,090	446
2025	12,741	182	135	0	0	0	0	0	0	0	2,091	454
2026	12,805	182	135	0	0	0	0	0	0	0	2,093	461
2027	12,869	182	135	0	0	0	0	0	0	0	2,096	468
2028	12,909	182	135	0	0	0	0	0	0	0	2,097	476
2029	12,932	182	135	0	0	0	0	0	0	0	2,096	480
2030	12,954	182	135	0	0	0	0	0	0	0	2,097	483
2031	12,977	182	135	0	0	0	0	0	0	0	2,098	485
2032	13.019	182	135	0	0	0	0	0	0	0	2.101	488
2033	13,152	182	135	0	0	0	0	0	0	0	2,109	493
2034	13,288	182	135	0	0	0	0	0	0	0	2,114	508
2035	13,428	182	135	0	0	0	0	0	0	0	2,119	523
2036	13,571	182	135	0	0	0	0	0	0	0	2,126	539
2037	13,829	182	135	0	0	0	0	0	0	0	2,140	554
2038	14,093	182	135	0	0	0	0	0	0	0	2,152	582
2039	14,363	182	135	0	0	0	0	0	0	0	2,163	611
2040	14,641	182	135	0	0	0	0	0	0	0	2,176	640
2041	14,936	182	135	0	0	0	0	0	0	0	2,188	671
2042	15,238	182	135	0	0	0	0	0	0	0	2,201	703
2043	15,572	182	135	0	0	0	0	0	0	0	2,216	736
2044	15,931	182	135	0	0	0	0	0	0	0	2,234	772
2045	16,299	182	135	0	0	0	0	0	0	0	2,248	811
2046	16,675	182	135	0	0	0	0	0	0	0	2,264	851
2047	17,061	182	135	0	0	0	0	0	0	0	2,281	892
2048	17,740	182	135	0	0	0	0	0	0	0	2,322	934
2049	18,358	182	135	0	0	0	0	0	0	0	2,343	1,008
2050	18,952	182	135	0	0	0	0	0	0	0	2,368	1,075
2051	19,574	182	135	0	0	0	0	0	0	0	2,395	1,140
2052	20,267	182	135	0	0	0	0	0	0	0	2,430	1,208
2053	20,977	182	135	0	0	0	0	0	0	0	2,457	1,283
2054	21,706	182	135	0	0	0	0	0	0	0	2,489	1,360
2055	22,501	182	135	0	0	0	0	0	0	0	2,524	1,440
2056	23,371	182	135	0	0	0	0	0	0	0	2,469	1,626
2057	24,263	182	135	0	0	0	0	0	0	0	2,459	1,764
2058	25,179	182	135	0	0	0	0	0	0	0	2,498	1,861
2059	26,120	182	135	0	0	0	0	0	0	0	2,539	1,961
2060	27,268	182	135	0	0	0	0	0	0	0	2,601	2,063

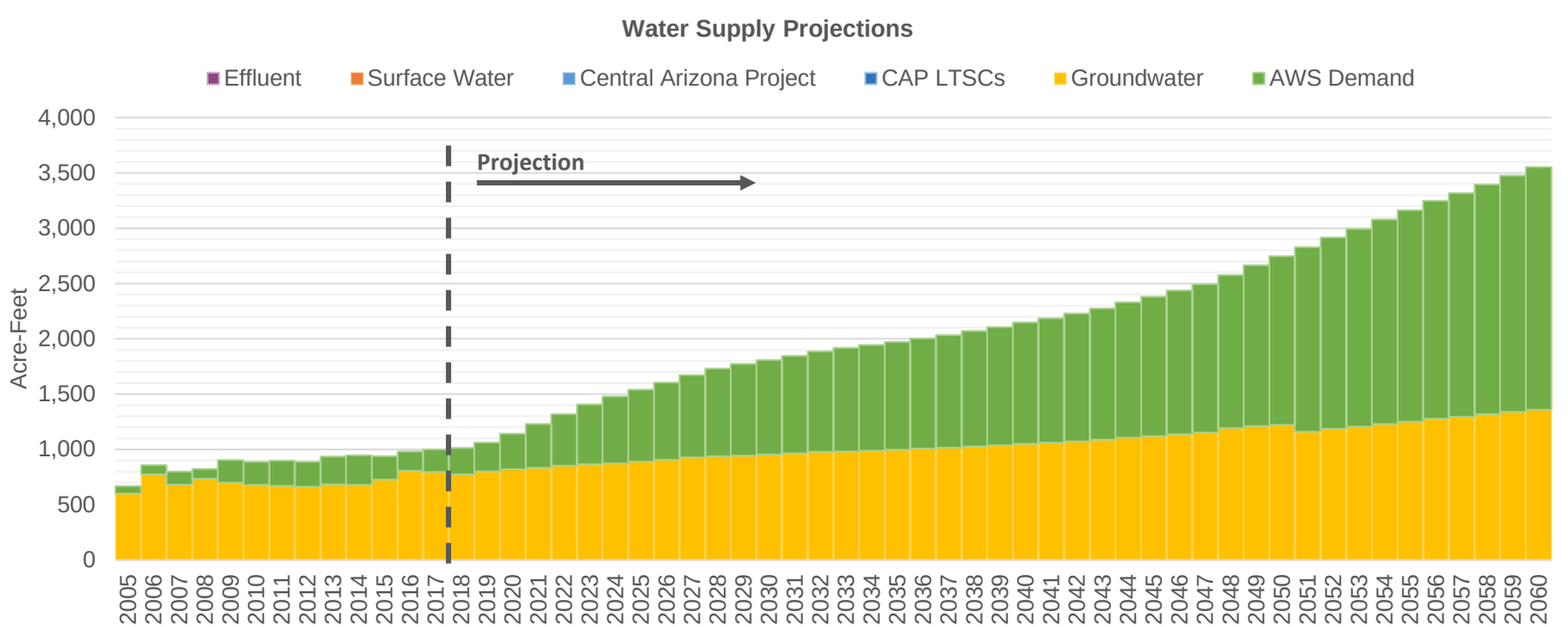
Central Arizona Project Service Area Model

FarmersWC

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

FarmersWC

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

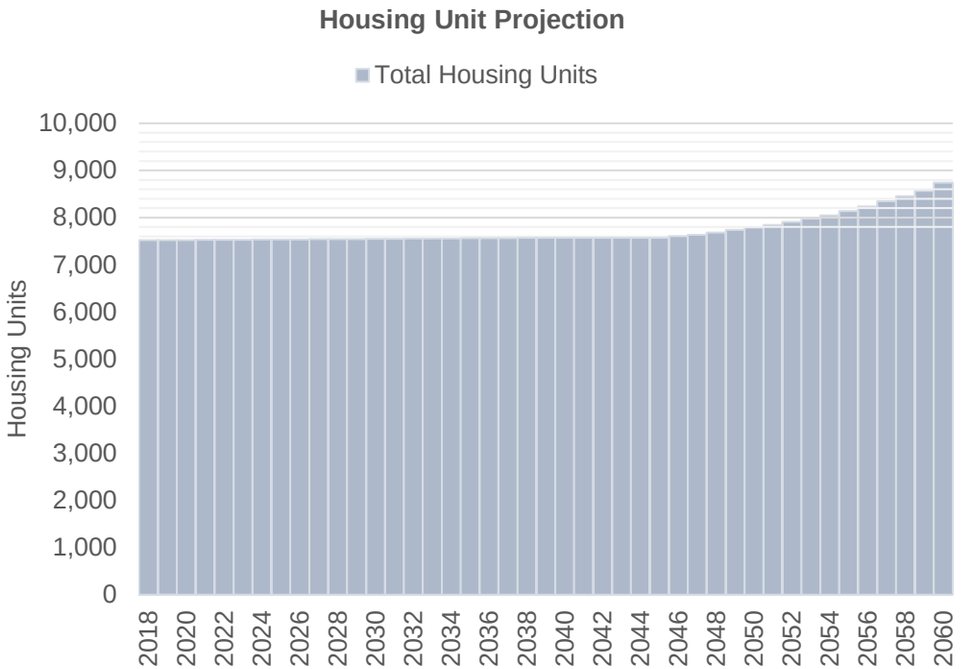
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

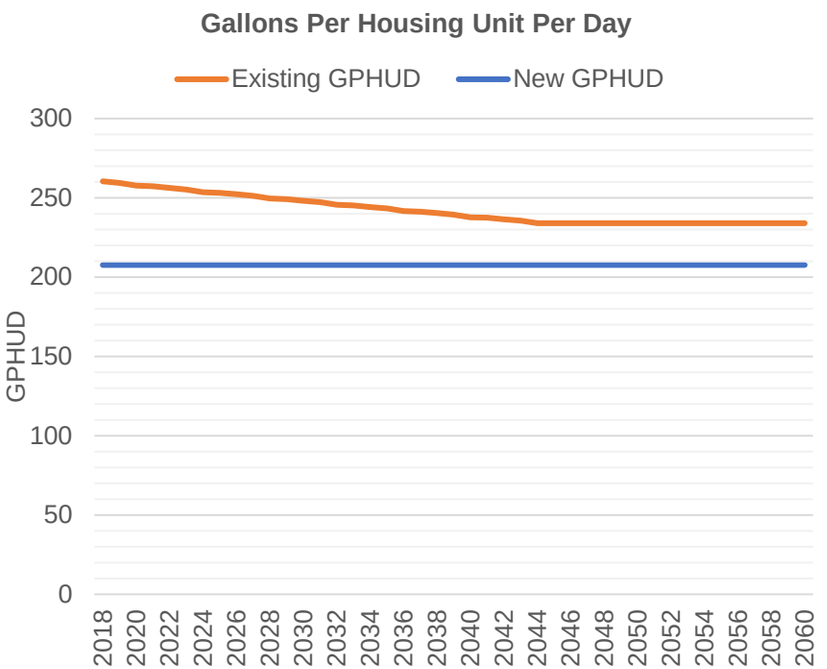
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,787	191	186	0	0	0	0	0	0	0	774	238
2019	5,143	191	186	0	0	0	0	0	0	0	803	258
2020	5,555	191	186	0	0	0	0	0	0	0	821	321
2021	5,986	191	186	0	0	0	0	0	0	0	835	394
2022	6,423	191	186	0	0	0	0	0	0	0	853	467
2023	6,816	191	186	0	0	0	0	0	0	0	865	541
2024	7,116	191	186	0	0	0	0	0	0	0	873	607
2025	7,421	191	186	0	0	0	0	0	0	0	889	653
2026	7,733	191	186	0	0	0	0	0	0	0	908	698
2027	8,051	191	186	0	0	0	0	0	0	0	927	745
2028	8,286	191	186	0	0	0	0	0	0	0	939	793
2029	8,461	191	186	0	0	0	0	0	0	0	944	828
2030	8,640	191	186	0	0	0	0	0	0	0	955	855
2031	8,823	191	186	0	0	0	0	0	0	0	965	882
2032	9.001	191	186	0	0	0	0	0	0	0	978	909
2033	9,131	191	186	0	0	0	0	0	0	0	981	936
2034	9,264	191	186	0	0	0	0	0	0	0	989	955
2035	9,400	191	186	0	0	0	0	0	0	0	997	975
2036	9,540	191	186	0	0	0	0	0	0	0	1,008	996
2037	9,711	191	186	0	0	0	0	0	0	0	1,017	1,017
2038	9,886	191	186	0	0	0	0	0	0	0	1,027	1,043
2039	10,066	191	186	0	0	0	0	0	0	0	1,038	1,069
2040	10,252	191	186	0	0	0	0	0	0	0	1,052	1,096
2041	10,453	191	186	0	0	0	0	0	0	0	1,061	1,124
2042	10,659	191	186	0	0	0	0	0	0	0	1,074	1,154
2043	10,895	191	186	0	0	0	0	0	0	0	1,089	1,185
2044	11,154	191	186	0	0	0	0	0	0	0	1,109	1,221
2045	11,420	191	186	0	0	0	0	0	0	0	1,121	1,260
2046	11,691	191	186	0	0	0	0	0	0	0	1,137	1,300
2047	11,970	191	186	0	0	0	0	0	0	0	1,153	1,340
2048	12,442	191	186	0	0	0	0	0	0	0	1,194	1,382
2049	12,852	191	186	0	0	0	0	0	0	0	1,211	1,453
2050	13,239	191	186	0	0	0	0	0	0	0	1,221	1,526
2051	13,633	191	186	0	0	0	0	0	0	0	1,160	1,669
2052	14,026	191	186	0	0	0	0	0	0	0	1,188	1,728
2053	14,429	191	186	0	0	0	0	0	0	0	1,206	1,787
2054	14,842	191	186	0	0	0	0	0	0	0	1,231	1,848
2055	15,233	191	186	0	0	0	0	0	0	0	1,253	1,910
2056	15,595	191	186	0	0	0	0	0	0	0	1,279	1,968
2057	15,966	191	186	0	0	0	0	0	0	0	1,295	2,023
2058	16,347	191	186	0	0	0	0	0	0	0	1,317	2,079
2059	16,739	191	186	0	0	0	0	0	0	0	1,341	2,136
2060	17,007	191	186	0	0	0	0	0	0	0	1,358	2,195

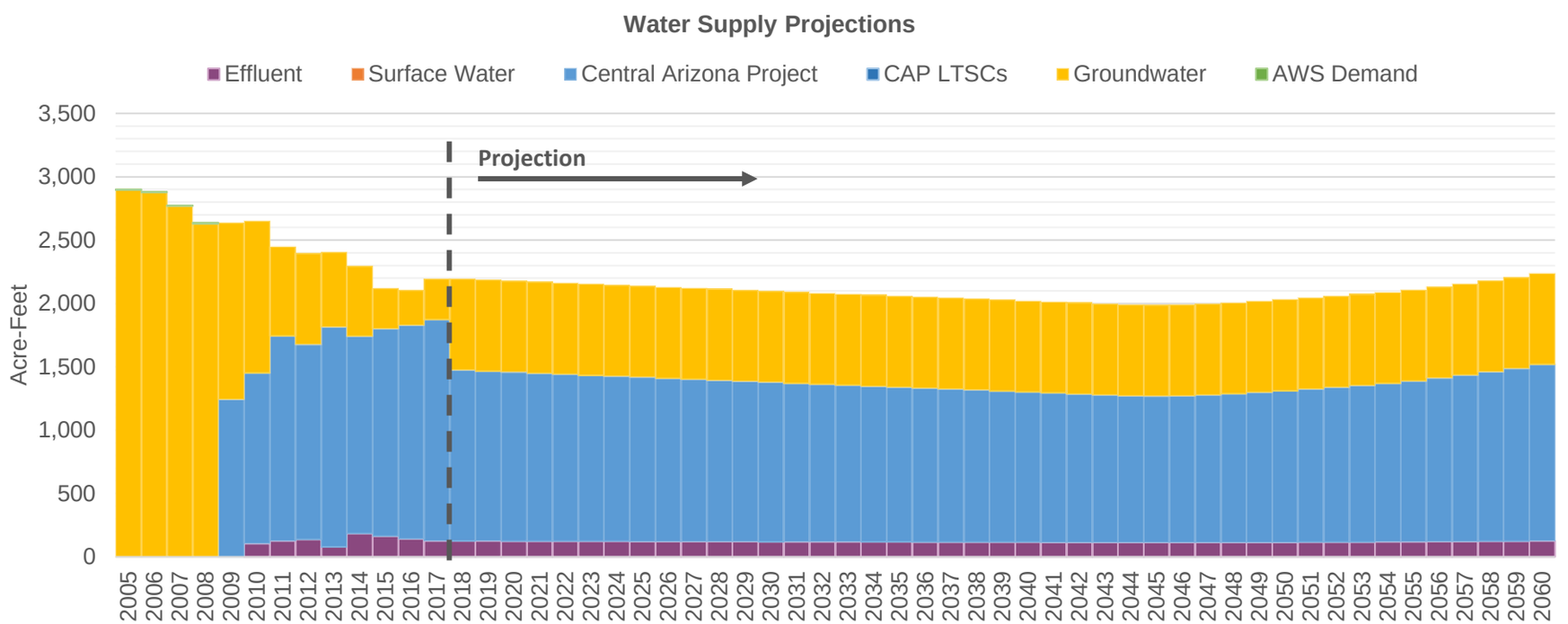
Central Arizona Project Service Area Model

FWID

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

FWID

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

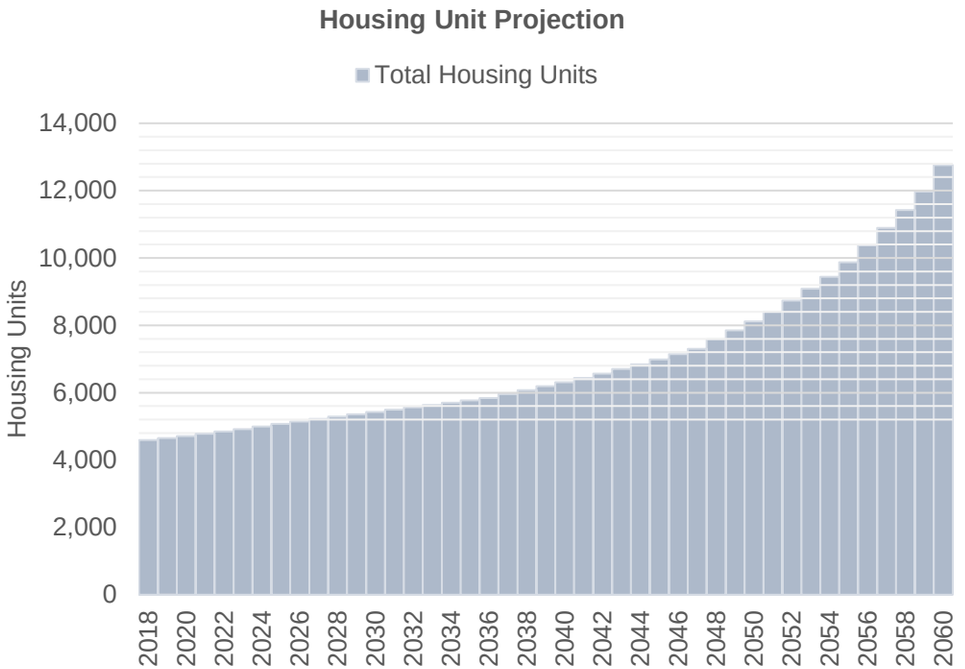
Water Supply Projections (Acre-Feet)

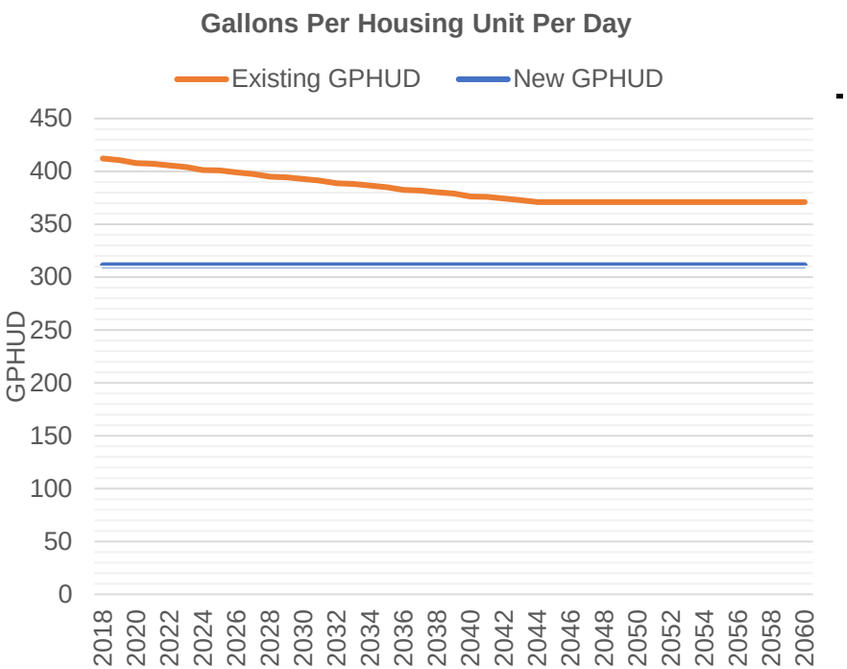
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	7,522	260	208	125	0	0	0	1,350	1,523	0	719	0
2019	7,523	259	208	125	0	0	0	1,341	1,532	0	719	0
2020	7,525	258	208	125	0	0	0	1,333	1,540	0	719	0
2021	7,528	257	208	124	0	0	0	1,326	1,547	0	719	0
2022	7,530	256	208	124	0	0	0	1,318	1,555	0	719	0
2023	7,532	255	208	123	0	0	0	1,310	1,563	0	719	0
2024	7,534	254	208	123	0	0	0	1,303	1,570	0	719	0
2025	7,537	253	208	122	0	0	0	1,295	1,578	0	719	0
2026	7,539	252	208	122	0	0	0	1,288	1,585	0	719	0
2027	7,541	251	208	121	0	0	0	1,280	1,593	0	719	0
2028	7,544	250	208	121	0	0	0	1,273	1,600	0	719	0
2029	7,546	249	208	120	0	0	0	1,266	1,607	0	719	0
2030	7,549	248	208	120	0	0	0	1,258	1,615	0	719	0
2031	7,551	247	208	119	0	0	0	1,251	1,622	0	719	0
2032	7,554	246	208	119	0	0	0	1,243	1,630	0	719	0
2033	7,556	245	208	119	0	0	0	1,236	1,637	0	719	0
2034	7,559	244	208	118	0	0	0	1,229	1,644	0	719	0
2035	7,561	243	208	118	0	0	0	1,222	1,651	0	719	0
2036	7,564	242	208	117	0	0	0	1,215	1,658	0	719	0
2037	7,567	241	208	117	0	0	0	1,207	1,666	0	719	0
2038	7,570	240	208	116	0	0	0	1,201	1,476	0	719	0
2039	7,573	239	208	116	0	0	0	1,193	1,030	0	719	0
2040	7,574	238	208	116	0	0	0	1,186	1,442	0	719	0
2041	7,574	237	208	115	0	0	0	1,179	1,649	0	719	0
2042	7,574	237	208	115	0	0	0	1,171	1,631	0	719	0
2043	7,574	236	208	114	0	0	0	1,164	1,709	0	719	0
2044	7,574	234	208	114	0	0	0	1,156	1,717	0	719	0
2045	7,574	234	208	113	0	0	0	1,155	1,718	0	719	0
2046	7,603	234	208	113	0	0	0	1,158	1,622	0	719	0
2047	7,632	234	208	113	0	0	0	1,165	1,708	0	719	0
2048	7,686	234	208	114	0	0	0	1,174	1,606	0	719	0
2049	7,738	234	208	114	0	0	0	1,186	1,594	0	719	0
2050	7,788	234	208	115	0	0	0	1,197	1,584	0	719	0
2051	7,843	234	208	116	0	0	0	1,208	1,572	0	719	0
2052	7,910	234	208	116	0	0	0	1,222	1,359	0	719	0
2053	7,979	234	208	117	0	0	0	1,237	1,344	0	719	0
2054	8,049	234	208	118	0	0	0	1,252	1,005	0	719	0
2055	8,135	234	208	119	0	0	0	1,269	739	0	719	0
2056	8,239	234	208	120	0	0	0	1,291	343	0	719	0
2057	8,346	234	208	121	0	0	0	1,314	943	0	719	0
2058	8,455	234	208	123	0	0	0	1,337	1,044	0	719	0
2059	8,567	234	208	124	0	0	0	1,362	970	0	719	0
2060	8,743	234	208	126	0	0	0	1,394	938	0	719	0

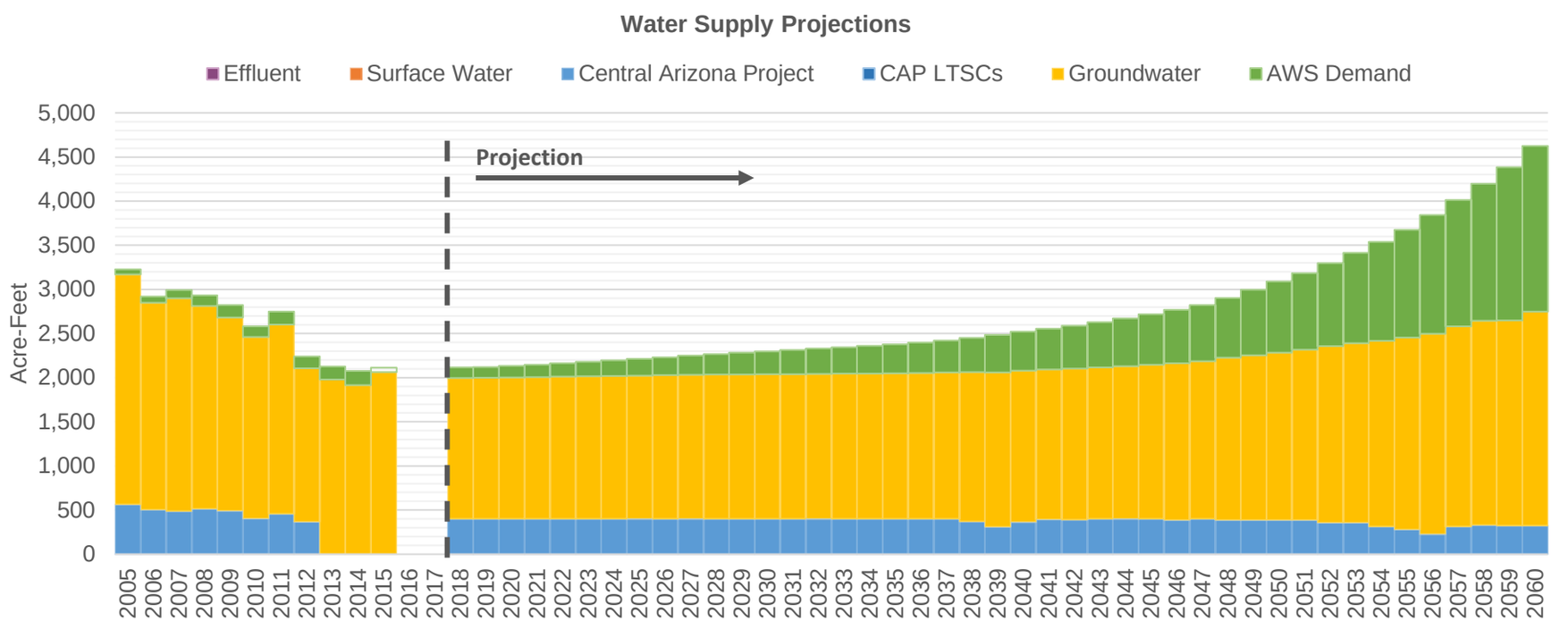
Central Arizona Project Service Area Model

GVDWID

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

GVDWID

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

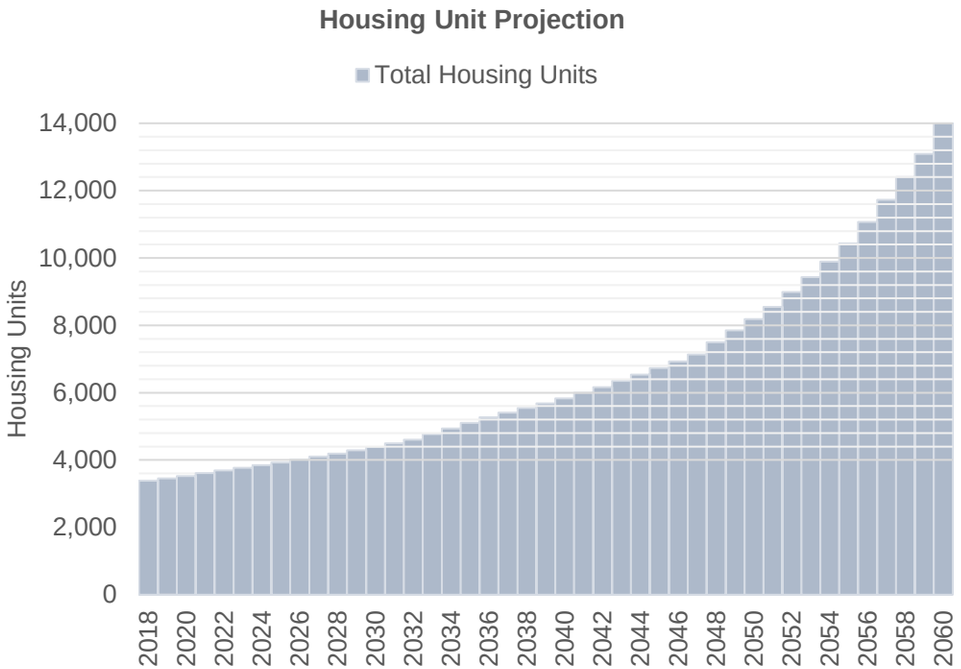
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

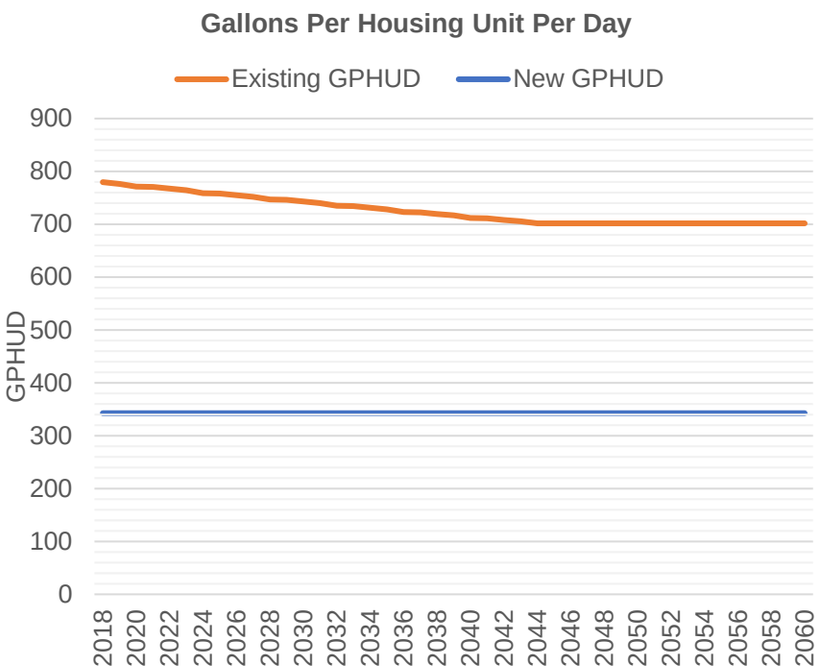
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,595	412	311	0	0	0	399	0	0	0	1,599	119
2019	4,651	411	311	0	0	0	399	0	0	0	1,600	122
2020	4,715	408	311	0	0	0	399	0	0	0	1,604	131
2021	4,783	407	311	0	0	0	399	0	0	0	1,608	141
2022	4,851	406	311	0	0	0	399	0	0	0	1,612	152
2023	4,921	404	311	0	0	0	399	0	0	0	1,617	164
2024	4,994	401	311	0	0	0	399	0	0	0	1,621	176
2025	5,069	401	311	0	0	0	399	0	0	0	1,625	189
2026	5,145	399	311	0	0	0	399	0	0	0	1,630	203
2027	5,223	398	311	0	0	0	399	0	0	0	1,634	217
2028	5,293	395	311	0	0	0	399	0	0	0	1,637	232
2029	5,358	394	311	0	0	0	399	0	0	0	1,639	246
2030	5,425	393	311	0	0	0	399	0	0	0	1,640	259
2031	5,492	391	311	0	0	0	399	0	0	0	1,642	273
2032	5.561	389	311	0	0	0	399	0	0	0	1.645	286
2033	5,630	388	311	0	0	0	399	0	0	0	1,646	301
2034	5,699	387	311	0	0	0	399	0	0	0	1,648	315
2035	5,771	385	311	0	0	0	399	0	0	0	1,650	329
2036	5,844	382	311	0	0	0	399	0	0	0	1,654	344
2037	5,956	382	311	0	0	0	399	0	0	0	1,662	359
2038	6,071	380	311	0	0	0	372	0	0	0	1,692	388
2039	6,189	379	311	0	0	0	309	0	0	0	1,751	424
2040	6,309	376	311	0	0	0	365	0	0	0	1,716	439
2041	6,435	376	311	0	0	0	393	0	0	0	1,702	458
2042	6,563	374	311	0	0	0	389	0	0	0	1,715	486
2043	6,700	373	311	0	0	0	399	0	0	0	1,718	511
2044	6,844	371	311	0	0	0	399	0	0	0	1,732	541
2045	6,992	371	311	0	0	0	399	0	0	0	1,748	572
2046	7,143	371	311	0	0	0	386	0	0	0	1,777	607
2047	7,298	371	311	0	0	0	399	0	0	0	1,788	637
2048	7,582	371	311	0	0	0	386	0	0	0	1,841	676
2049	7,851	371	311	0	0	0	386	0	0	0	1,869	742
2050	8,114	371	311	0	0	0	386	0	0	0	1,899	804
2051	8,396	371	311	0	0	0	386	0	0	0	1,933	866
2052	8,737	371	311	0	0	0	358	0	0	0	1,998	941
2053	9,087	371	311	0	0	0	358	0	0	0	2,033	1,022
2054	9,445	371	311	0	0	0	313	0	0	0	2,103	1,121
2055	9,872	371	311	0	0	0	279	0	0	0	2,176	1,219
2056	10,377	371	311	0	0	0	227	0	0	0	2,272	1,342
2057	10,895	371	311	0	0	0	313	0	0	0	2,269	1,432
2058	11,426	371	311	0	0	0	331	0	0	0	2,316	1,551
2059	11,972	371	311	0	0	0	324	0	0	0	2,323	1,738
2060	12,761	371	311	0	0	0	324	0	0	0	2,426	1,876

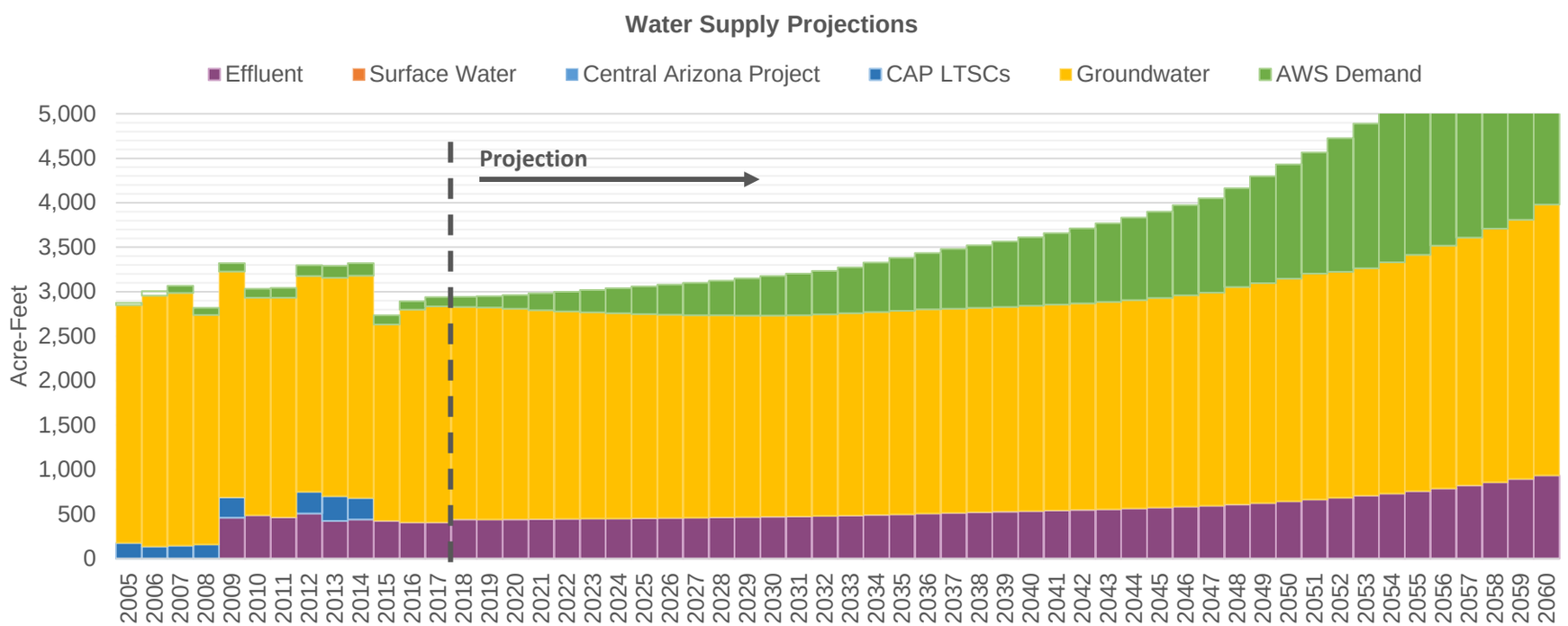
LagoDelOro

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LagoDelOro

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

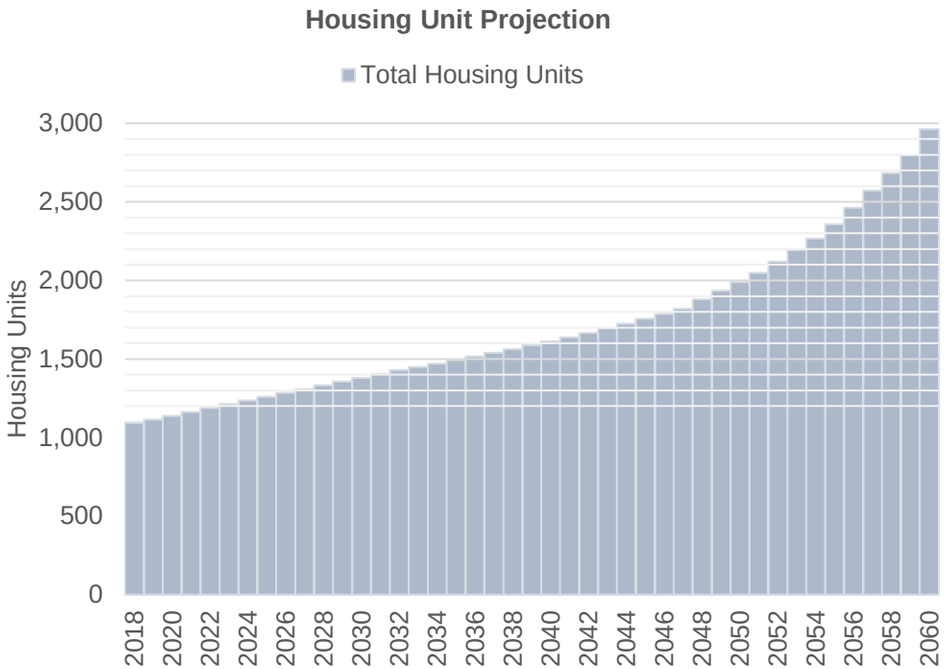
Water Supply Projections (Acre-Feet)

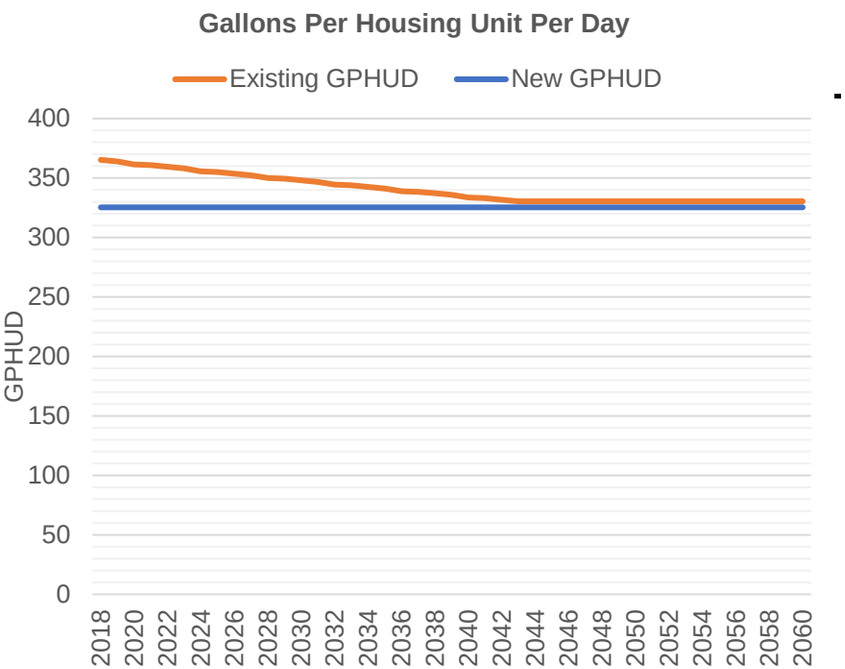
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,387	780	343	441	0	0	0	0	0	0	2,387	116
2019	3,452	777	343	441	0	0	0	0	0	0	2,382	126
2020	3,528	771	343	442	0	0	0	0	0	0	2,367	155
2021	3,607	770	343	444	0	0	0	0	0	0	2,348	190
2022	3,687	767	343	447	0	0	0	0	0	0	2,334	220
2023	3,767	764	343	450	0	0	0	0	0	0	2,319	251
2024	3,848	759	343	452	0	0	0	0	0	0	2,307	281
2025	3,930	758	343	455	0	0	0	0	0	0	2,293	311
2026	4,014	755	343	458	0	0	0	0	0	0	2,285	337
2027	4,100	752	343	461	0	0	0	0	0	0	2,276	364
2028	4,192	747	343	465	0	0	0	0	0	0	2,271	389
2029	4,290	746	343	468	0	0	0	0	0	0	2,265	416
2030	4,390	743	343	472	0	0	0	0	0	0	2,261	443
2031	4,492	740	343	476	0	0	0	0	0	0	2,261	467
2032	4.604	735	343	480	0	0	0	0	0	0	2.264	490
2033	4,766	734	343	485	0	0	0	0	0	0	2,274	516
2034	4,932	731	343	491	0	0	0	0	0	0	2,283	553
2035	5,101	728	343	498	0	0	0	0	0	0	2,289	592
2036	5,273	723	343	506	0	0	0	0	0	0	2,298	632
2037	5,407	723	343	515	0	0	0	0	0	0	2,295	672
2038	5,543	720	343	522	0	0	0	0	0	0	2,297	704
2039	5,683	717	343	528	0	0	0	0	0	0	2,301	736
2040	5,830	712	343	534	0	0	0	0	0	0	2,309	769
2041	5,996	711	343	541	0	0	0	0	0	0	2,314	804
2042	6,167	708	343	548	0	0	0	0	0	0	2,321	843
2043	6,347	705	343	556	0	0	0	0	0	0	2,330	883
2044	6,536	702	343	565	0	0	0	0	0	0	2,342	926
2045	6,729	702	343	574	0	0	0	0	0	0	2,355	971
2046	6,927	702	343	584	0	0	0	0	0	0	2,374	1,017
2047	7,130	702	343	595	0	0	0	0	0	0	2,393	1,063
2048	7,499	702	343	607	0	0	0	0	0	0	2,446	1,113
2049	7,847	702	343	624	0	0	0	0	0	0	2,474	1,201
2050	8,188	702	343	644	0	0	0	0	0	0	2,504	1,283
2051	8,551	702	343	664	0	0	0	0	0	0	2,539	1,363
2052	8,987	702	343	684	0	0	0	0	0	0	2,540	1,501
2053	9,434	702	343	708	0	0	0	0	0	0	2,557	1,625
2054	9,892	702	343	732	0	0	0	0	0	0	2,600	1,731
2055	10,434	702	343	758	0	0	0	0	0	0	2,657	1,840
2056	11,073	702	343	787	0	0	0	0	0	0	2,732	1,970
2057	11,729	702	343	822	0	0	0	0	0	0	2,786	2,121
2058	12,402	702	343	858	0	0	0	0	0	0	2,850	2,277
2059	13,092	702	343	897	0	0	0	0	0	0	2,914	2,436
2060	14,107	702	343	936	0	0	0	0	0	0	3,045	2,603

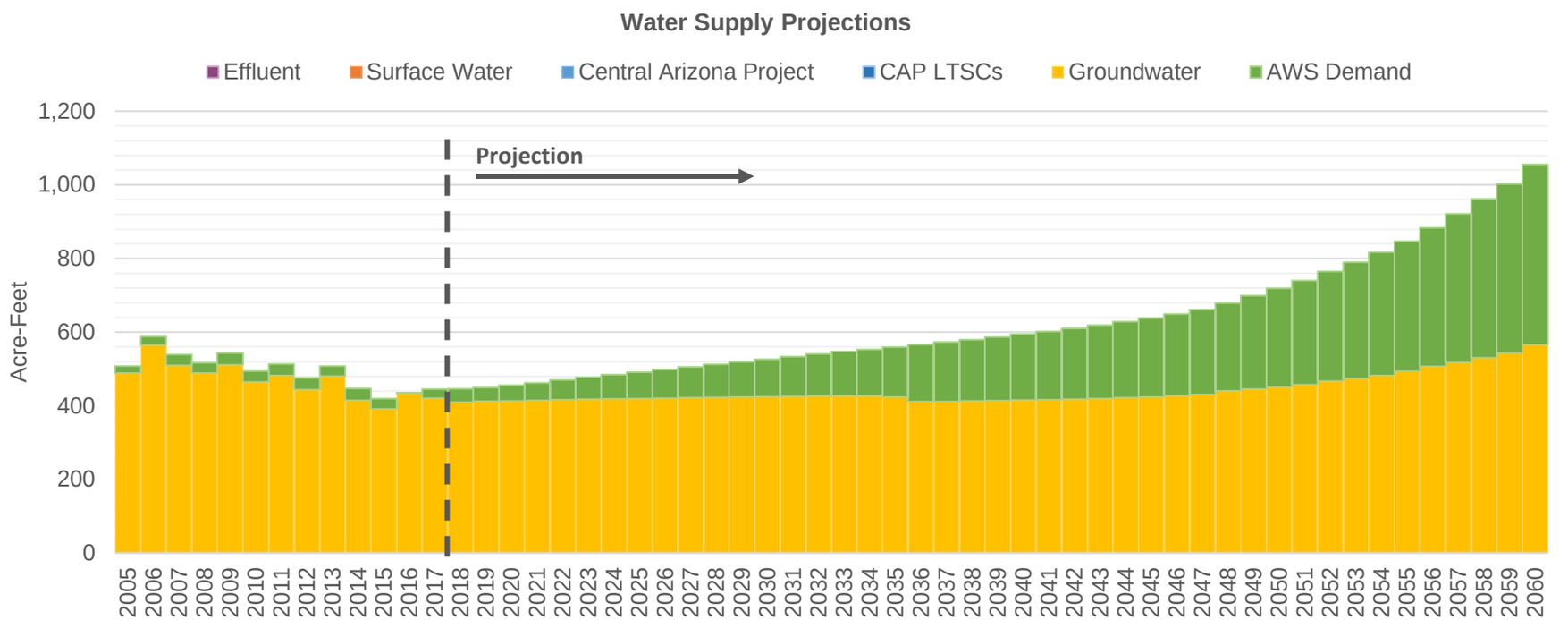
LasQuintas

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LasQuintas

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

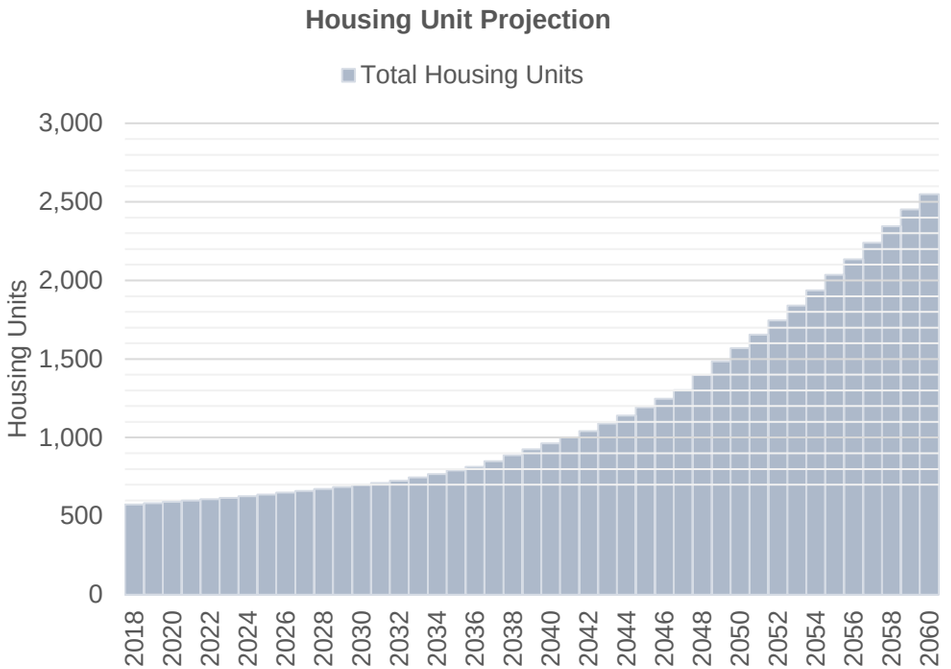
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

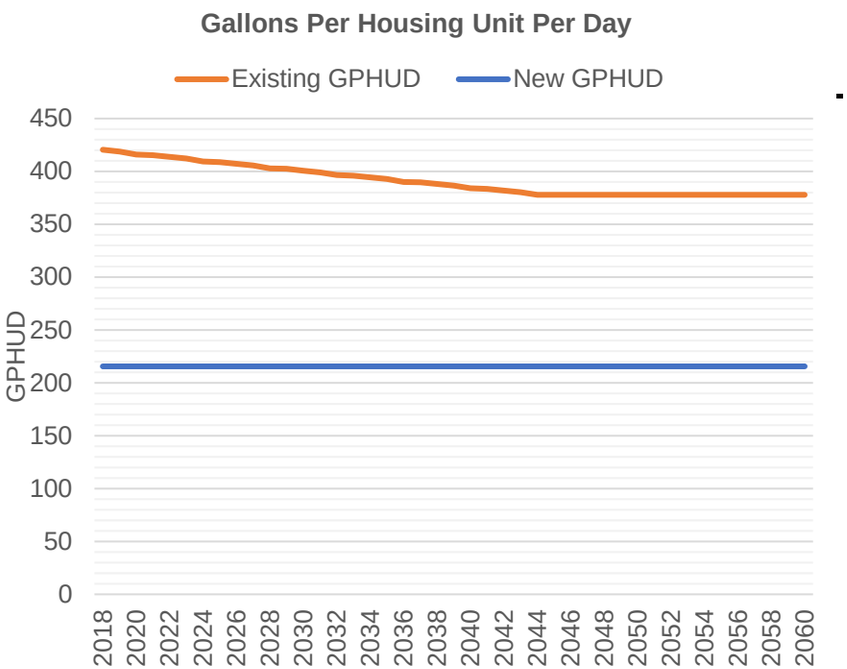
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,094	365	325	0	0	0	0	0	0	0	410	36
2019	1,115	364	325	0	0	0	0	0	0	0	412	37
2020	1,138	361	325	0	0	0	0	0	0	0	414	42
2021	1,163	361	325	0	0	0	0	0	0	0	415	47
2022	1,188	359	325	0	0	0	0	0	0	0	416	54
2023	1,213	358	325	0	0	0	0	0	0	0	418	60
2024	1,236	356	325	0	0	0	0	0	0	0	419	66
2025	1,260	355	325	0	0	0	0	0	0	0	420	71
2026	1,284	354	325	0	0	0	0	0	0	0	421	77
2027	1,309	352	325	0	0	0	0	0	0	0	422	84
2028	1,333	350	325	0	0	0	0	0	0	0	423	90
2029	1,356	350	325	0	0	0	0	0	0	0	423	96
2030	1,380	348	325	0	0	0	0	0	0	0	424	102
2031	1,405	347	325	0	0	0	0	0	0	0	425	108
2032	1,429	344	325	0	0	0	0	0	0	0	427	114
2033	1,450	344	325	0	0	0	0	0	0	0	427	121
2034	1,471	343	325	0	0	0	0	0	0	0	427	126
2035	1,493	341	325	0	0	0	0	0	0	0	424	136
2036	1,516	339	325	0	0	0	0	0	0	0	411	155
2037	1,539	338	325	0	0	0	0	0	0	0	412	161
2038	1,563	337	325	0	0	0	0	0	0	0	413	167
2039	1,588	336	325	0	0	0	0	0	0	0	414	173
2040	1,613	334	325	0	0	0	0	0	0	0	416	179
2041	1,639	333	325	0	0	0	0	0	0	0	416	186
2042	1,666	332	325	0	0	0	0	0	0	0	418	192
2043	1,695	330	325	0	0	0	0	0	0	0	419	199
2044	1,725	330	325	0	0	0	0	0	0	0	422	207
2045	1,755	330	325	0	0	0	0	0	0	0	424	214
2046	1,787	330	325	0	0	0	0	0	0	0	427	222
2047	1,819	330	325	0	0	0	0	0	0	0	431	230
2048	1,879	330	325	0	0	0	0	0	0	0	440	238
2049	1,935	330	325	0	0	0	0	0	0	0	445	254
2050	1,990	330	325	0	0	0	0	0	0	0	451	268
2051	2,049	330	325	0	0	0	0	0	0	0	458	282
2052	2,120	330	325	0	0	0	0	0	0	0	467	297
2053	2,193	330	325	0	0	0	0	0	0	0	474	316
2054	2,268	330	325	0	0	0	0	0	0	0	483	334
2055	2,357	330	325	0	0	0	0	0	0	0	493	354
2056	2,463	330	325	0	0	0	0	0	0	0	507	376
2057	2,571	330	325	0	0	0	0	0	0	0	518	404
2058	2,683	330	325	0	0	0	0	0	0	0	530	431
2059	2,797	330	325	0	0	0	0	0	0	0	543	460
2060	2,962	330	325	0	0	0	0	0	0	0	566	489

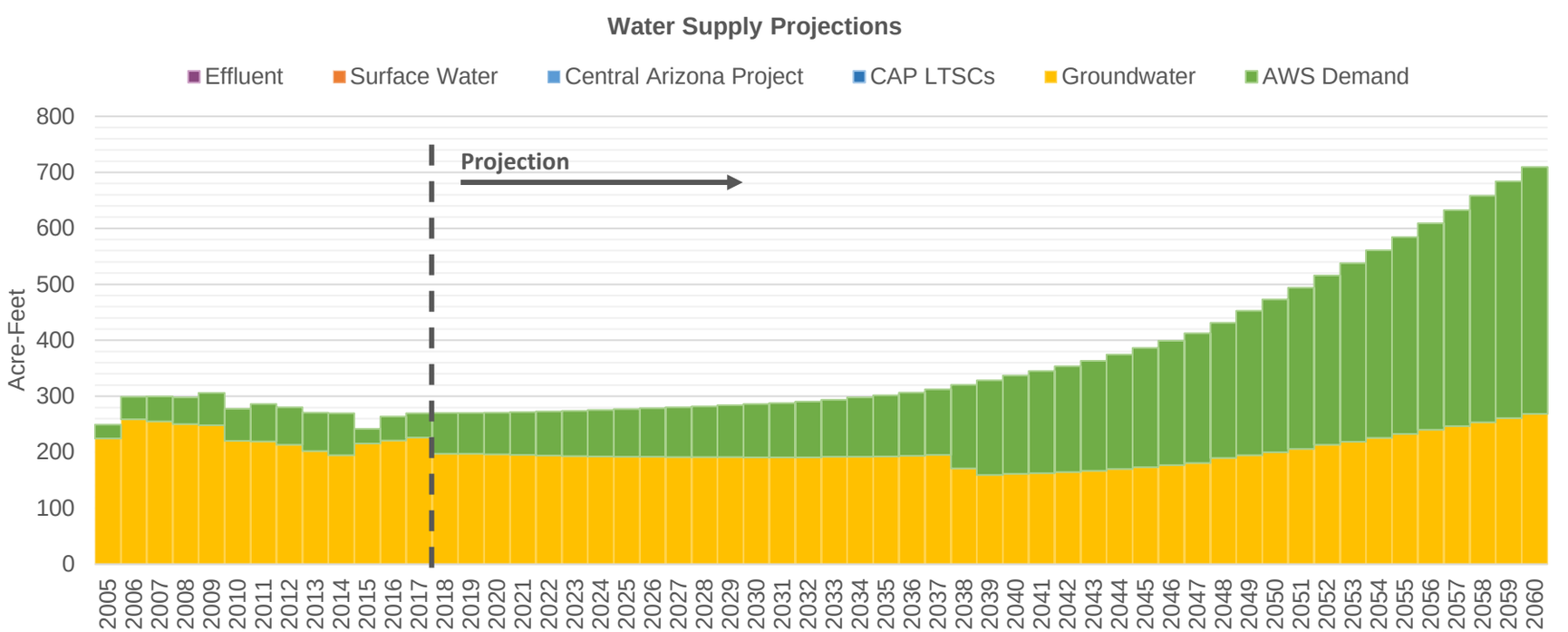
LosCerros

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

LosCerros

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

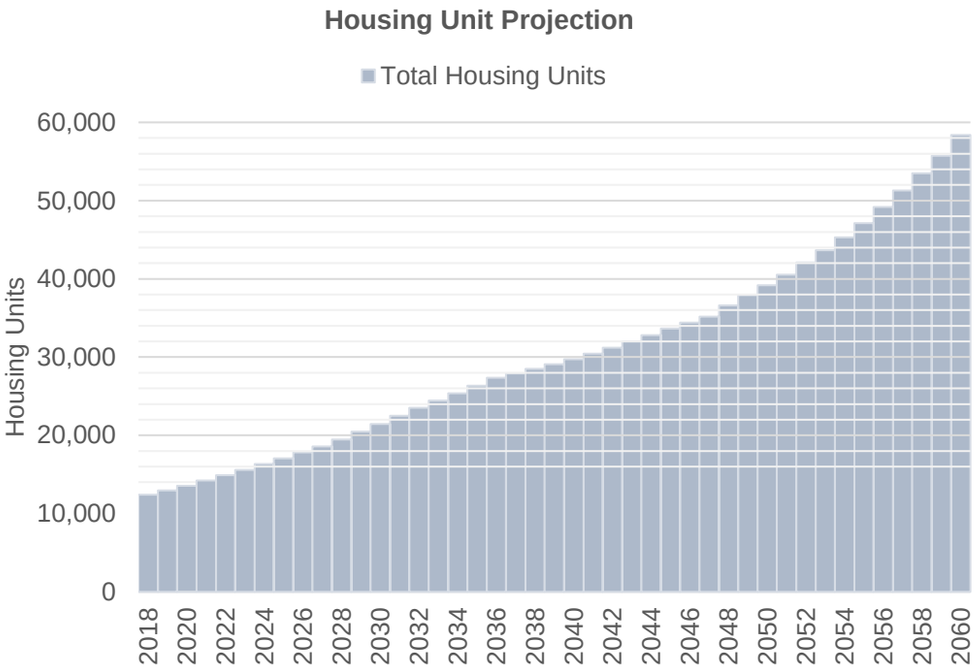
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

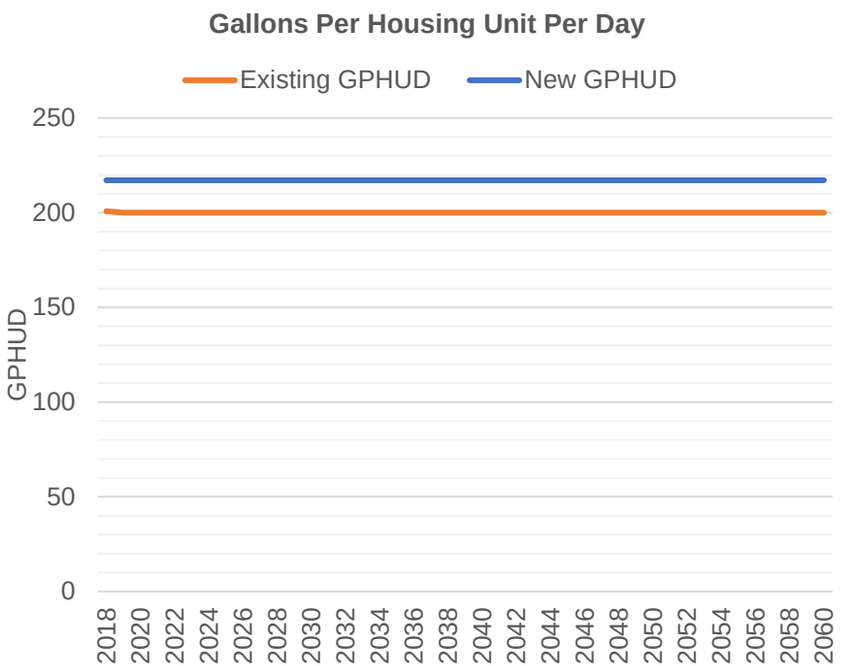
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	575	421	216	0	0	0	0	0	0	0	198	73
2019	582	419	216	0	0	0	0	0	0	0	197	73
2020	590	416	216	0	0	0	0	0	0	0	196	75
2021	599	415	216	0	0	0	0	0	0	0	195	77
2022	607	414	216	0	0	0	0	0	0	0	194	79
2023	616	412	216	0	0	0	0	0	0	0	193	81
2024	627	409	216	0	0	0	0	0	0	0	193	83
2025	638	409	216	0	0	0	0	0	0	0	192	85
2026	650	407	216	0	0	0	0	0	0	0	192	87
2027	661	406	216	0	0	0	0	0	0	0	192	89
2028	673	403	216	0	0	0	0	0	0	0	192	91
2029	686	402	216	0	0	0	0	0	0	0	191	93
2030	698	401	216	0	0	0	0	0	0	0	191	95
2031	711	399	216	0	0	0	0	0	0	0	191	97
2032	726	396	216	0	0	0	0	0	0	0	191	99
2033	747	396	216	0	0	0	0	0	0	0	192	102
2034	768	394	216	0	0	0	0	0	0	0	192	106
2035	790	393	216	0	0	0	0	0	0	0	193	109
2036	813	390	216	0	0	0	0	0	0	0	193	113
2037	849	390	216	0	0	0	0	0	0	0	195	117
2038	887	388	216	0	0	0	0	0	0	0	171	149
2039	925	387	216	0	0	0	0	0	0	0	159	169
2040	964	384	216	0	0	0	0	0	0	0	161	176
2041	1,002	383	216	0	0	0	0	0	0	0	163	182
2042	1,042	382	216	0	0	0	0	0	0	0	165	189
2043	1,089	380	216	0	0	0	0	0	0	0	167	196
2044	1,140	378	216	0	0	0	0	0	0	0	170	204
2045	1,193	378	216	0	0	0	0	0	0	0	173	213
2046	1,247	378	216	0	0	0	0	0	0	0	177	222
2047	1,302	378	216	0	0	0	0	0	0	0	181	232
2048	1,399	378	216	0	0	0	0	0	0	0	190	241
2049	1,485	378	216	0	0	0	0	0	0	0	195	258
2050	1,568	378	216	0	0	0	0	0	0	0	200	273
2051	1,654	378	216	0	0	0	0	0	0	0	206	288
2052	1,746	378	216	0	0	0	0	0	0	0	213	303
2053	1,840	378	216	0	0	0	0	0	0	0	219	319
2054	1,936	378	216	0	0	0	0	0	0	0	226	335
2055	2,035	378	216	0	0	0	0	0	0	0	232	352
2056	2,135	378	216	0	0	0	0	0	0	0	240	369
2057	2,239	378	216	0	0	0	0	0	0	0	246	386
2058	2,344	378	216	0	0	0	0	0	0	0	254	404
2059	2,453	378	216	0	0	0	0	0	0	0	261	423
2060	2,549	378	216	0	0	0	0	0	0	0	268	442

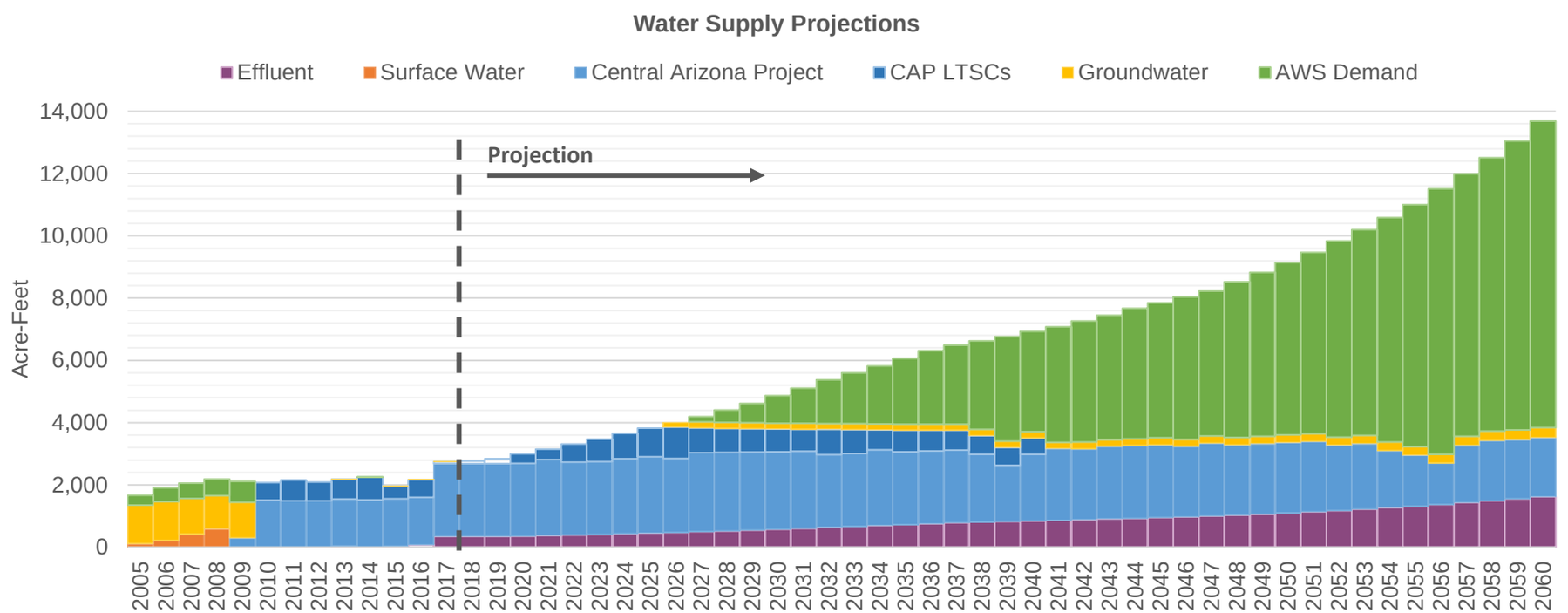
Central Arizona Project Service Area Model

Marana

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Marana

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

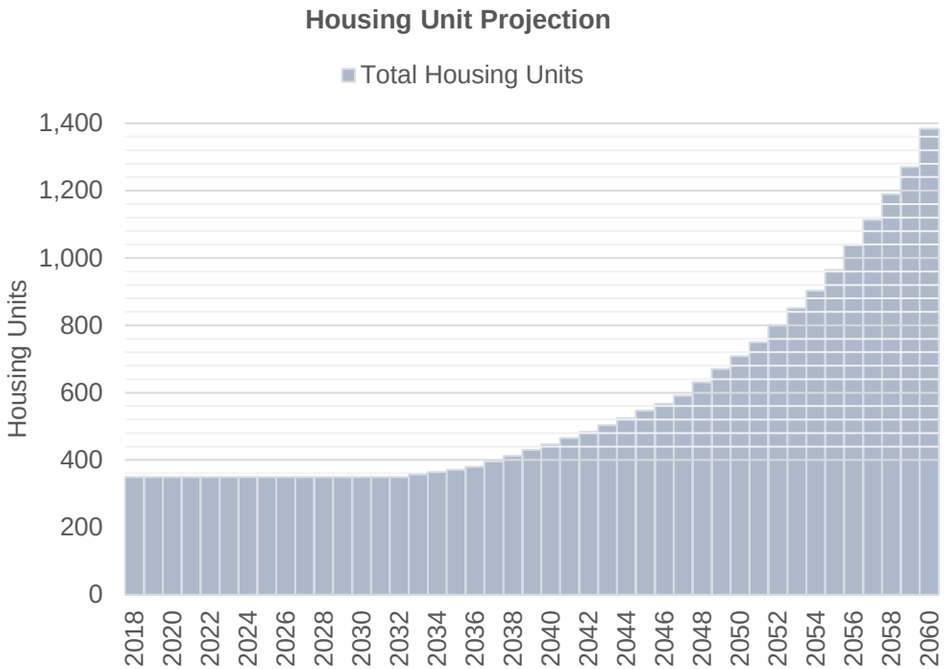
Water Supply Projections (Acre-Feet)

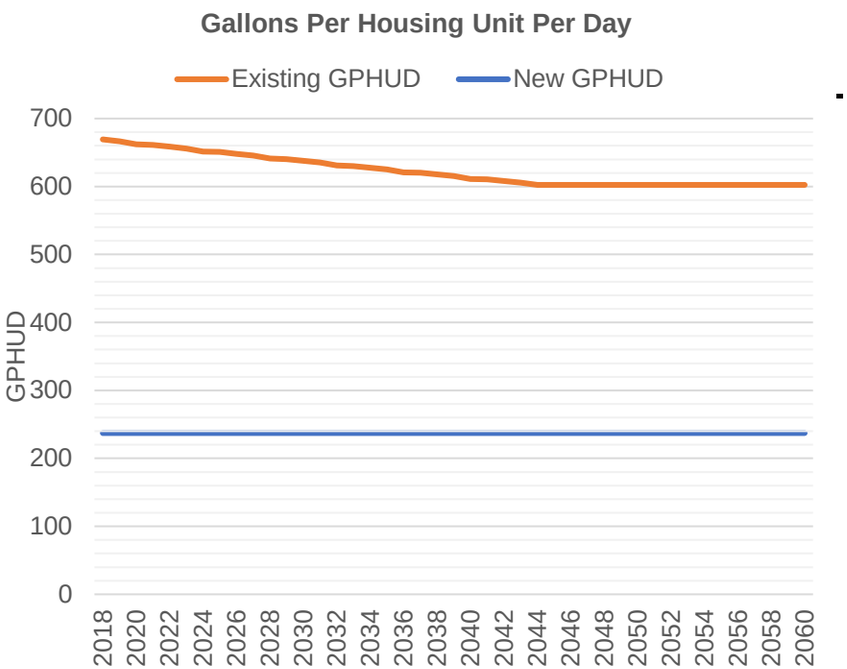
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	12,394	201	217	345	0	0	0	2,336	0	89	0	0
2019	12,942	200	217	345	0	0	0	2,336	0	166	0	0
2020	13,575	200	217	354	0	0	0	2,336	0	308	0	0
2021	14,237	200	217	373	0	0	0	2,444	0	330	0	0
2022	14,907	200	217	392	0	0	0	2,339	0	579	0	0
2023	15,596	200	217	412	0	0	0	2,336	0	727	0	0
2024	16,322	200	217	433	0	0	0	2,408	0	816	0	0
2025	17,063	200	217	455	0	0	0	2,456	0	915	0	0
2026	17,818	200	217	476	0	0	0	2,376	0	1,009	147	0
2027	18,590	200	217	499	0	0	0	2,536	0	798	195	165
2028	19,480	200	217	522	0	0	0	2,520	0	774	193	398
2029	20,463	200	217	549	0	0	0	2,505	0	751	192	627
2030	21,466	200	217	575	0	0	0	2,489	0	729	191	880
2031	22,491	200	217	605	0	0	0	2,474	0	707	191	1,134
2032	23,515	200	217	636	0	0	0	2,336	0	810	191	1,402
2033	24,443	200	217	669	0	0	0	2,342	0	764	191	1,631
2034	25,392	200	217	697	0	0	0	2,431	0	637	193	1,869
2035	26,361	200	217	725	0	0	0	2,336	0	700	194	2,104
2036	27,347	200	217	754	0	0	0	2,336	0	665	196	2,363
2037	27,915	200	217	786	0	0	0	2,336	0	632	198	2,534
2038	28,496	200	217	807	0	0	0	2,177	0	600	201	2,841
2039	29,090	200	217	825	0	0	0	1,808	0	570	204	3,362
2040	29,718	200	217	842	0	0	0	2,137	0	529	207	3,221
2041	30,449	200	217	863	0	0	0	2,300	0	0	210	3,709
2042	31,197	200	217	882	0	0	0	2,279	0	0	214	3,888
2043	31,993	200	217	904	0	0	0	2,336	0	0	217	3,993
2044	32,828	200	217	927	0	0	0	2,336	0	0	221	4,185
2045	33,662	200	217	955	0	0	0	2,336	0	0	225	4,336
2046	34,418	200	217	977	0	0	0	2,261	0	0	229	4,578
2047	35,192	200	217	1,001	0	0	0	2,336	0	0	233	4,660
2048	36,608	200	217	1,024	0	0	0	2,261	0	0	237	4,998
2049	37,922	200	217	1,061	0	0	0	2,261	0	0	242	5,266
2050	39,197	200	217	1,099	0	0	0	2,261	0	0	247	5,537
2051	40,542	200	217	1,138	0	0	0	2,261	0	0	252	5,811
2052	42,090	200	217	1,178	0	0	0	2,098	0	0	258	6,306
2053	43,677	200	217	1,225	0	0	0	2,098	0	0	264	6,608
2054	45,305	200	217	1,269	0	0	0	1,835	0	0	270	7,211
2055	47,136	200	217	1,318	0	0	0	1,633	0	0	277	7,779
2056	49,199	200	217	1,370	0	0	0	1,329	0	0	285	8,528
2057	51,317	200	217	1,433	0	0	0	1,835	0	0	292	8,428
2058	53,490	200	217	1,492	0	0	0	1,936	0	0	301	8,781
2059	55,720	200	217	1,557	0	0	0	1,896	0	0	310	9,283
2060	58,412	200	217	1,624	0	0	0	1,896	0	0	319	9,843

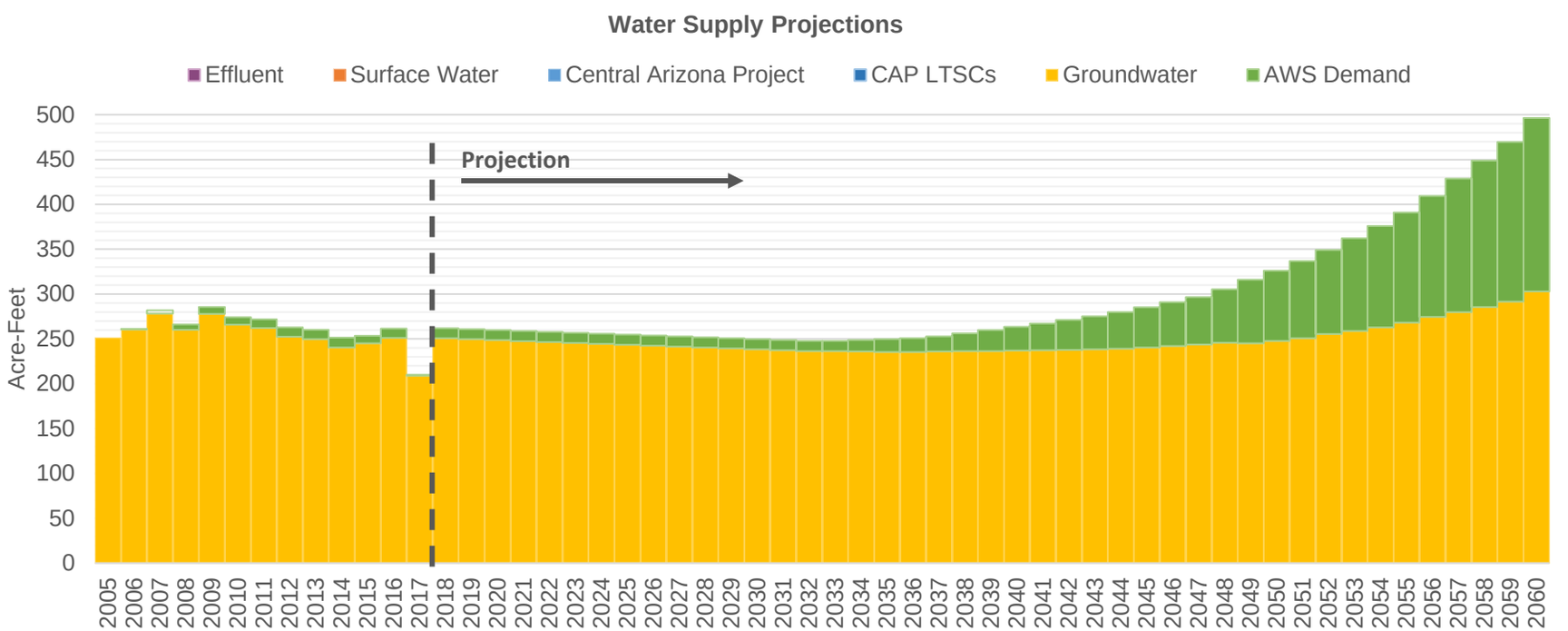
Central Arizona Project Service Area Model

MaranaDomestic

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MaranaDomesti

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

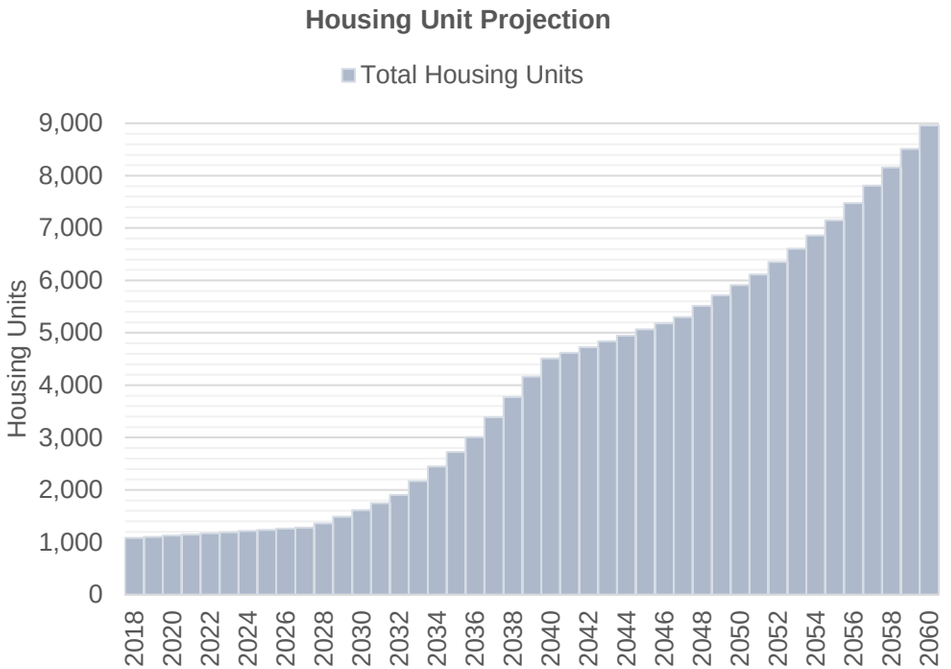
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

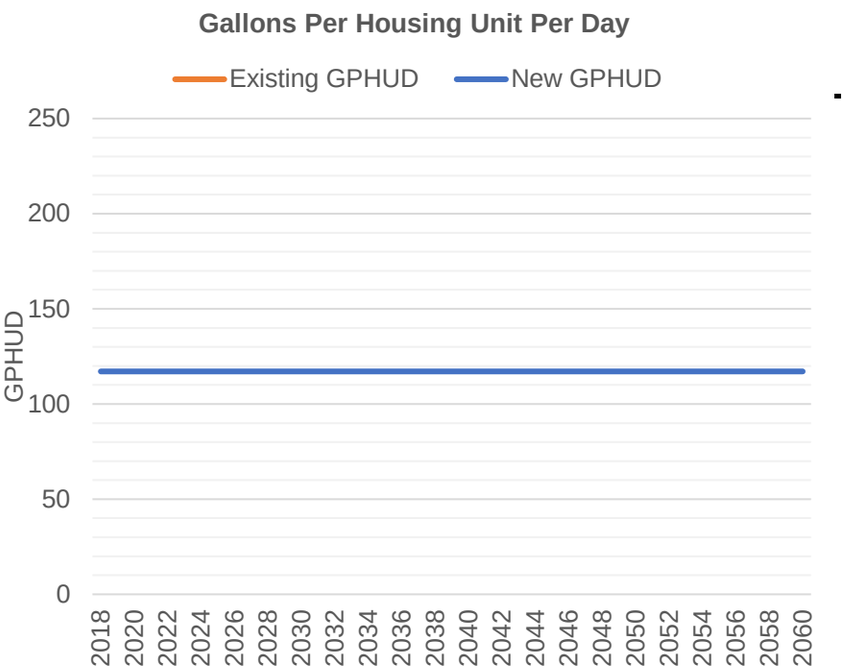
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	349	669	237	0	0	0	0	0	0	0	251	11
2019	349	667	237	0	0	0	0	0	0	0	250	11
2020	349	662	237	0	0	0	0	0	0	0	249	11
2021	349	661	237	0	0	0	0	0	0	0	248	11
2022	349	659	237	0	0	0	0	0	0	0	247	11
2023	349	656	237	0	0	0	0	0	0	0	246	11
2024	349	652	237	0	0	0	0	0	0	0	245	11
2025	349	651	237	0	0	0	0	0	0	0	243	11
2026	349	648	237	0	0	0	0	0	0	0	242	11
2027	349	646	237	0	0	0	0	0	0	0	241	11
2028	349	641	237	0	0	0	0	0	0	0	240	11
2029	349	640	237	0	0	0	0	0	0	0	239	11
2030	349	638	237	0	0	0	0	0	0	0	238	11
2031	349	635	237	0	0	0	0	0	0	0	237	11
2032	349	631	237	0	0	0	0	0	0	0	236	11
2033	357	630	237	0	0	0	0	0	0	0	237	11
2034	364	628	237	0	0	0	0	0	0	0	236	13
2035	371	625	237	0	0	0	0	0	0	0	236	14
2036	379	621	237	0	0	0	0	0	0	0	235	15
2037	395	620	237	0	0	0	0	0	0	0	236	17
2038	412	618	237	0	0	0	0	0	0	0	236	20
2039	429	615	237	0	0	0	0	0	0	0	237	23
2040	446	611	237	0	0	0	0	0	0	0	237	27
2041	465	610	237	0	0	0	0	0	0	0	237	30
2042	483	608	237	0	0	0	0	0	0	0	238	33
2043	503	606	237	0	0	0	0	0	0	0	238	37
2044	524	602	237	0	0	0	0	0	0	0	239	41
2045	546	602	237	0	0	0	0	0	0	0	240	45
2046	567	602	237	0	0	0	0	0	0	0	242	49
2047	590	602	237	0	0	0	0	0	0	0	244	53
2048	631	602	237	0	0	0	0	0	0	0	246	60
2049	670	602	237	0	0	0	0	0	0	0	245	71
2050	708	602	237	0	0	0	0	0	0	0	248	78
2051	749	602	237	0	0	0	0	0	0	0	251	86
2052	799	602	237	0	0	0	0	0	0	0	255	94
2053	850	602	237	0	0	0	0	0	0	0	259	103
2054	902	602	237	0	0	0	0	0	0	0	263	113
2055	964	602	237	0	0	0	0	0	0	0	268	123
2056	1,037	602	237	0	0	0	0	0	0	0	275	135
2057	1,112	602	237	0	0	0	0	0	0	0	280	149
2058	1,189	602	237	0	0	0	0	0	0	0	286	163
2059	1,269	602	237	0	0	0	0	0	0	0	292	178
2060	1,383	602	237	0	0	0	0	0	0	0	303	193

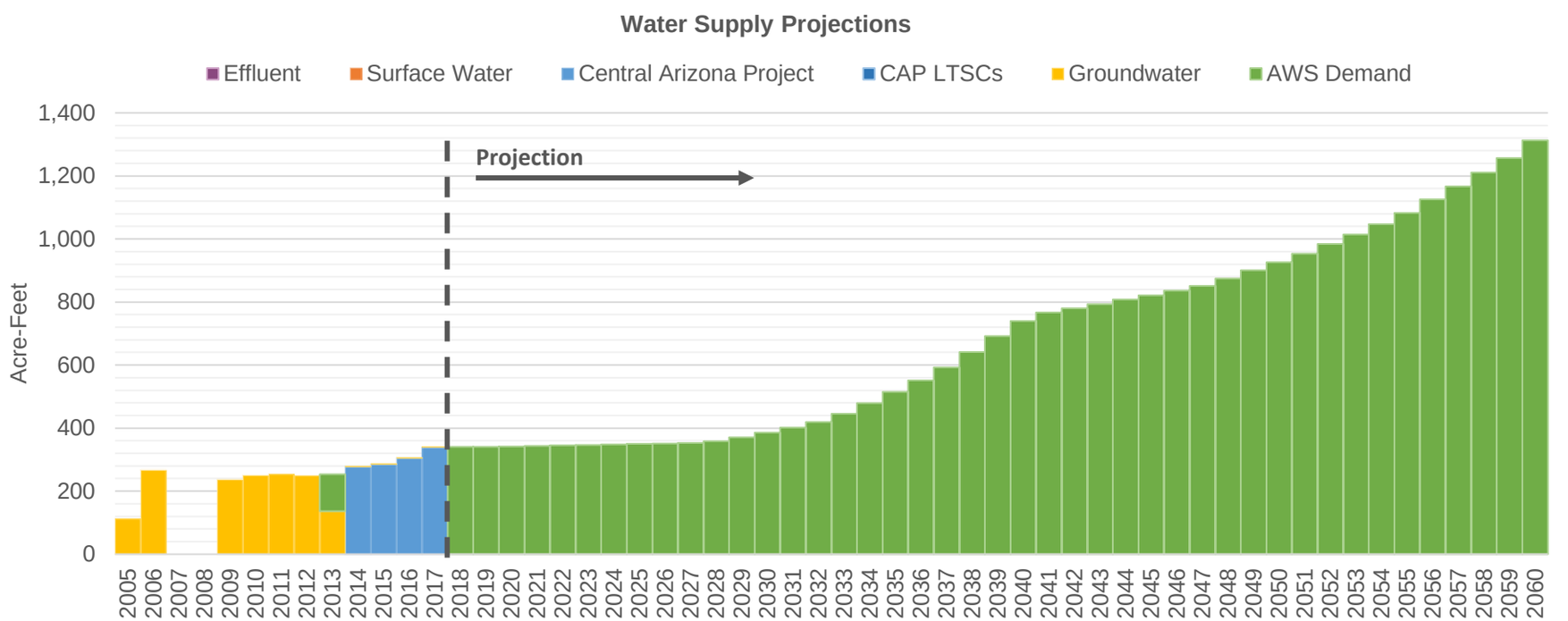
Central Arizona Project Service Area Model

MetroDiablo

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroDiablo

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

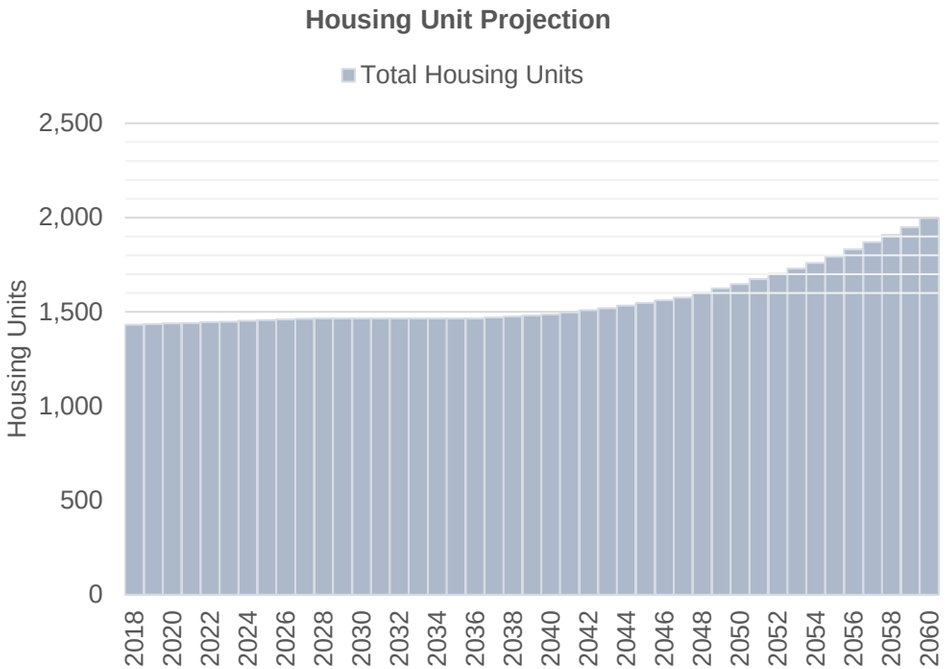
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

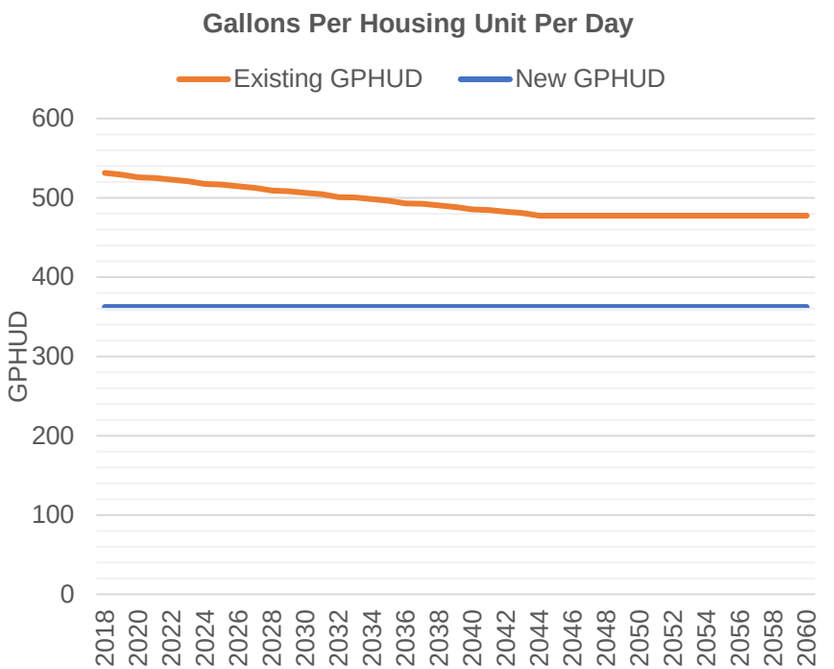
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,087	281	117	0	0	0	0	0	0	0	0	340
2019	1,106	280	117	0	0	0	0	0	0	0	0	341
2020	1,127	278	117	0	0	0	0	0	0	0	0	342
2021	1,149	277	117	0	0	0	0	0	0	0	0	343
2022	1,172	276	117	0	0	0	0	0	0	0	0	345
2023	1,194	275	117	0	0	0	0	0	0	0	0	347
2024	1,216	273	117	0	0	0	0	0	0	0	0	348
2025	1,238	273	117	0	0	0	0	0	0	0	0	350
2026	1,260	272	117	0	0	0	0	0	0	0	0	351
2027	1,283	271	117	0	0	0	0	0	0	0	0	353
2028	1,365	269	117	0	0	0	0	0	0	0	0	359
2029	1,490	269	117	0	0	0	0	0	0	0	0	371
2030	1,618	267	117	0	0	0	0	0	0	0	0	386
2031	1,749	266	117	0	0	0	0	0	0	0	0	402
2032	1.903	265	117	0	0	0	0	0	0	0	0	419
2033	2,171	264	117	0	0	0	0	0	0	0	0	446
2034	2,445	263	117	0	0	0	0	0	0	0	0	480
2035	2,725	262	117	0	0	0	0	0	0	0	0	515
2036	3,012	260	117	0	0	0	0	0	0	0	0	551
2037	3,388	260	117	0	0	0	0	0	0	0	0	593
2038	3,773	259	117	0	0	0	0	0	0	0	0	642
2039	4,167	258	117	0	0	0	0	0	0	0	0	691
2040	4,514	256	117	0	0	0	0	0	0	0	0	740
2041	4,620	256	117	0	0	0	0	0	0	0	0	767
2042	4,728	255	117	0	0	0	0	0	0	0	0	780
2043	4,838	254	117	0	0	0	0	0	0	0	0	793
2044	4,949	253	117	0	0	0	0	0	0	0	0	808
2045	5,063	253	117	0	0	0	0	0	0	0	0	821
2046	5,179	253	117	0	0	0	0	0	0	0	0	836
2047	5,298	253	117	0	0	0	0	0	0	0	0	851
2048	5,513	253	117	0	0	0	0	0	0	0	0	875
2049	5,714	253	117	0	0	0	0	0	0	0	0	901
2050	5,909	253	117	0	0	0	0	0	0	0	0	927
2051	6,116	253	117	0	0	0	0	0	0	0	0	953
2052	6,356	253	117	0	0	0	0	0	0	0	0	984
2053	6,603	253	117	0	0	0	0	0	0	0	0	1,014
2054	6,857	253	117	0	0	0	0	0	0	0	0	1,047
2055	7,145	253	117	0	0	0	0	0	0	0	0	1,083
2056	7,473	253	117	0	0	0	0	0	0	0	0	1,125
2057	7,809	253	117	0	0	0	0	0	0	0	0	1,167
2058	8,155	253	117	0	0	0	0	0	0	0	0	1,211
2059	8,509	253	117	0	0	0	0	0	0	0	0	1,257
2060	8,959	253	117	0	0	0	0	0	0	0	0	1,313

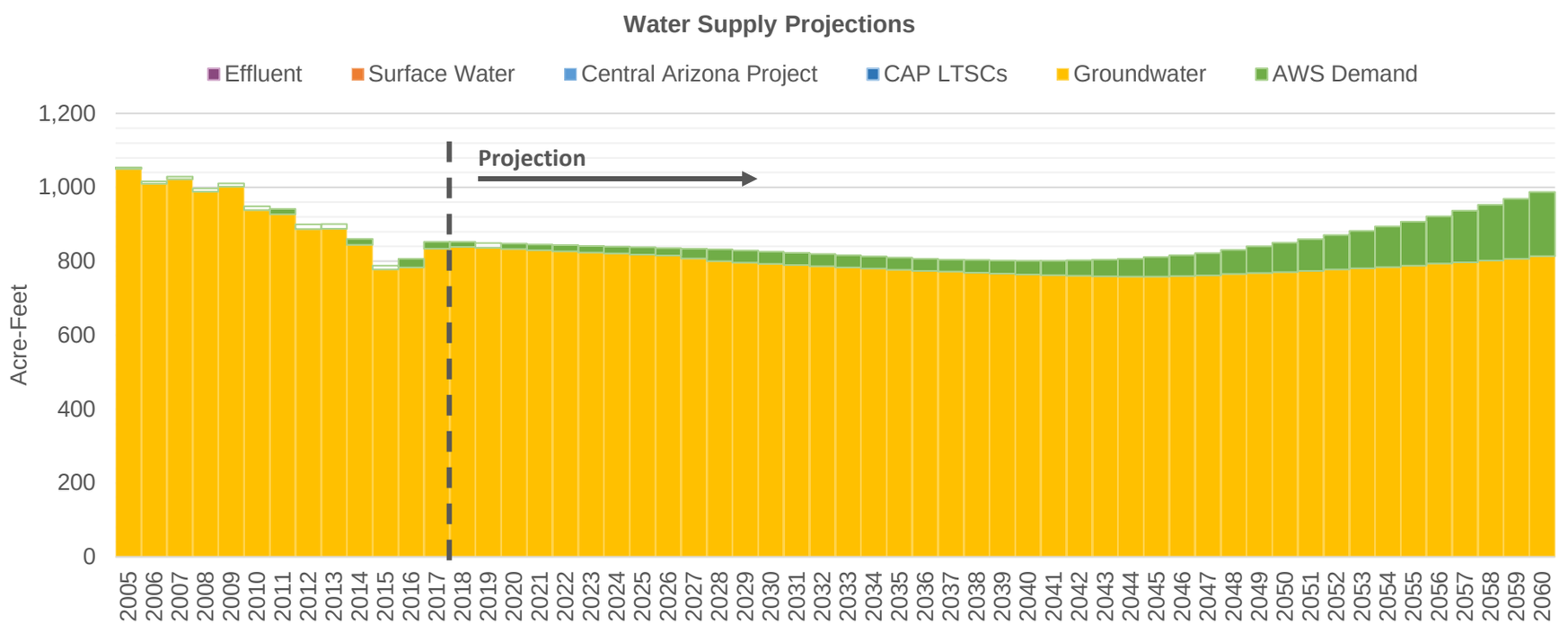
Central Arizona Project Service Area Model

MetroHub

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroHub

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

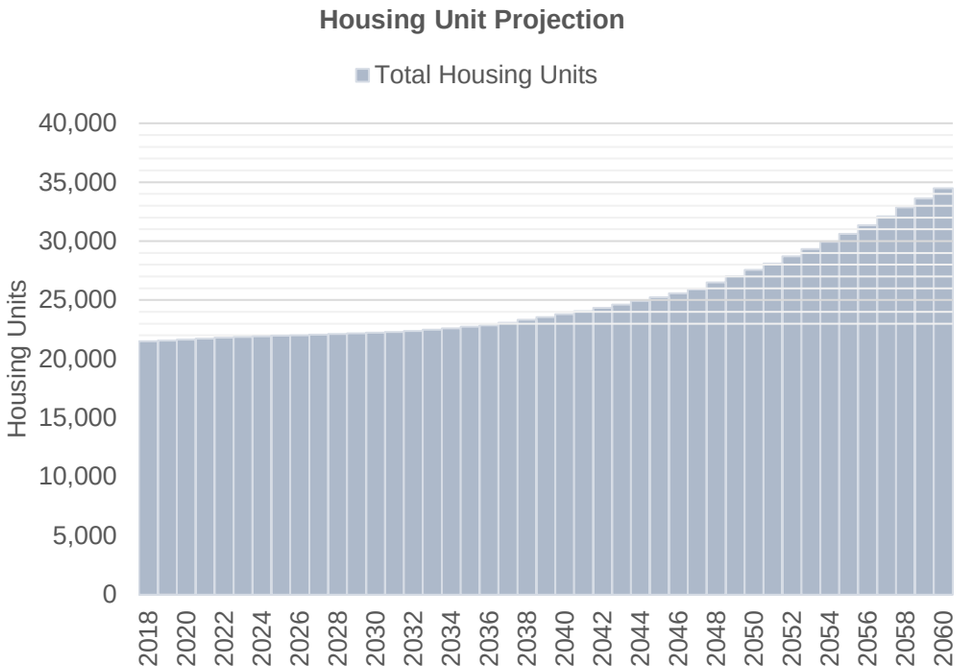
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

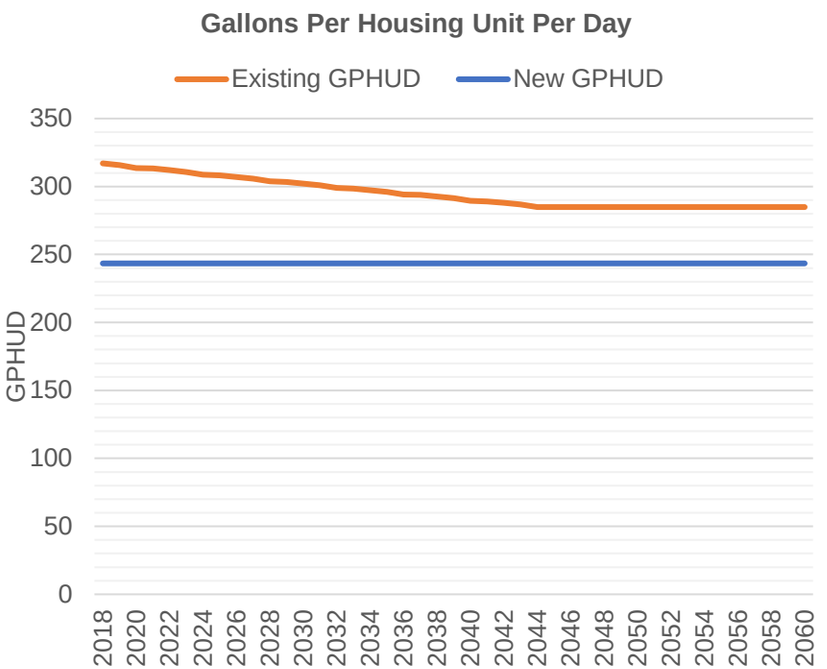
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,432	531	362	0	0	0	0	0	0	0	839	13
2019	1,435	529	362	0	0	0	0	0	0	0	836	13
2020	1,438	526	362	0	0	0	0	0	0	0	833	14
2021	1,441	525	362	0	0	0	0	0	0	0	830	15
2022	1,445	523	362	0	0	0	0	0	0	0	827	16
2023	1,448	521	362	0	0	0	0	0	0	0	824	17
2024	1,452	517	362	0	0	0	0	0	0	0	821	18
2025	1,456	517	362	0	0	0	0	0	0	0	818	20
2026	1,460	515	362	0	0	0	0	0	0	0	815	21
2027	1,464	513	362	0	0	0	0	0	0	0	807	27
2028	1,465	509	362	0	0	0	0	0	0	0	800	32
2029	1,465	509	362	0	0	0	0	0	0	0	797	32
2030	1,465	506	362	0	0	0	0	0	0	0	793	32
2031	1,465	504	362	0	0	0	0	0	0	0	790	32
2032	1,465	501	362	0	0	0	0	0	0	0	787	32
2033	1,465	500	362	0	0	0	0	0	0	0	784	32
2034	1,465	498	362	0	0	0	0	0	0	0	780	32
2035	1,465	496	362	0	0	0	0	0	0	0	777	32
2036	1,465	493	362	0	0	0	0	0	0	0	774	32
2037	1,470	492	362	0	0	0	0	0	0	0	772	32
2038	1,475	490	362	0	0	0	0	0	0	0	769	34
2039	1,480	489	362	0	0	0	0	0	0	0	767	35
2040	1,486	485	362	0	0	0	0	0	0	0	764	37
2041	1,497	485	362	0	0	0	0	0	0	0	763	39
2042	1,508	483	362	0	0	0	0	0	0	0	761	42
2043	1,520	481	362	0	0	0	0	0	0	0	759	45
2044	1,534	478	362	0	0	0	0	0	0	0	758	48
2045	1,547	478	362	0	0	0	0	0	0	0	759	53
2046	1,561	478	362	0	0	0	0	0	0	0	760	56
2047	1,575	478	362	0	0	0	0	0	0	0	762	60
2048	1,601	478	362	0	0	0	0	0	0	0	766	65
2049	1,625	478	362	0	0	0	0	0	0	0	768	72
2050	1,648	478	362	0	0	0	0	0	0	0	771	79
2051	1,673	478	362	0	0	0	0	0	0	0	774	86
2052	1,701	478	362	0	0	0	0	0	0	0	778	93
2053	1,730	478	362	0	0	0	0	0	0	0	781	101
2054	1,760	478	362	0	0	0	0	0	0	0	784	110
2055	1,793	478	362	0	0	0	0	0	0	0	788	119
2056	1,831	478	362	0	0	0	0	0	0	0	793	128
2057	1,869	478	362	0	0	0	0	0	0	0	797	139
2058	1,909	478	362	0	0	0	0	0	0	0	802	151
2059	1,949	478	362	0	0	0	0	0	0	0	807	162
2060	1,998	478	362	0	0	0	0	0	0	0	814	174

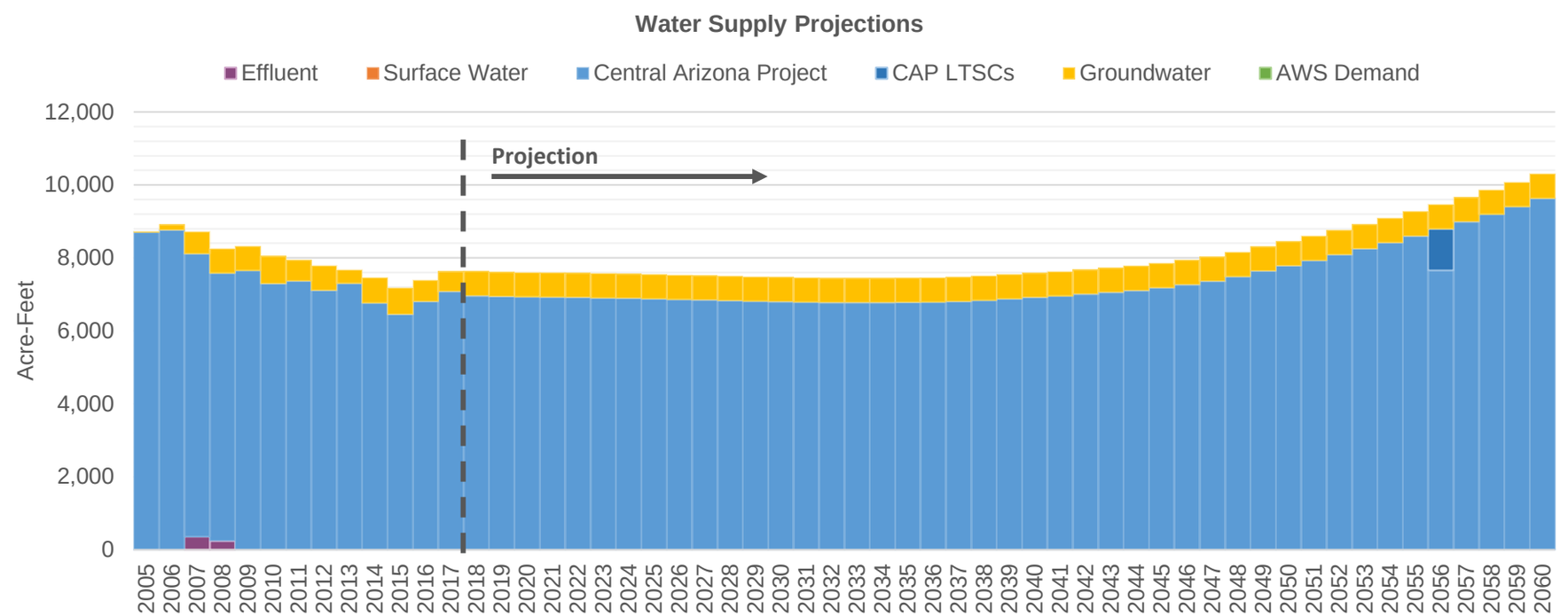
Central Arizona Project Service Area Model

MetroMain

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroMain

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

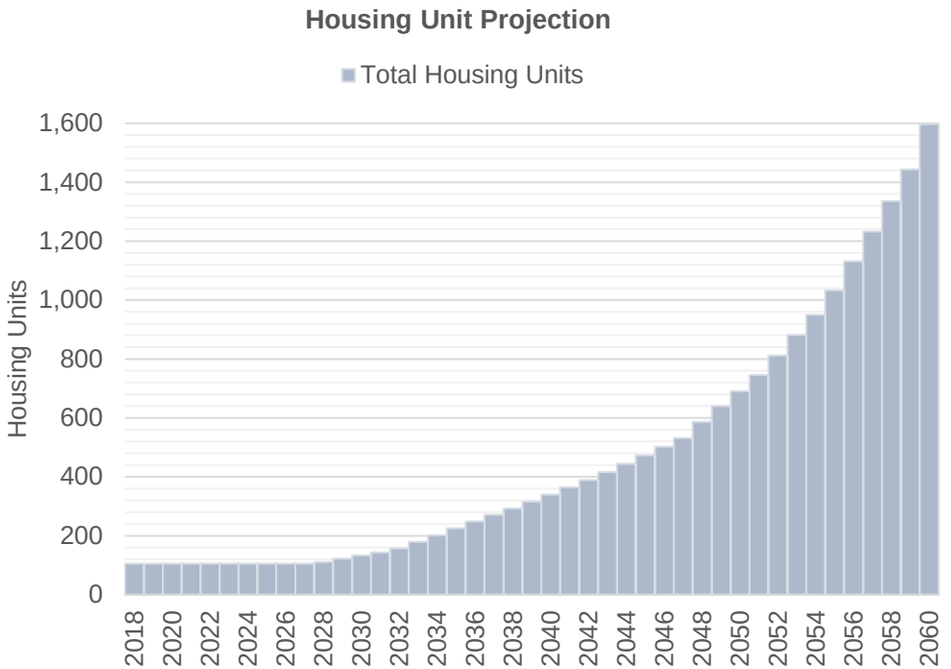
Water Supply Projections (Acre-Feet)

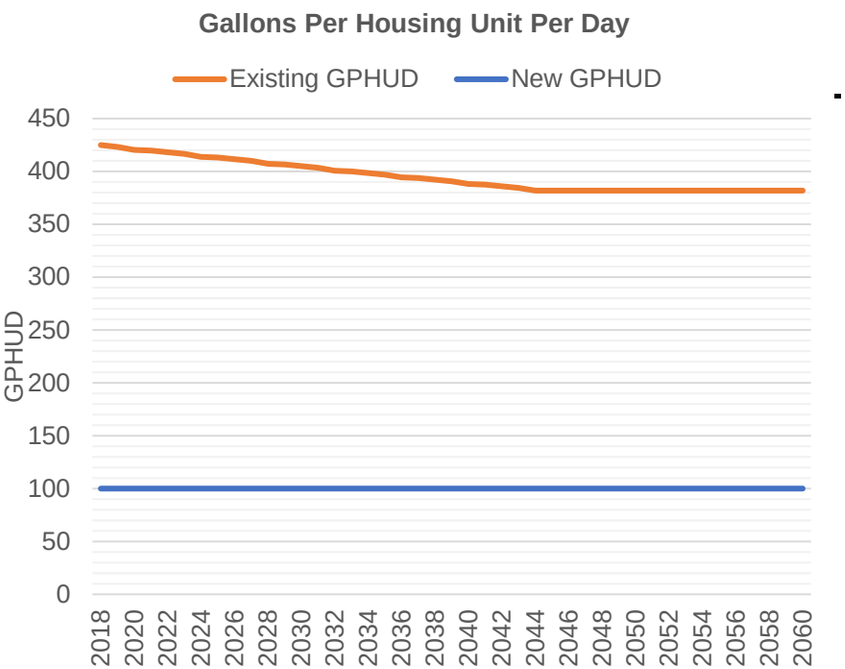
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	21,497	317	243	0	0	0	0	6,962	6,498	0	668	0
2019	21,564	316	243	0	0	0	0	6,943	6,517	0	668	0
2020	21,640	314	243	0	0	0	0	6,933	6,527	0	668	0
2021	21,720	313	243	0	0	0	0	6,924	6,536	0	668	0
2022	21,802	312	243	0	0	0	0	6,916	6,544	0	668	0
2023	21,873	311	243	0	0	0	0	6,906	6,554	0	668	0
2024	21,922	309	243	0	0	0	0	6,893	6,567	0	668	0
2025	21,972	308	243	0	0	0	0	6,877	6,583	0	668	0
2026	22,023	307	243	0	0	0	0	6,861	6,599	0	668	0
2027	22,075	306	243	0	0	0	0	6,845	6,615	0	668	0
2028	22,129	304	243	0	0	0	0	6,831	6,629	0	668	0
2029	22,183	303	243	0	0	0	0	6,816	6,644	0	668	0
2030	22,239	302	243	0	0	0	0	6,801	6,659	0	668	0
2031	22,296	301	243	0	0	0	0	6,788	6,672	0	668	0
2032	22,364	299	243	0	0	0	0	6,776	6,684	0	668	0
2033	22,483	299	243	0	0	0	0	6,772	6,688	0	668	0
2034	22,605	297	243	0	0	0	0	6,777	6,683	0	668	0
2035	22,729	296	243	0	0	0	0	6,782	6,678	0	668	0
2036	22,857	294	243	0	0	0	0	6,788	6,672	0	668	0
2037	23,085	294	243	0	0	0	0	6,808	6,652	0	668	0
2038	23,318	293	243	0	0	0	0	6,842	5,699	0	668	0
2039	23,557	291	243	0	0	0	0	6,878	3,538	0	668	0
2040	23,803	289	243	0	0	0	0	6,918	5,394	0	668	0
2041	24,069	289	243	0	0	0	0	6,958	6,291	0	668	0
2042	24,341	288	243	0	0	0	0	7,004	6,126	0	668	0
2043	24,627	287	243	0	0	0	0	7,052	6,408	0	668	0
2044	24,926	285	243	0	0	0	0	7,107	6,353	0	668	0
2045	25,236	285	243	0	0	0	0	7,179	6,281	0	668	0
2046	25,566	285	243	0	0	0	0	7,267	5,758	0	668	0
2047	25,904	285	243	0	0	0	0	7,358	6,102	0	668	0
2048	26,499	285	243	0	0	0	0	7,489	5,537	0	668	0
2049	27,040	285	243	0	0	0	0	7,640	5,385	0	668	0
2050	27,561	285	243	0	0	0	0	7,785	5,240	0	668	0
2051	28,105	285	243	0	0	0	0	7,930	5,095	0	668	0
2052	28,706	285	243	0	0	0	0	8,091	4,000	0	668	0
2053	29,322	285	243	0	0	0	0	8,252	3,839	0	668	0
2054	29,954	285	243	0	0	0	0	8,422	2,152	0	668	0
2055	30,628	285	243	0	0	0	0	8,600	806	0	668	0
2056	31,350	285	243	0	0	0	0	7,656	0	1,142	668	0
2057	32,091	285	243	0	0	0	0	8,990	1,584	0	668	0
2058	32,851	285	243	0	0	0	0	9,195	1,963	0	668	0
2059	33,631	285	243	0	0	0	0	9,405	1,519	0	668	0
2060	34,480	285	243	0	0	0	0	9,636	1,288	0	668	0

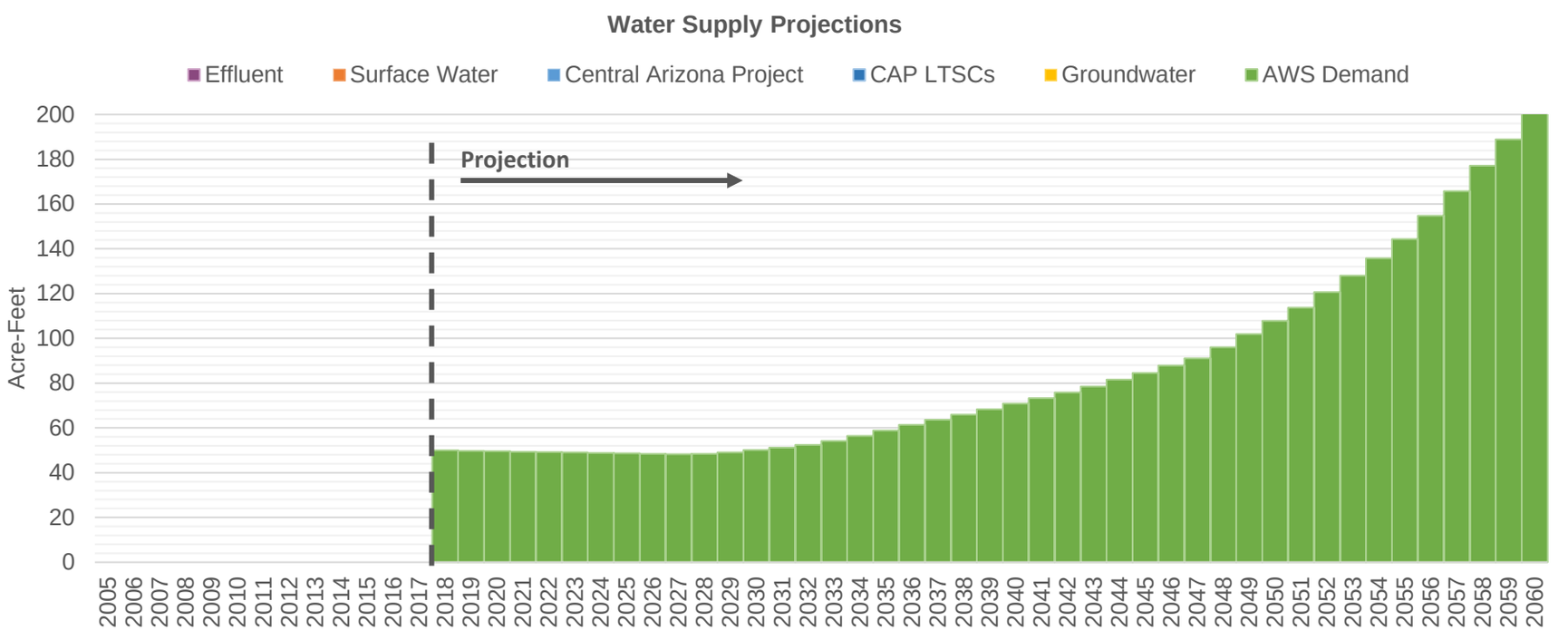
Central Arizona Project Service Area Model

MetroWest

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

MetroWest

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

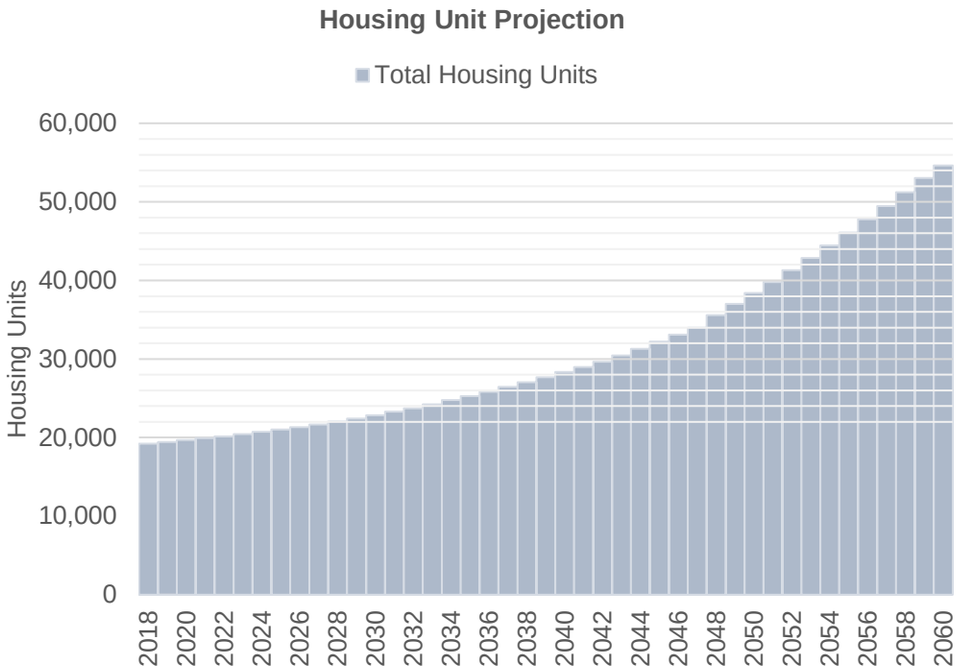
Water Supply Projections (Acre-Feet)

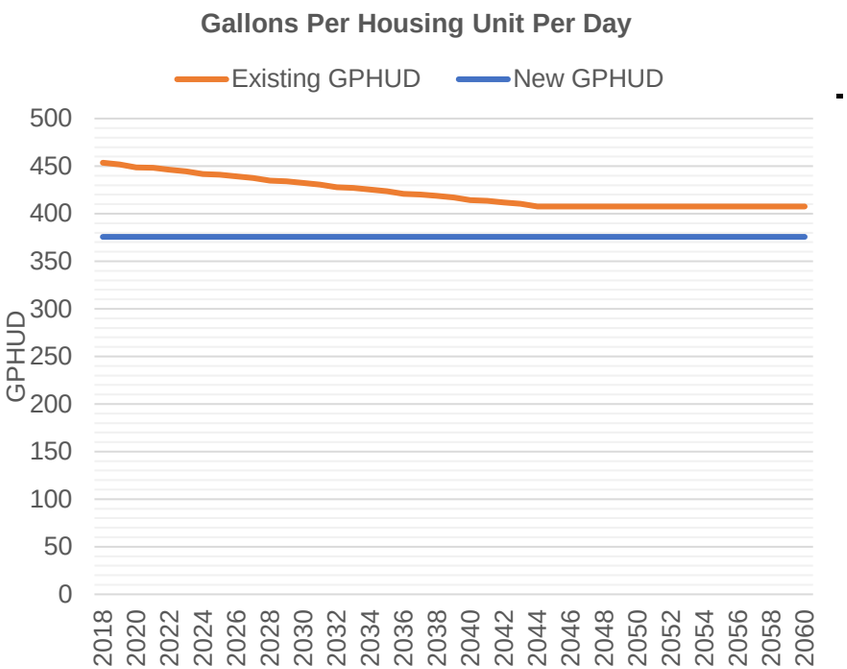
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	105	425	100	0	0	0	0	0	0	0	0	50
2019	105	423	100	0	0	0	0	0	0	0	0	50
2020	105	420	100	0	0	0	0	0	0	0	0	50
2021	105	420	100	0	0	0	0	0	0	0	0	49
2022	105	418	100	0	0	0	0	0	0	0	0	49
2023	105	417	100	0	0	0	0	0	0	0	0	49
2024	105	414	100	0	0	0	0	0	0	0	0	49
2025	105	413	100	0	0	0	0	0	0	0	0	49
2026	105	412	100	0	0	0	0	0	0	0	0	48
2027	105	410	100	0	0	0	0	0	0	0	0	48
2028	111	407	100	0	0	0	0	0	0	0	0	48
2029	122	407	100	0	0	0	0	0	0	0	0	49
2030	133	405	100	0	0	0	0	0	0	0	0	50
2031	144	403	100	0	0	0	0	0	0	0	0	51
2032	157	401	100	0	0	0	0	0	0	0	0	52
2033	179	400	100	0	0	0	0	0	0	0	0	54
2034	202	399	100	0	0	0	0	0	0	0	0	56
2035	225	397	100	0	0	0	0	0	0	0	0	59
2036	249	394	100	0	0	0	0	0	0	0	0	61
2037	271	394	100	0	0	0	0	0	0	0	0	64
2038	293	392	100	0	0	0	0	0	0	0	0	66
2039	316	391	100	0	0	0	0	0	0	0	0	68
2040	340	388	100	0	0	0	0	0	0	0	0	71
2041	364	388	100	0	0	0	0	0	0	0	0	73
2042	389	386	100	0	0	0	0	0	0	0	0	76
2043	416	384	100	0	0	0	0	0	0	0	0	79
2044	444	382	100	0	0	0	0	0	0	0	0	82
2045	473	382	100	0	0	0	0	0	0	0	0	85
2046	502	382	100	0	0	0	0	0	0	0	0	88
2047	532	382	100	0	0	0	0	0	0	0	0	91
2048	587	382	100	0	0	0	0	0	0	0	0	96
2049	640	382	100	0	0	0	0	0	0	0	0	102
2050	691	382	100	0	0	0	0	0	0	0	0	108
2051	746	382	100	0	0	0	0	0	0	0	0	114
2052	812	382	100	0	0	0	0	0	0	0	0	121
2053	881	382	100	0	0	0	0	0	0	0	0	128
2054	950	382	100	0	0	0	0	0	0	0	0	136
2055	1,033	382	100	0	0	0	0	0	0	0	0	144
2056	1,132	382	100	0	0	0	0	0	0	0	0	155
2057	1,233	382	100	0	0	0	0	0	0	0	0	166
2058	1,336	382	100	0	0	0	0	0	0	0	0	177
2059	1,443	382	100	0	0	0	0	0	0	0	0	189
2060	1,597	382	100	0	0	0	0	0	0	0	0	204

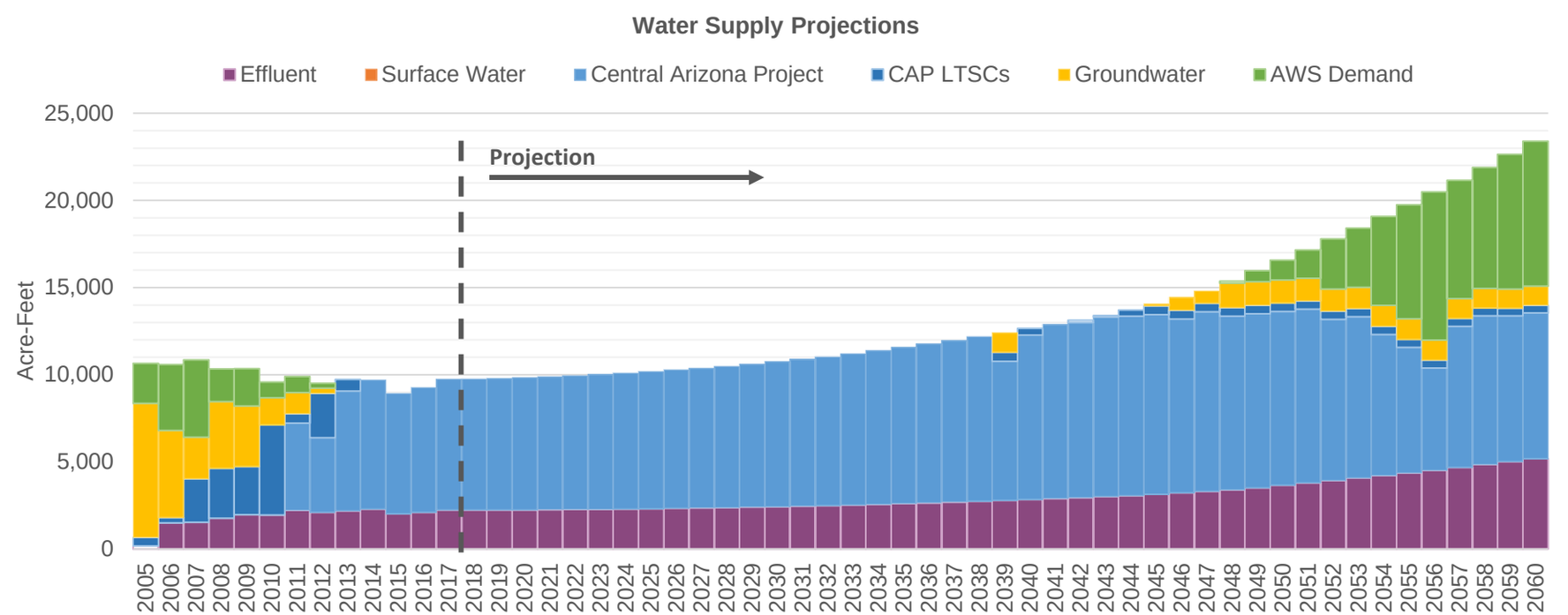
OroValley

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

OroValley

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

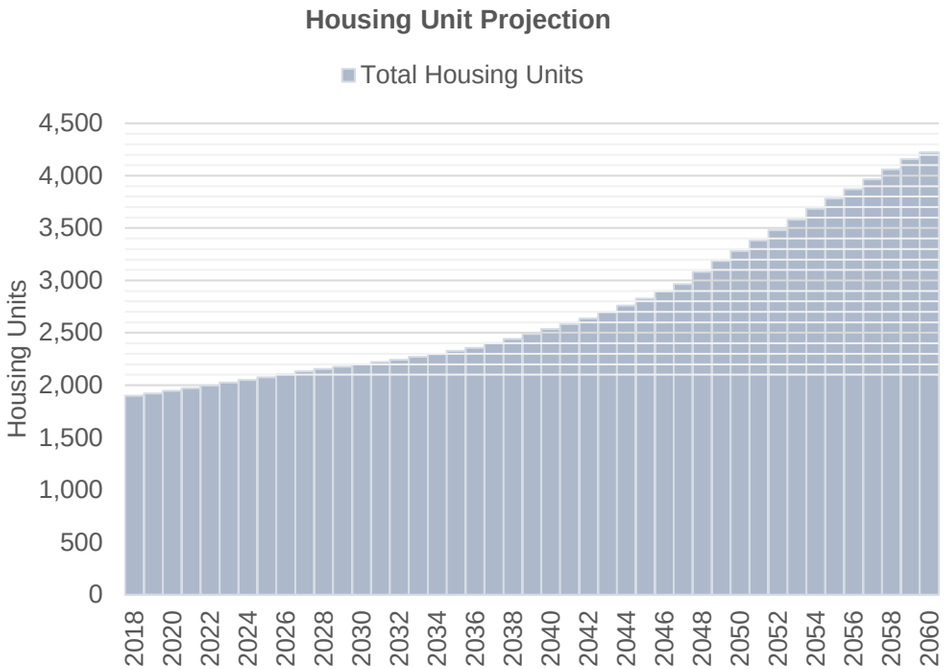
Demand Assumptions **Water Supply Projections** (Acre-Feet)

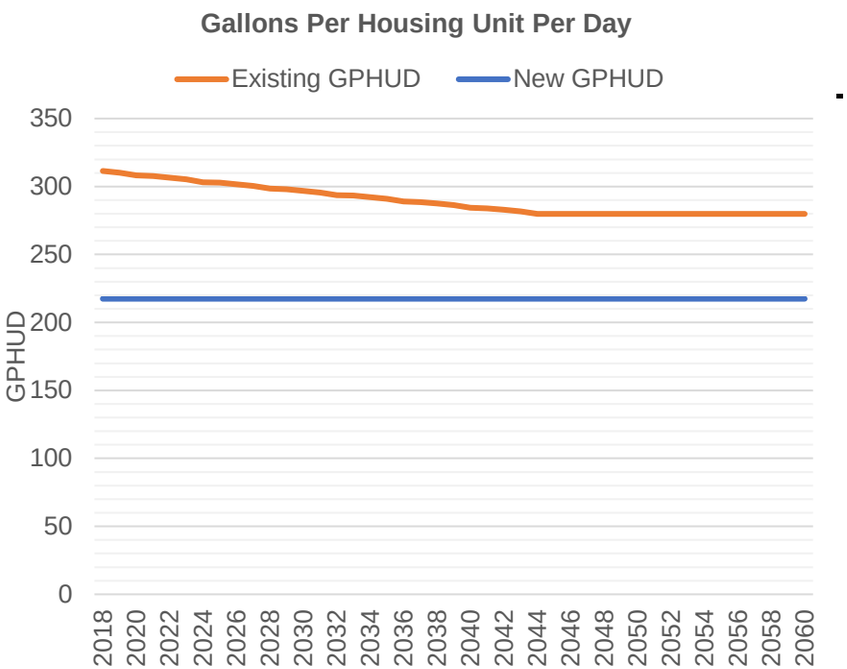
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	19,239	454	376	2,232	0	0	0	7,524	2,781	0	0	0
2019	19,441	452	376	2,232	0	0	0	7,541	2,764	0	0	0
2020	19,675	449	376	2,236	0	0	0	7,591	2,714	0	0	0
2021	19,919	448	376	2,248	0	0	0	7,640	2,665	0	0	0
2022	20,166	446	376	2,262	0	0	0	7,691	2,614	0	0	0
2023	20,430	445	376	2,277	0	0	0	7,745	2,560	0	0	0
2024	20,727	442	376	2,293	0	0	0	7,811	2,494	0	0	0
2025	21,029	441	376	2,311	0	0	0	7,879	2,426	0	0	0
2026	21,338	439	376	2,331	0	0	0	7,949	2,356	0	0	0
2027	21,653	438	376	2,352	0	0	0	8,022	2,283	0	0	0
2028	22,023	435	376	2,373	0	0	0	8,111	2,194	0	0	0
2029	22,434	434	376	2,398	0	0	0	8,209	2,096	0	0	0
2030	22,854	432	376	2,427	0	0	0	8,318	1,987	0	0	0
2031	23,283	431	376	2,458	0	0	0	8,428	1,877	0	0	0
2032	23,731	428	376	2,491	0	0	0	8,548	1,757	0	0	0
2033	24,242	427	376	2,525	0	0	0	8,674	1,631	0	0	0
2034	24,764	425	376	2,562	0	0	0	8,818	1,487	0	0	0
2035	25,297	424	376	2,603	0	0	0	8,962	1,343	0	0	0
2036	25,843	421	376	2,646	0	0	0	9,117	1,188	0	0	0
2037	26,446	420	376	2,691	0	0	0	9,270	1,035	0	0	0
2038	27,062	419	376	2,736	0	0	0	9,446	156	0	0	0
2039	27,693	417	376	2,787	0	0	0	7,975	0	519	1,128	0
2040	28,337	414	376	2,839	0	0	0	9,426	0	385	0	0
2041	28,988	414	376	2,894	0	0	0	9,983	161	0	0	0
2042	29,654	412	376	2,946	0	0	0	10,052	0	120	0	0
2043	30,438	410	376	3,001	0	0	0	10,305	0	82	0	0
2044	31,312	408	376	3,063	0	0	0	10,305	0	348	0	0
2045	32,202	408	376	3,138	0	0	0	10,305	0	505	115	0
2046	33,091	408	376	3,217	0	0	0	9,972	0	500	748	0
2047	34,002	408	376	3,303	0	0	0	10,305	0	495	713	0
2048	35,591	408	376	3,390	0	0	0	9,972	0	490	1,401	107
2049	37,016	408	376	3,514	0	0	0	9,972	0	486	1,360	644
2050	38,382	408	376	3,655	0	0	0	9,972	0	481	1,323	1,133
2051	39,797	408	376	3,789	0	0	0	9,972	0	476	1,289	1,623
2052	41,315	408	376	3,923	0	0	0	9,257	0	471	1,258	2,882
2053	42,871	408	376	4,070	0	0	0	9,257	0	466	1,229	3,390
2054	44,467	408	376	4,212	0	0	0	8,095	0	462	1,203	5,104
2055	46,099	408	376	4,364	0	0	0	7,202	0	457	1,180	6,552
2056	47,767	408	376	4,519	0	0	0	5,861	0	453	1,159	8,490
2057	49,479	408	376	4,686	0	0	0	8,095	0	448	1,140	6,791
2058	51,236	408	376	4,841	0	0	0	8,542	0	444	1,124	6,939
2059	53,039	408	376	5,008	0	0	0	8,363	0	439	1,111	7,718
2060	54,646	408	376	5,179	0	0	0	8,363	0	435	1,099	8,321

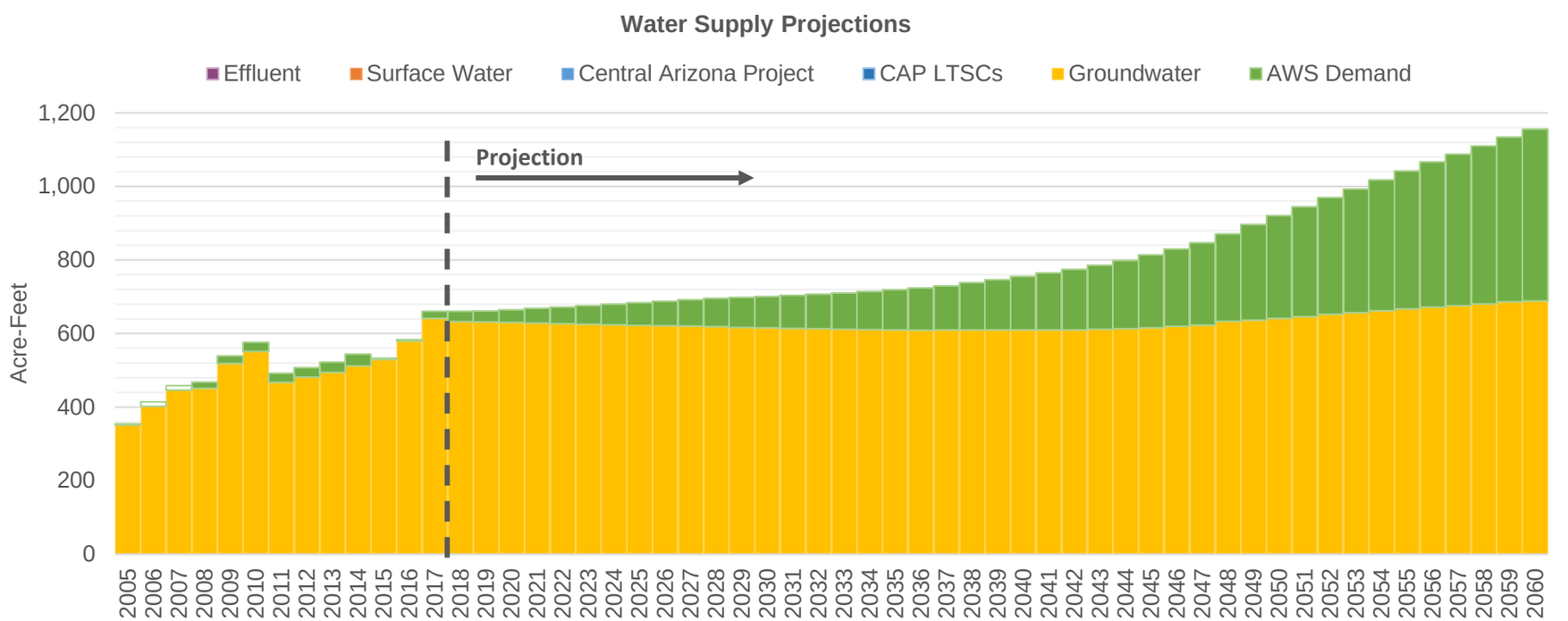
QuailCreek

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

QuailCreek

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

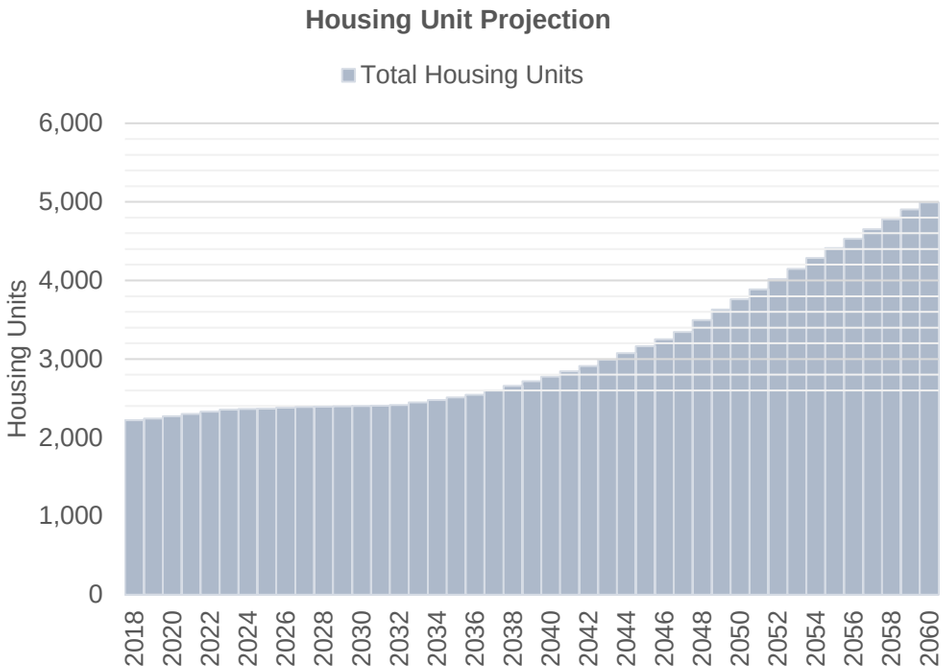
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

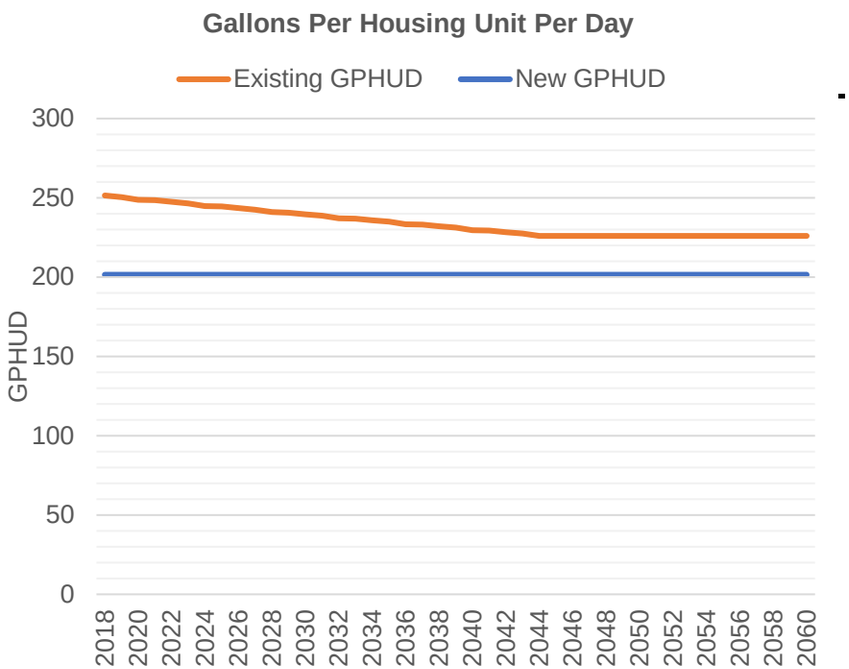
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,899	311	217	0	0	0	0	0	0	0	633	28
2019	1,920	310	217	0	0	0	0	0	0	0	632	30
2020	1,945	308	217	0	0	0	0	0	0	0	630	34
2021	1,971	308	217	0	0	0	0	0	0	0	628	40
2022	1,997	306	217	0	0	0	0	0	0	0	627	45
2023	2,024	305	217	0	0	0	0	0	0	0	625	51
2024	2,050	303	217	0	0	0	0	0	0	0	624	56
2025	2,077	303	217	0	0	0	0	0	0	0	622	61
2026	2,104	302	217	0	0	0	0	0	0	0	621	66
2027	2,132	300	217	0	0	0	0	0	0	0	620	72
2028	2,156	298	217	0	0	0	0	0	0	0	619	77
2029	2,176	298	217	0	0	0	0	0	0	0	617	82
2030	2,198	297	217	0	0	0	0	0	0	0	615	86
2031	2,220	296	217	0	0	0	0	0	0	0	614	90
2032	2,243	294	217	0	0	0	0	0	0	0	613	94
2033	2,270	293	217	0	0	0	0	0	0	0	612	98
2034	2,298	292	217	0	0	0	0	0	0	0	611	104
2035	2,327	291	217	0	0	0	0	0	0	0	610	109
2036	2,356	289	217	0	0	0	0	0	0	0	609	115
2037	2,399	289	217	0	0	0	0	0	0	0	610	120
2038	2,443	287	217	0	0	0	0	0	0	0	610	128
2039	2,488	286	217	0	0	0	0	0	0	0	610	137
2040	2,535	284	217	0	0	0	0	0	0	0	610	146
2041	2,585	284	217	0	0	0	0	0	0	0	610	155
2042	2,636	283	217	0	0	0	0	0	0	0	610	164
2043	2,696	282	217	0	0	0	0	0	0	0	612	174
2044	2,760	280	217	0	0	0	0	0	0	0	613	186
2045	2,827	280	217	0	0	0	0	0	0	0	616	198
2046	2,895	280	217	0	0	0	0	0	0	0	619	211
2047	2,965	280	217	0	0	0	0	0	0	0	623	224
2048	3,083	280	217	0	0	0	0	0	0	0	633	237
2049	3,185	280	217	0	0	0	0	0	0	0	636	260
2050	3,282	280	217	0	0	0	0	0	0	0	641	280
2051	3,381	280	217	0	0	0	0	0	0	0	646	298
2052	3,479	280	217	0	0	0	0	0	0	0	652	317
2053	3,580	280	217	0	0	0	0	0	0	0	657	336
2054	3,683	280	217	0	0	0	0	0	0	0	662	356
2055	3,781	280	217	0	0	0	0	0	0	0	667	376
2056	3,872	280	217	0	0	0	0	0	0	0	672	394
2057	3,965	280	217	0	0	0	0	0	0	0	676	412
2058	4,060	280	217	0	0	0	0	0	0	0	681	430
2059	4,158	280	217	0	0	0	0	0	0	0	686	448
2060	4,225	280	217	0	0	0	0	0	0	0	689	467

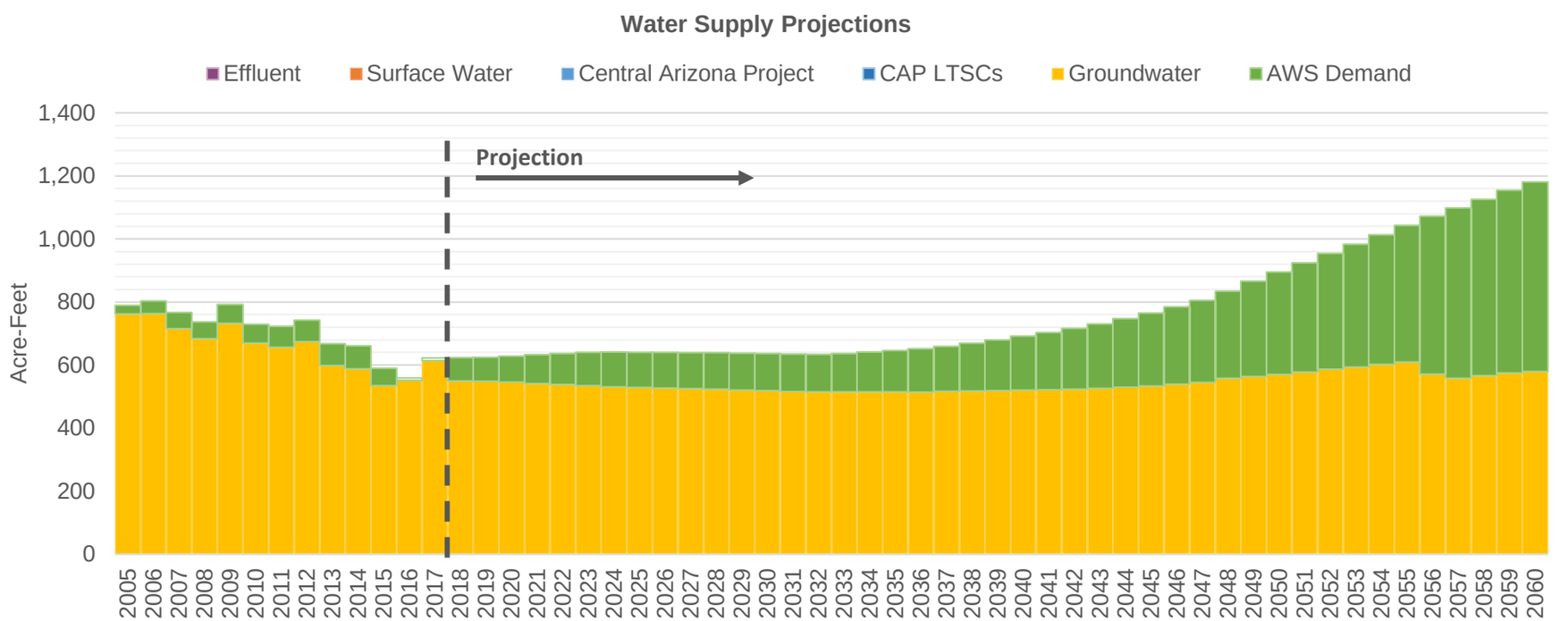
RayWC

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

RayWC

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

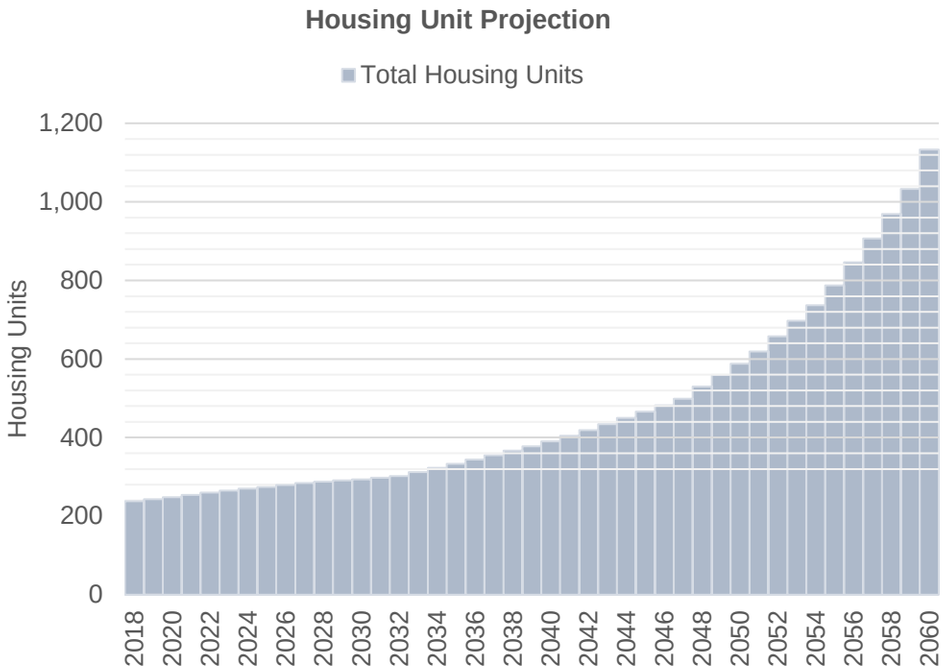
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

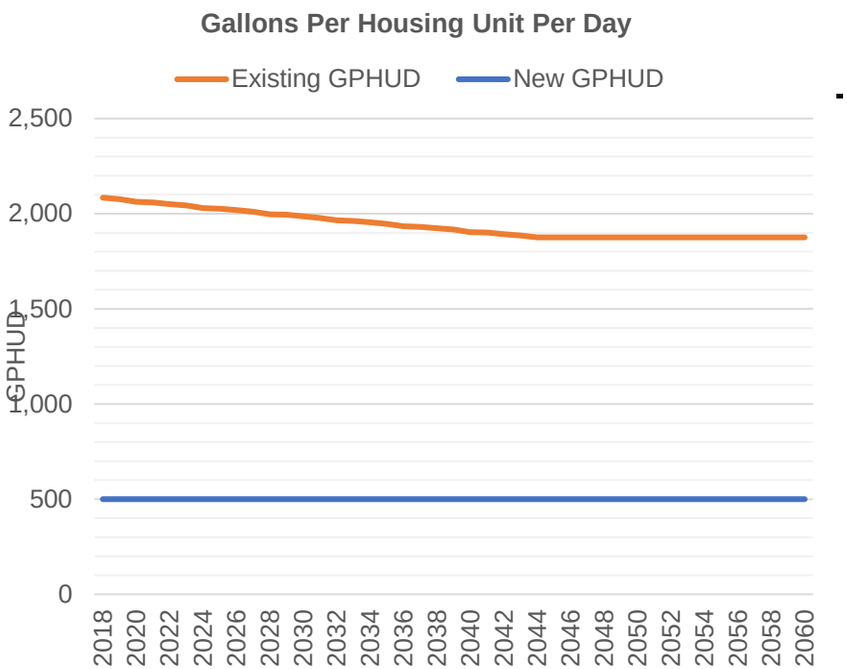
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	2,219	252	202	0	0	0	0	0	0	0	550	74
2019	2,243	250	202	0	0	0	0	0	0	0	549	76
2020	2,272	249	202	0	0	0	0	0	0	0	545	83
2021	2,301	248	202	0	0	0	0	0	0	0	541	91
2022	2,331	248	202	0	0	0	0	0	0	0	538	99
2023	2,354	247	202	0	0	0	0	0	0	0	534	106
2024	2,362	245	202	0	0	0	0	0	0	0	531	111
2025	2,370	245	202	0	0	0	0	0	0	0	529	112
2026	2,379	244	202	0	0	0	0	0	0	0	527	113
2027	2,388	243	202	0	0	0	0	0	0	0	525	115
2028	2,394	241	202	0	0	0	0	0	0	0	523	116
2029	2,398	241	202	0	0	0	0	0	0	0	520	117
2030	2,403	240	202	0	0	0	0	0	0	0	518	118
2031	2,407	239	202	0	0	0	0	0	0	0	516	119
2032	2,416	237	202	0	0	0	0	0	0	0	515	119
2033	2,447	237	202	0	0	0	0	0	0	0	515	121
2034	2,479	236	202	0	0	0	0	0	0	0	515	126
2035	2,511	235	202	0	0	0	0	0	0	0	514	132
2036	2,545	233	202	0	0	0	0	0	0	0	514	137
2037	2,601	233	202	0	0	0	0	0	0	0	516	143
2038	2,658	232	202	0	0	0	0	0	0	0	517	152
2039	2,717	231	202	0	0	0	0	0	0	0	519	162
2040	2,778	230	202	0	0	0	0	0	0	0	520	171
2041	2,844	229	202	0	0	0	0	0	0	0	522	182
2042	2,912	228	202	0	0	0	0	0	0	0	524	193
2043	2,989	228	202	0	0	0	0	0	0	0	526	204
2044	3,074	226	202	0	0	0	0	0	0	0	530	217
2045	3,161	226	202	0	0	0	0	0	0	0	534	231
2046	3,250	226	202	0	0	0	0	0	0	0	539	246
2047	3,342	226	202	0	0	0	0	0	0	0	545	261
2048	3,496	226	202	0	0	0	0	0	0	0	558	276
2049	3,631	226	202	0	0	0	0	0	0	0	564	302
2050	3,758	226	202	0	0	0	0	0	0	0	570	325
2051	3,887	226	202	0	0	0	0	0	0	0	578	346
2052	4,016	226	202	0	0	0	0	0	0	0	587	368
2053	4,149	226	202	0	0	0	0	0	0	0	593	390
2054	4,284	226	202	0	0	0	0	0	0	0	602	412
2055	4,412	226	202	0	0	0	0	0	0	0	609	434
2056	4,531	226	202	0	0	0	0	0	0	0	571	502
2057	4,653	226	202	0	0	0	0	0	0	0	558	540
2058	4,778	226	202	0	0	0	0	0	0	0	566	560
2059	4,906	226	202	0	0	0	0	0	0	0	574	580
2060	4,994	226	202	0	0	0	0	0	0	0	580	601

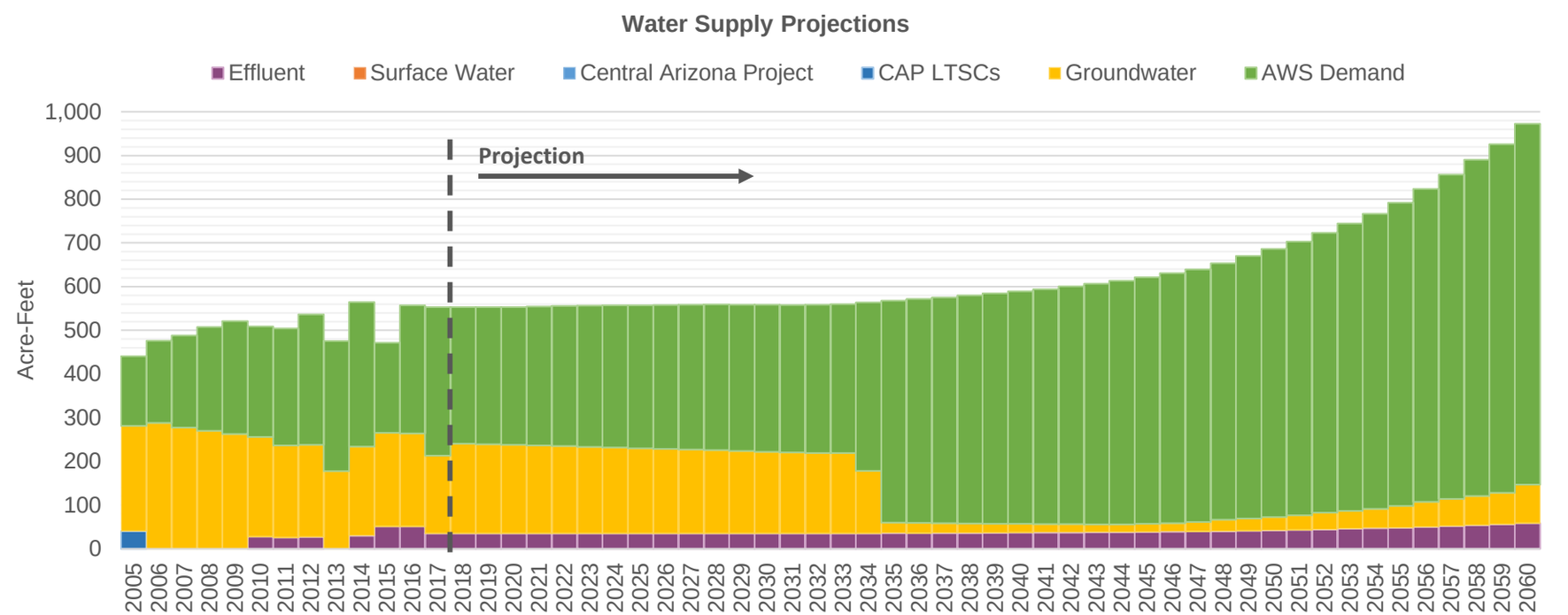
RidgeView

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

RidgeView

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

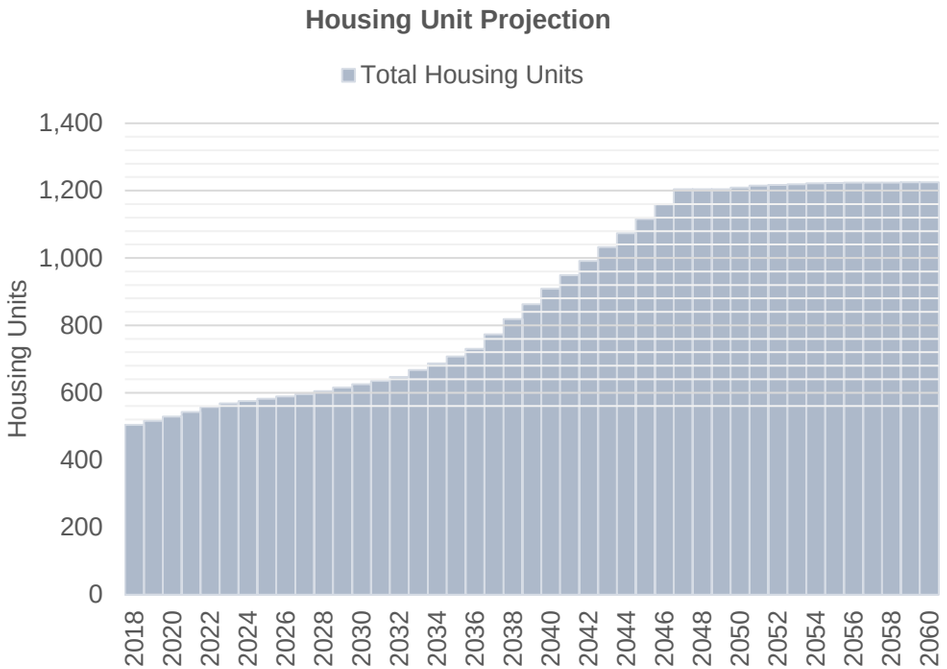
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

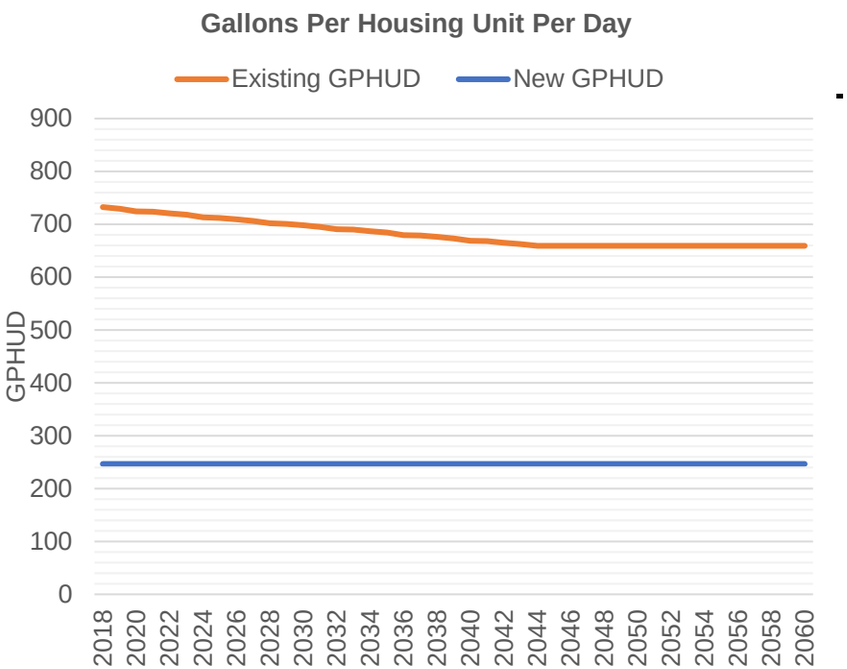
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	238	2,084	500	35	0	0	0	0	0	0	206	313
2019	243	2,076	500	35	0	0	0	0	0	0	205	313
2020	248	2,062	500	35	0	0	0	0	0	0	203	316
2021	254	2,059	500	35	0	0	0	0	0	0	201	318
2022	260	2,051	500	35	0	0	0	0	0	0	200	320
2023	265	2,043	500	35	0	0	0	0	0	0	198	323
2024	270	2,029	500	35	0	0	0	0	0	0	197	325
2025	274	2,027	500	35	0	0	0	0	0	0	195	327
2026	279	2,018	500	35	0	0	0	0	0	0	194	329
2027	284	2,010	500	35	0	0	0	0	0	0	192	331
2028	288	1,997	500	35	0	0	0	0	0	0	191	333
2029	291	1,994	500	35	0	0	0	0	0	0	189	335
2030	294	1,986	500	35	0	0	0	0	0	0	187	336
2031	298	1,978	500	35	0	0	0	0	0	0	186	337
2032	302	1,965	500	35	0	0	0	0	0	0	184	339
2033	312	1,963	500	35	0	0	0	0	0	0	185	340
2034	323	1,955	500	35	0	0	0	0	0	0	143	386
2035	333	1,947	500	36	0	0	0	0	0	0	24	507
2036	344	1,934	500	36	0	0	0	0	0	0	24	512
2037	355	1,931	500	36	0	0	0	0	0	0	23	517
2038	367	1,924	500	36	0	0	0	0	0	0	22	522
2039	378	1,916	500	37	0	0	0	0	0	0	21	527
2040	390	1,903	500	37	0	0	0	0	0	0	20	532
2041	405	1,901	500	37	0	0	0	0	0	0	20	537
2042	419	1,893	500	38	0	0	0	0	0	0	19	544
2043	434	1,885	500	38	0	0	0	0	0	0	18	550
2044	450	1,876	500	38	0	0	0	0	0	0	18	557
2045	466	1,876	500	39	0	0	0	0	0	0	19	564
2046	482	1,876	500	39	0	0	0	0	0	0	20	572
2047	499	1,876	500	40	0	0	0	0	0	0	21	578
2048	530	1,876	500	40	0	0	0	0	0	0	27	587
2049	559	1,876	500	41	0	0	0	0	0	0	28	601
2050	588	1,876	500	42	0	0	0	0	0	0	31	614
2051	619	1,876	500	43	0	0	0	0	0	0	33	627
2052	658	1,876	500	44	0	0	0	0	0	0	39	641
2053	697	1,876	500	46	0	0	0	0	0	0	41	658
2054	737	1,876	500	47	0	0	0	0	0	0	44	675
2055	787	1,876	500	48	0	0	0	0	0	0	50	693
2056	846	1,876	500	50	0	0	0	0	0	0	58	716
2057	907	1,876	500	52	0	0	0	0	0	0	62	742
2058	969	1,876	500	54	0	0	0	0	0	0	67	769
2059	1,033	1,876	500	56	0	0	0	0	0	0	72	797
2060	1,133	1,876	500	59	0	0	0	0	0	0	88	826

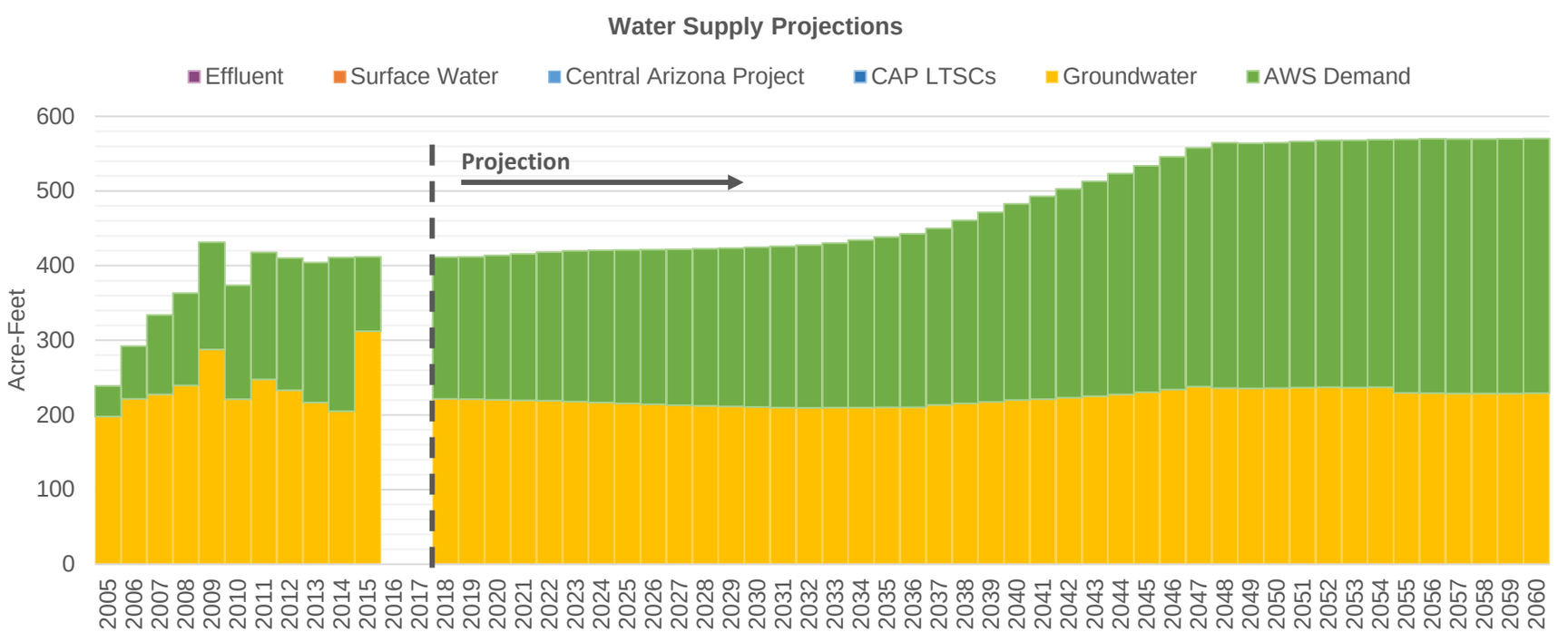
Central Arizona Project Service Area Model

Saguaro

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Saguaro

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7/15/20 9:31 AM

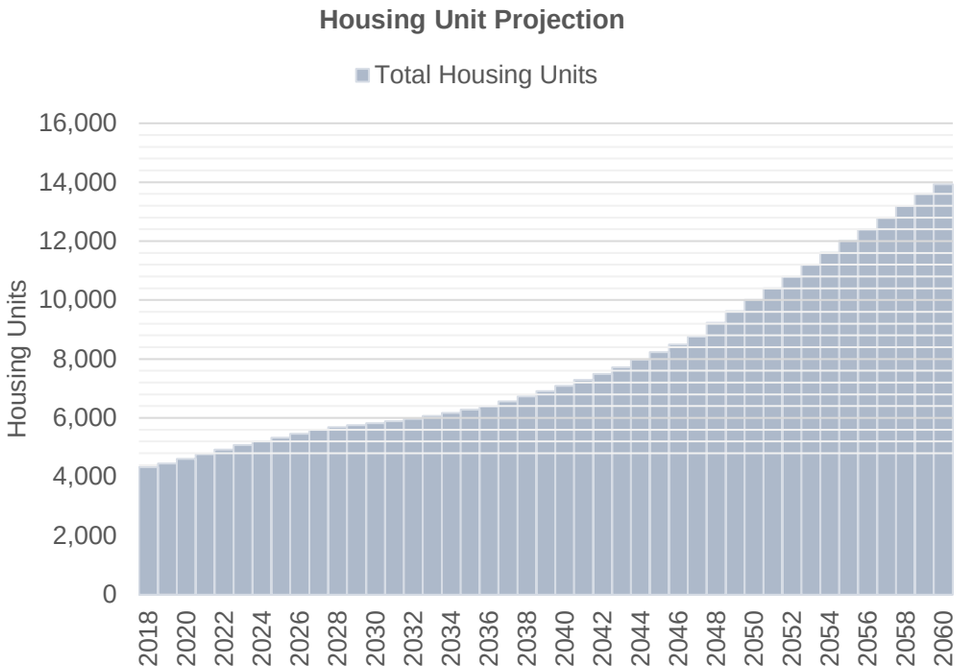
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

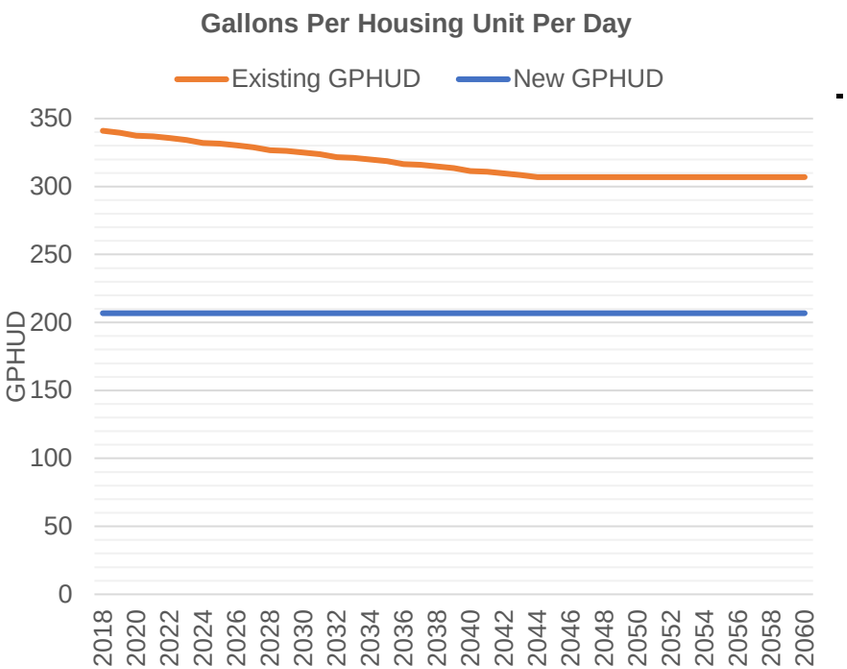
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	504	732	247	0	0	0	0	0	0	0	221	190
2019	516	730	247	0	0	0	0	0	0	0	221	191
2020	529	725	247	0	0	0	0	0	0	0	220	193
2021	543	724	247	0	0	0	0	0	0	0	220	196
2022	557	721	247	0	0	0	0	0	0	0	219	199
2023	568	718	247	0	0	0	0	0	0	0	218	202
2024	575	713	247	0	0	0	0	0	0	0	216	204
2025	582	712	247	0	0	0	0	0	0	0	215	206
2026	589	709	247	0	0	0	0	0	0	0	214	207
2027	596	707	247	0	0	0	0	0	0	0	213	209
2028	605	702	247	0	0	0	0	0	0	0	212	210
2029	615	701	247	0	0	0	0	0	0	0	212	212
2030	625	698	247	0	0	0	0	0	0	0	211	214
2031	635	695	247	0	0	0	0	0	0	0	210	216
2032	647	691	247	0	0	0	0	0	0	0	210	218
2033	667	690	247	0	0	0	0	0	0	0	210	220
2034	687	687	247	0	0	0	0	0	0	0	210	224
2035	708	684	247	0	0	0	0	0	0	0	210	228
2036	730	680	247	0	0	0	0	0	0	0	210	232
2037	773	679	247	0	0	0	0	0	0	0	213	237
2038	818	676	247	0	0	0	0	0	0	0	215	245
2039	863	673	247	0	0	0	0	0	0	0	217	254
2040	909	669	247	0	0	0	0	0	0	0	220	263
2041	949	668	247	0	0	0	0	0	0	0	221	272
2042	991	665	247	0	0	0	0	0	0	0	223	280
2043	1,032	663	247	0	0	0	0	0	0	0	225	288
2044	1,074	659	247	0	0	0	0	0	0	0	228	296
2045	1,116	659	247	0	0	0	0	0	0	0	230	304
2046	1,159	659	247	0	0	0	0	0	0	0	234	312
2047	1,204	659	247	0	0	0	0	0	0	0	238	320
2048	1,204	659	247	0	0	0	0	0	0	0	236	329
2049	1,204	659	247	0	0	0	0	0	0	0	235	329
2050	1,209	659	247	0	0	0	0	0	0	0	236	329
2051	1,215	659	247	0	0	0	0	0	0	0	237	330
2052	1,217	659	247	0	0	0	0	0	0	0	237	331
2053	1,219	659	247	0	0	0	0	0	0	0	237	331
2054	1,222	659	247	0	0	0	0	0	0	0	237	332
2055	1,223	659	247	0	0	0	0	0	0	0	230	340
2056	1,224	659	247	0	0	0	0	0	0	0	229	341
2057	1,224	659	247	0	0	0	0	0	0	0	229	341
2058	1,224	659	247	0	0	0	0	0	0	0	229	341
2059	1,225	659	247	0	0	0	0	0	0	0	229	341
2060	1,225	659	247	0	0	0	0	0	0	0	229	341

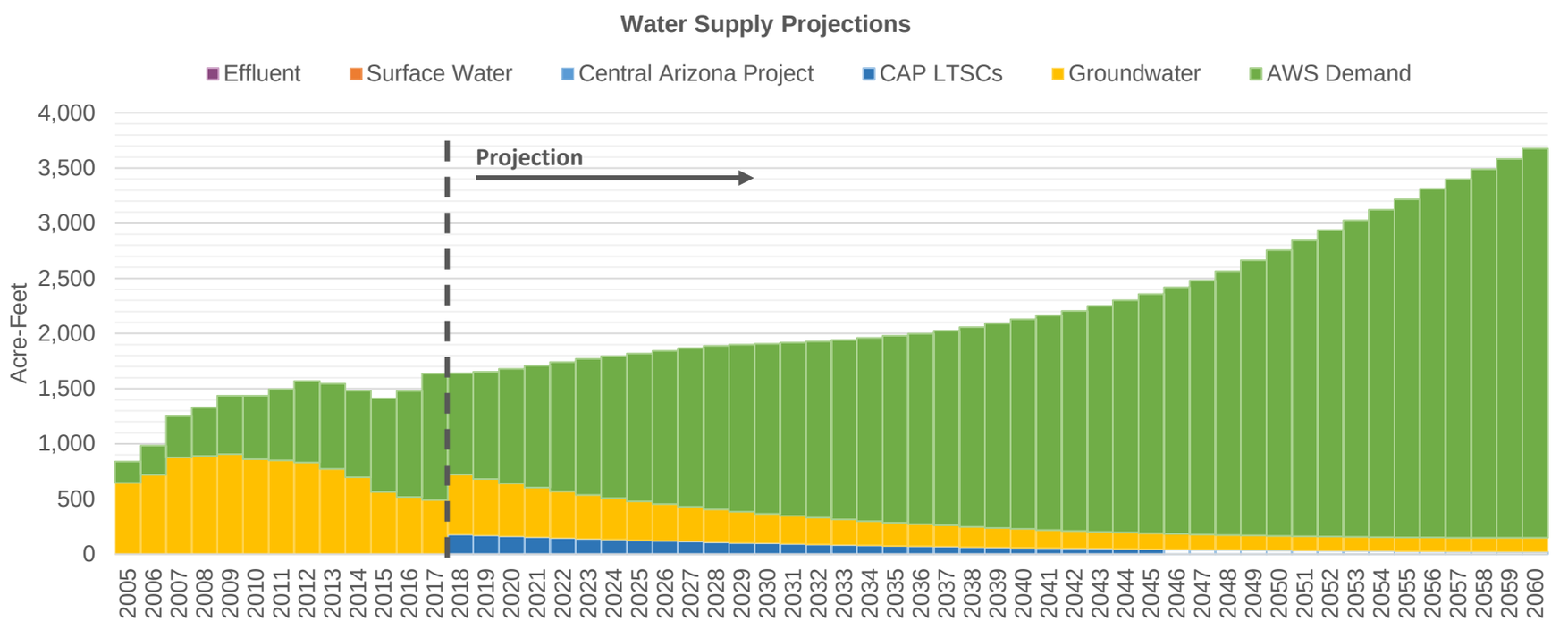
Central Arizona Project Service Area Model

Sahuarita

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Sahuarita

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

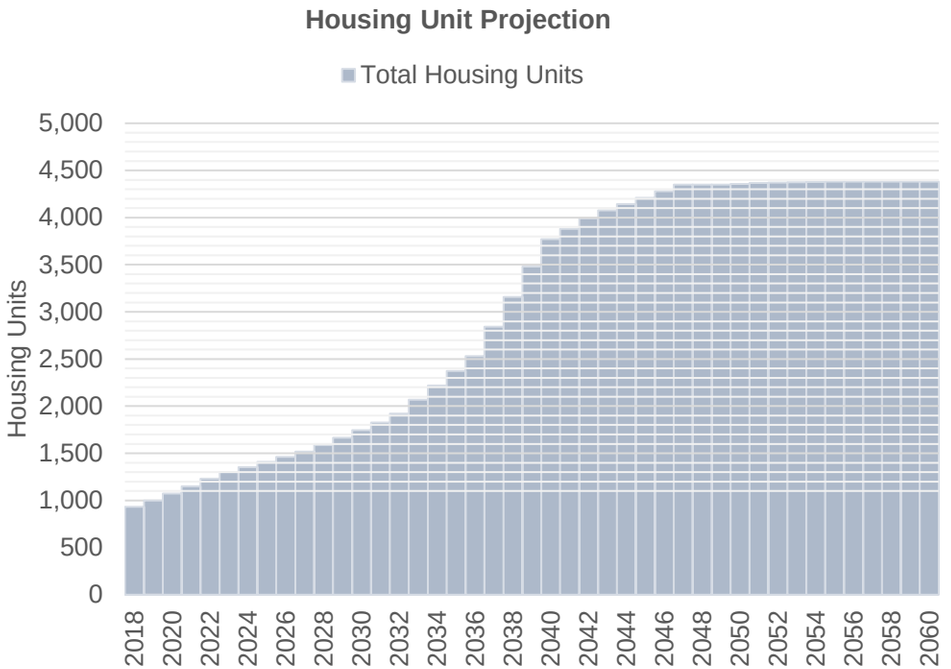
Demand Assumptions | **Water Supply Projections** (Acre-Feet)

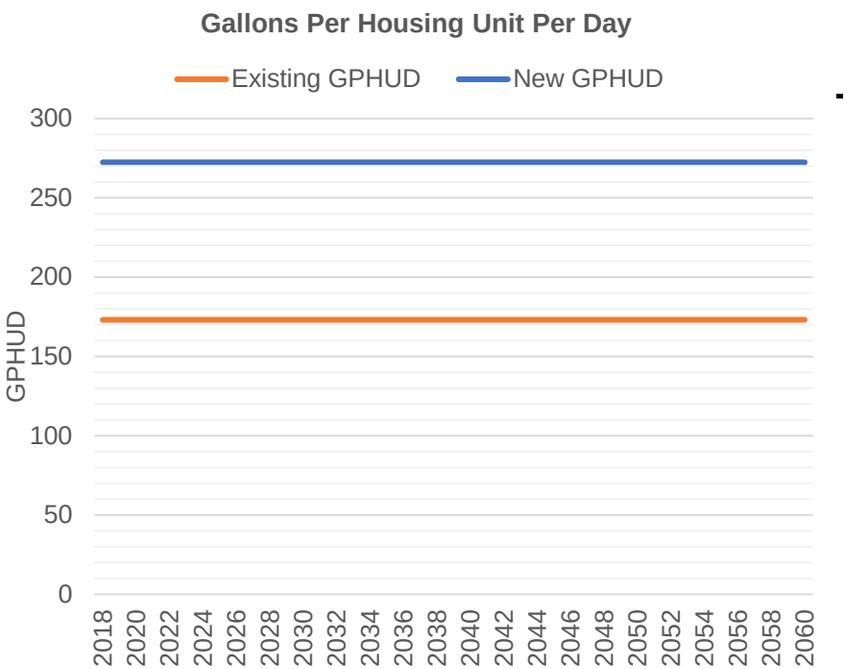
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	4,324	341	207	0	0	0	0	0	0	179	544	918
2019	4,455	340	207	0	0	0	0	0	0	171	510	973
2020	4,607	337	207	0	0	0	0	0	0	162	479	1,040
2021	4,766	337	207	0	0	0	0	0	0	154	450	1,106
2022	4,927	336	207	0	0	0	0	0	0	146	423	1,171
2023	5,077	334	207	0	0	0	0	0	0	139	399	1,233
2024	5,203	332	207	0	0	0	0	0	0	132	375	1,289
2025	5,331	332	207	0	0	0	0	0	0	125	354	1,339
2026	5,462	330	207	0	0	0	0	0	0	119	334	1,389
2027	5,595	329	207	0	0	0	0	0	0	113	316	1,437
2028	5,689	327	207	0	0	0	0	0	0	107	299	1,481
2029	5,754	326	207	0	0	0	0	0	0	102	283	1,513
2030	5,821	325	207	0	0	0	0	0	0	97	269	1,542
2031	5,889	324	207	0	0	0	0	0	0	92	255	1,570
2032	5.963	322	207	0	0	0	0	0	0	88	243	1.598
2033	6,067	321	207	0	0	0	0	0	0	83	231	1,627
2034	6,174	320	207	0	0	0	0	0	0	79	220	1,661
2035	6,282	319	207	0	0	0	0	0	0	75	210	1,693
2036	6,394	316	207	0	0	0	0	0	0	71	201	1,727
2037	6,562	316	207	0	0	0	0	0	0	68	193	1,764
2038	6,734	315	207	0	0	0	0	0	0	64	185	1,809
2039	6,910	313	207	0	0	0	0	0	0	61	177	1,854
2040	7,093	311	207	0	0	0	0	0	0	58	171	1,901
2041	7,289	311	207	0	0	0	0	0	0	55	165	1,946
2042	7,491	310	207	0	0	0	0	0	0	52	159	1,994
2043	7,721	309	207	0	0	0	0	0	0	50	154	2,046
2044	7,972	307	207	0	0	0	0	0	0	47	149	2,105
2045	8,230	307	207	0	0	0	0	0	0	45	145	2,167
2046	8,494	307	207	0	0	0	0	0	0	43	142	2,233
2047	8,765	307	207	0	0	0	0	0	0	41	138	2,300
2048	9,226	307	207	0	0	0	0	0	0	39	135	2,393
2049	9,628	307	207	0	0	0	0	0	0	37	133	2,495
2050	10,008	307	207	0	0	0	0	0	0	35	131	2,589
2051	10,398	307	207	0	0	0	0	0	0	33	129	2,682
2052	10,792	307	207	0	0	0	0	0	0	31	128	2,780
2053	11,196	307	207	0	0	0	0	0	0	30	127	2,870
2054	11,611	307	207	0	0	0	0	0	0	28	126	2,967
2055	12,012	307	207	0	0	0	0	0	0	27	126	3,064
2056	12,394	307	207	0	0	0	0	0	0	26	126	3,161
2057	12,787	307	207	0	0	0	0	0	0	24	126	3,247
2058	13,190	307	207	0	0	0	0	0	0	23	126	3,340
2059	13,604	307	207	0	0	0	0	0	0	22	127	3,435
2060	13,930	307	207	0	0	0	0	0	0	21	128	3,527

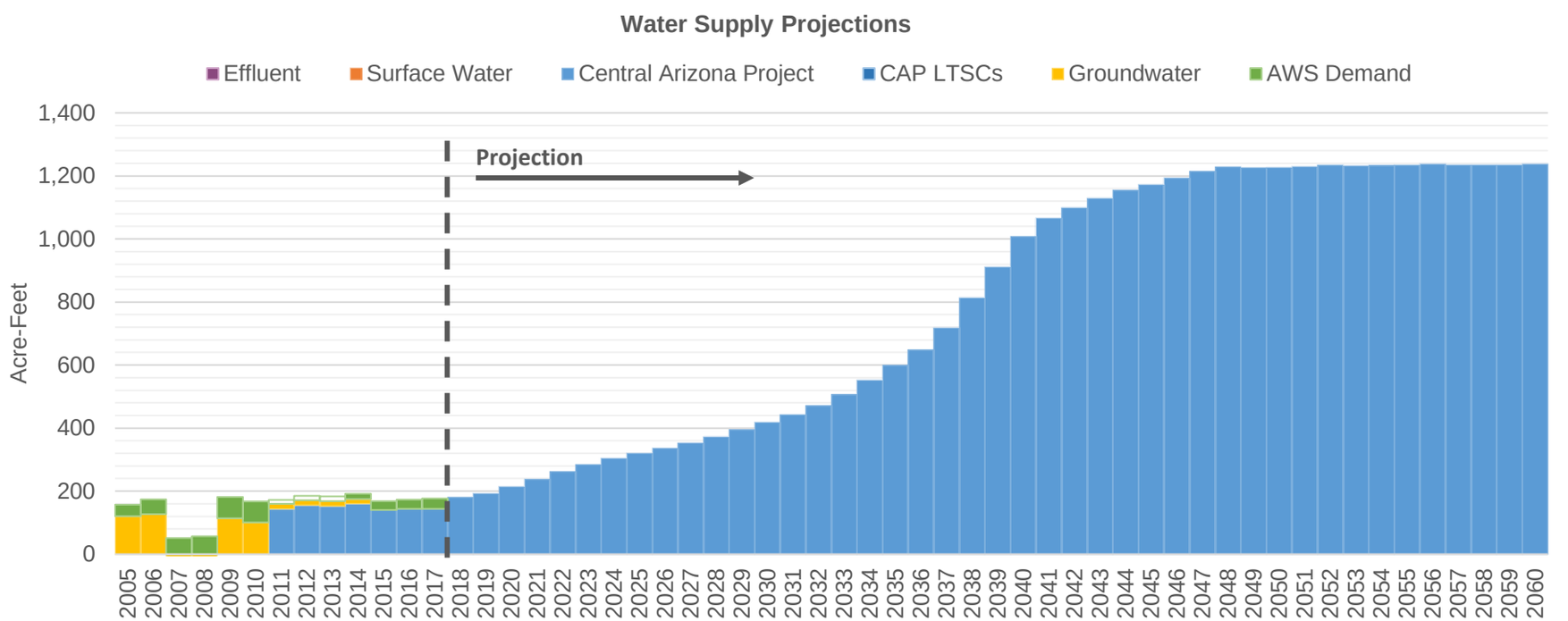
Central Arizona Project Service Area Model

SpanishTrailWC

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

SpanishTrailWC

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

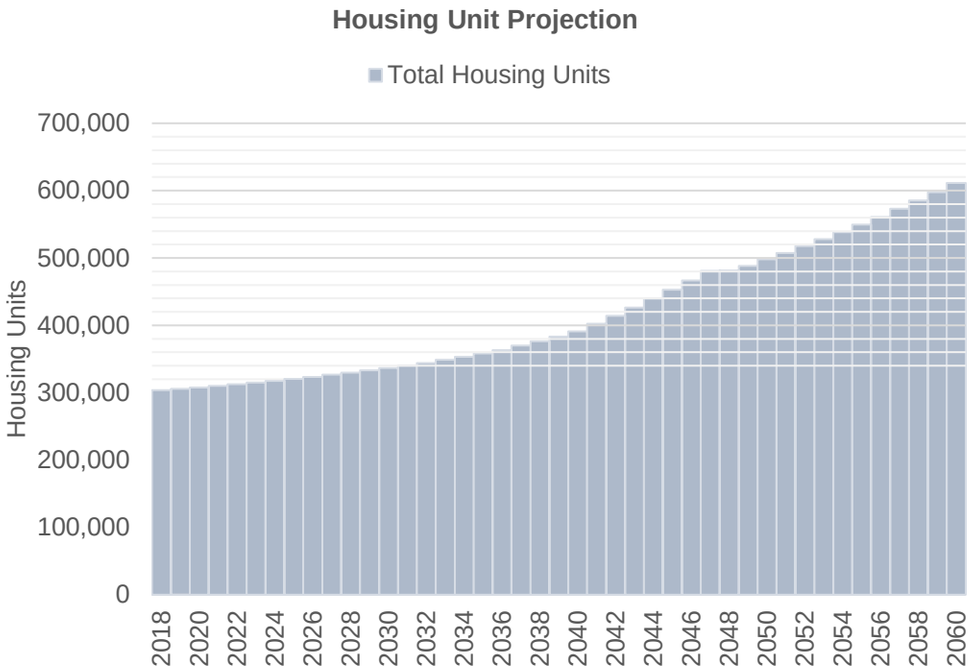
Demand Assumptions **Water Supply Projections** (Acre-Feet)

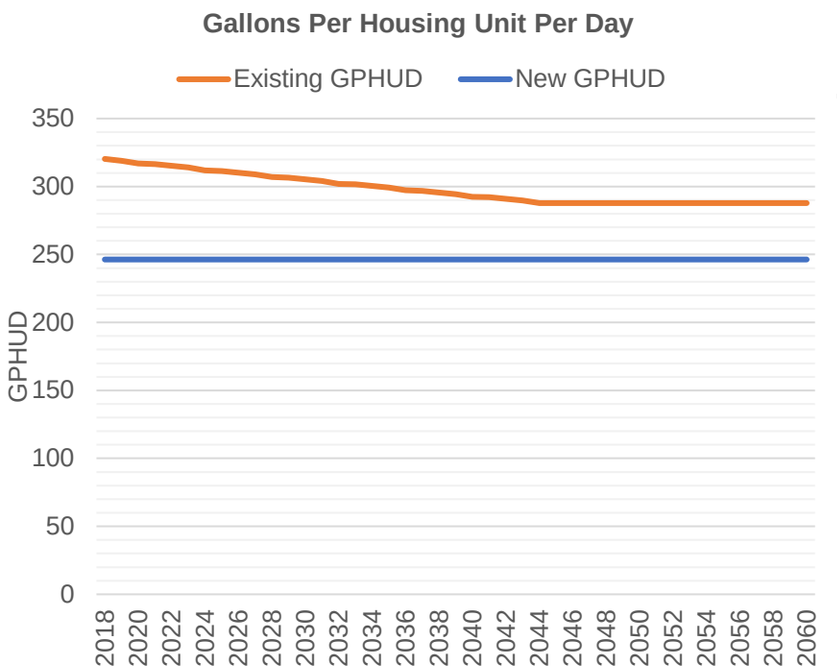
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	933	173	272	0	0	0	0	180	2,857	0	0	0
2019	998	173	272	0	0	0	0	193	2,844	0	0	0
2020	1,073	173	272	0	0	0	0	215	2,822	0	0	0
2021	1,151	173	272	0	0	0	0	238	2,799	0	0	0
2022	1,231	173	272	0	0	0	0	262	2,775	0	0	0
2023	1,302	173	272	0	0	0	0	285	2,752	0	0	0
2024	1,354	173	272	0	0	0	0	304	2,733	0	0	0
2025	1,408	173	272	0	0	0	0	320	2,717	0	0	0
2026	1,462	173	272	0	0	0	0	336	2,701	0	0	0
2027	1,518	173	272	0	0	0	0	353	2,684	0	0	0
2028	1,587	173	272	0	0	0	0	373	2,664	0	0	0
2029	1,665	173	272	0	0	0	0	395	2,642	0	0	0
2030	1,744	173	272	0	0	0	0	419	2,618	0	0	0
2031	1,826	173	272	0	0	0	0	443	2,594	0	0	0
2032	1.919	173	272	0	0	0	0	471	2.566	0	0	0
2033	2,067	173	272	0	0	0	0	507	2,530	0	0	0
2034	2,218	173	272	0	0	0	0	552	2,485	0	0	0
2035	2,373	173	272	0	0	0	0	599	2,438	0	0	0
2036	2,532	173	272	0	0	0	0	648	2,389	0	0	0
2037	2,842	173	272	0	0	0	0	718	2,319	0	0	0
2038	3,158	173	272	0	0	0	0	814	2,016	0	0	0
2039	3,482	173	272	0	0	0	0	911	1,439	0	0	0
2040	3,771	173	272	0	0	0	0	1,007	1,771	0	0	0
2041	3,881	173	272	0	0	0	0	1,066	1,924	0	0	0
2042	3,993	173	272	0	0	0	0	1,100	1,863	0	0	0
2043	4,077	173	272	0	0	0	0	1,130	1,907	0	0	0
2044	4,142	173	272	0	0	0	0	1,155	1,882	0	0	0
2045	4,210	173	272	0	0	0	0	1,173	1,864	0	0	0
2046	4,278	173	272	0	0	0	0	1,193	1,745	0	0	0
2047	4,349	173	272	0	0	0	0	1,215	1,822	0	0	0
2048	4,349	173	272	0	0	0	0	1,228	1,711	0	0	0
2049	4,349	173	272	0	0	0	0	1,225	1,713	0	0	0
2050	4,358	173	272	0	0	0	0	1,227	1,712	0	0	0
2051	4,366	173	272	0	0	0	0	1,229	1,709	0	0	0
2052	4,370	173	272	0	0	0	0	1,234	1,494	0	0	0
2053	4,373	173	272	0	0	0	0	1,232	1,496	0	0	0
2054	4,377	173	272	0	0	0	0	1,233	1,152	0	0	0
2055	4,380	173	272	0	0	0	0	1,234	888	0	0	0
2056	4,380	173	272	0	0	0	0	1,238	490	0	0	0
2057	4,381	173	272	0	0	0	0	1,235	1,151	0	0	0
2058	4,381	173	272	0	0	0	0	1,235	1,282	0	0	0
2059	4,382	173	272	0	0	0	0	1,235	1,229	0	0	0
2060	4,382	173	272	0	0	0	0	1,238	1,226	0	0	0

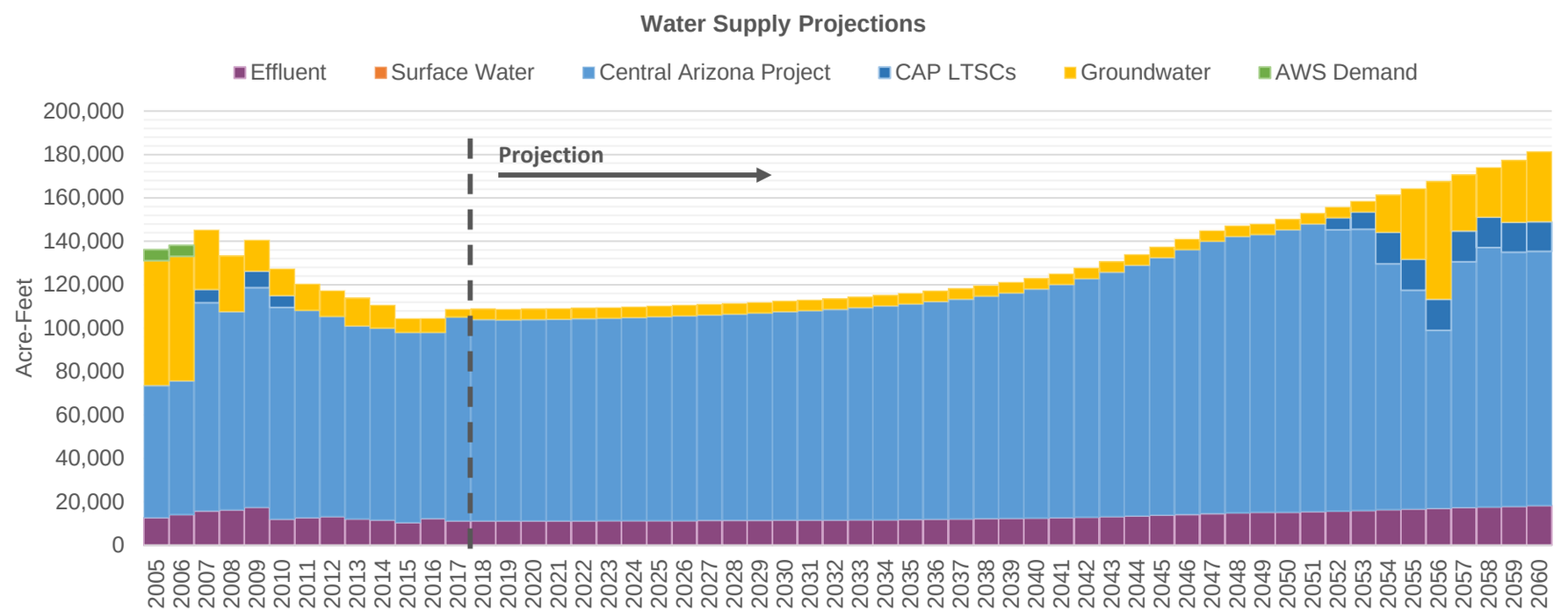
Central Arizona Project Service Area Model

Tucson

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

Tucson

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions

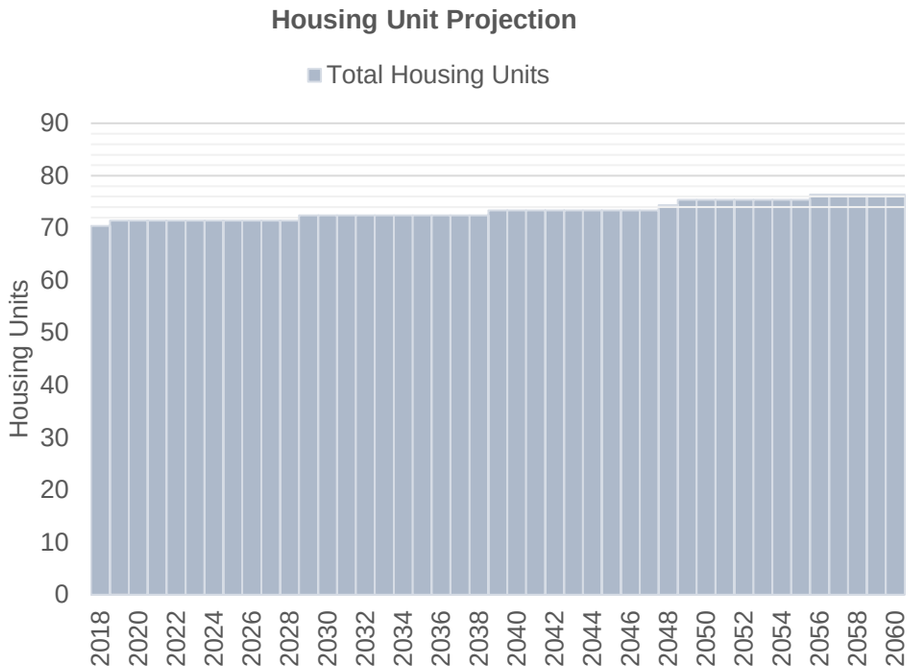
Water Supply Projections (Acre-Feet)

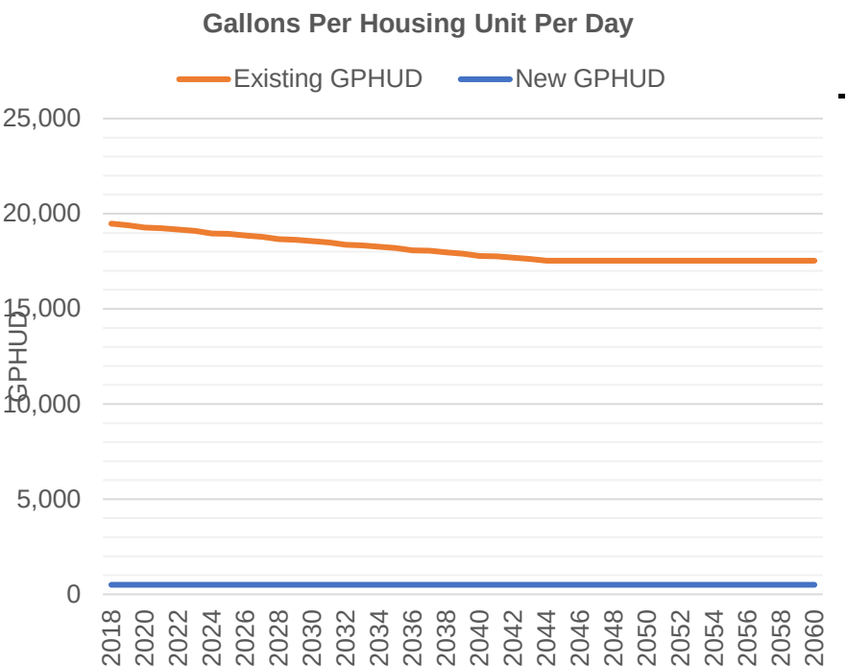
Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	303,802	320	246	11,236	0	0	0	92,687	51,485	0	4,951	0
2019	305,670	319	246	11,236	0	0	0	92,590	51,582	0	4,951	0
2020	307,830	317	246	11,226	0	0	0	92,725	51,447	0	4,951	0
2021	310,088	316	246	11,239	0	0	0	92,887	51,285	0	4,951	0
2022	312,375	315	246	11,257	0	0	0	93,066	51,106	0	4,951	0
2023	314,846	314	246	11,277	0	0	0	93,274	50,898	0	4,951	0
2024	317,694	312	246	11,301	0	0	0	93,567	50,605	0	4,951	0
2025	320,599	311	246	11,334	0	0	0	93,894	50,278	0	4,951	0
2026	323,563	310	246	11,371	0	0	0	94,243	49,929	0	4,951	0
2027	326,589	309	246	11,410	0	0	0	94,609	49,563	0	4,951	0
2028	329,821	307	246	11,452	0	0	0	95,029	49,143	0	4,951	0
2029	333,224	306	246	11,500	0	0	0	95,459	48,713	0	4,951	0
2030	336,698	305	246	11,549	0	0	0	95,943	48,229	0	4,951	0
2031	340,247	304	246	11,604	0	0	0	96,442	47,730	0	4,951	0
2032	344.022	302	246	11.661	0	0	0	97.012	47.160	0	4.951	0
2033	348,673	302	246	11,726	0	0	0	97,668	46,504	0	4,951	0
2034	353,426	300	246	11,801	0	0	0	98,481	45,691	0	4,951	0
2035	358,283	299	246	11,892	0	0	0	99,307	44,865	0	4,951	0
2036	363,263	297	246	11,987	0	0	0	100,206	43,966	0	4,951	0
2037	369,842	297	246	12,090	0	0	0	101,250	42,922	0	4,951	0
2038	376,569	296	246	12,208	0	0	0	102,564	31,770	0	4,951	0
2039	383,450	294	246	12,356	0	0	0	103,892	7,678	0	4,951	0
2040	391,218	292	246	12,508	0	0	0	105,424	26,457	0	4,951	0
2041	402,457	292	246	12,682	0	0	0	107,410	34,509	0	4,951	0
2042	413,959	291	246	12,905	0	0	0	109,928	30,711	0	4,951	0
2043	426,369	290	246	13,187	0	0	0	112,549	31,623	0	4,951	0
2044	439,516	288	246	13,487	0	0	0	115,479	28,693	0	4,951	0
2045	452,973	288	246	13,821	0	0	0	118,605	25,567	0	4,951	0
2046	466,737	288	246	14,178	0	0	0	122,003	17,510	0	4,951	0
2047	480,835	288	246	14,565	0	0	0	125,460	18,712	0	4,951	0
2048	481,573	288	246	14,962	0	0	0	127,244	12,269	0	4,951	0
2049	488,319	288	246	15,187	0	0	0	127,917	11,597	0	4,951	0
2050	497,810	288	246	15,280	0	0	0	130,064	9,449	0	4,951	0
2051	507,551	288	246	15,511	0	0	0	132,486	7,027	0	4,951	0
2052	517,595	288	246	15,785	0	0	0	129,512	0	5,589	4,951	0
2053	527,894	288	246	16,083	0	0	0	129,512	0	7,939	4,951	0
2054	538,457	288	246	16,356	0	0	0	113,258	0	14,562	17,185	0
2055	549,507	288	246	16,653	0	0	0	100,756	0	14,417	32,518	0
2056	561,091	288	246	16,961	0	0	0	82,002	0	14,273	54,421	0
2057	572,978	288	246	17,302	0	0	0	113,258	0	14,130	26,014	0
2058	585,178	288	246	17,617	0	0	0	119,510	0	13,989	22,912	0
2059	597,701	288	246	17,960	0	0	0	117,009	0	13,849	28,620	0
2060	611,536	288	246	18,312	0	0	0	117,009	0	13,710	32,271	0

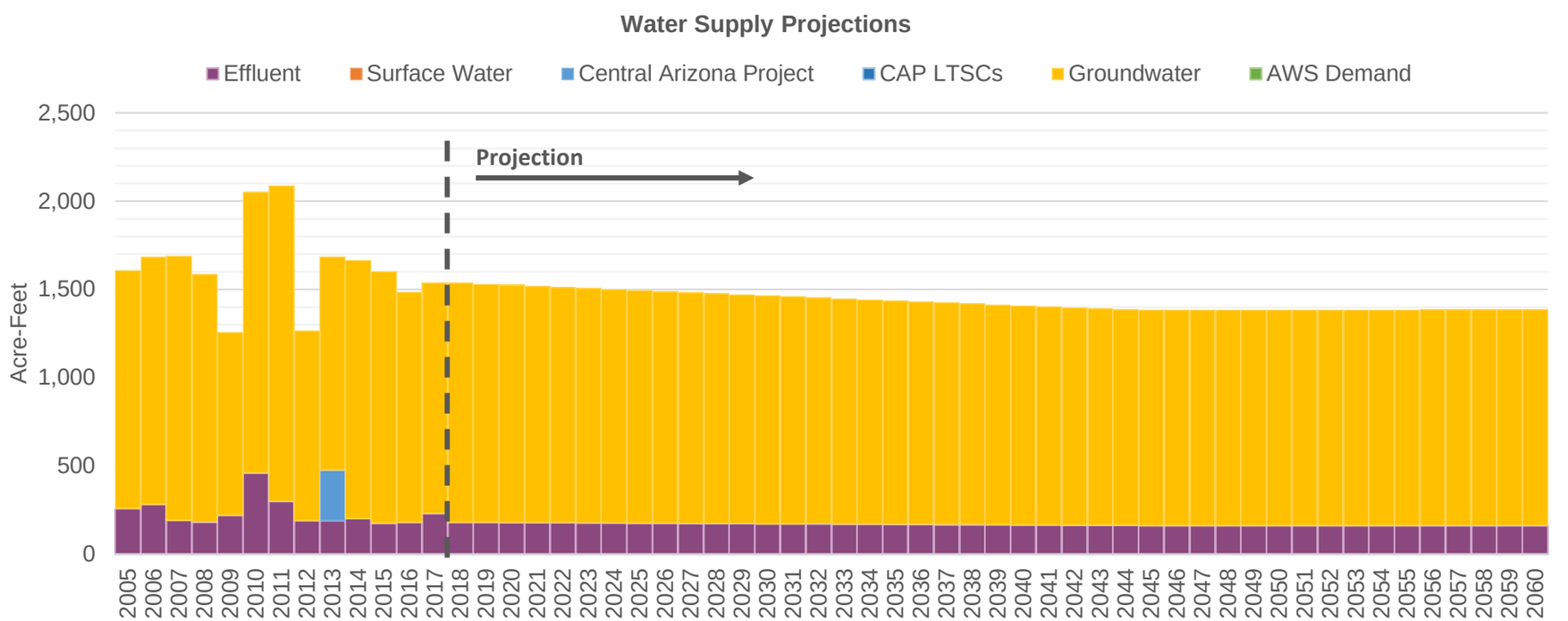
UniversityofAZ

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

UniversityofAZ

F. Rapid, Outward, Very Dry Climate [LSCRBS]

7/15/20 9:31 AM

Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	70	19,478	500	180	0	0	0	0	0	0	1,356	0
2019	71	19,400	500	180	0	0	0	0	0	0	1,350	0
2020	71	19,270	500	179	0	0	0	0	0	0	1,345	0
2021	71	19,245	500	179	0	0	0	0	0	0	1,340	0
2022	71	19,168	500	178	0	0	0	0	0	0	1,334	0
2023	71	19,092	500	177	0	0	0	0	0	0	1,329	0
2024	71	18,963	500	176	0	0	0	0	0	0	1,324	0
2025	71	18,939	500	176	0	0	0	0	0	0	1,318	0
2026	71	18,863	500	175	0	0	0	0	0	0	1,313	0
2027	71	18,788	500	174	0	0	0	0	0	0	1,308	0
2028	71	18,662	500	174	0	0	0	0	0	0	1,303	0
2029	72	18,638	500	173	0	0	0	0	0	0	1,298	0
2030	72	18,563	500	172	0	0	0	0	0	0	1,293	0
2031	72	18,489	500	172	0	0	0	0	0	0	1,287	0
2032	72	18,365	500	171	0	0	0	0	0	0	1,282	0
2033	72	18,341	500	170	0	0	0	0	0	0	1,277	0
2034	72	18,268	500	170	0	0	0	0	0	0	1,272	0
2035	72	18,195	500	169	0	0	0	0	0	0	1,267	0
2036	72	18,073	500	168	0	0	0	0	0	0	1,262	0
2037	72	18,050	500	168	0	0	0	0	0	0	1,257	0
2038	72	17,978	500	167	0	0	0	0	0	0	1,252	0
2039	73	17,906	500	166	0	0	0	0	0	0	1,247	0
2040	73	17,785	500	166	0	0	0	0	0	0	1,242	0
2041	73	17,763	500	165	0	0	0	0	0	0	1,237	0
2042	73	17,692	500	164	0	0	0	0	0	0	1,233	0
2043	73	17,621	500	164	0	0	0	0	0	0	1,228	0
2044	73	17,530	500	163	0	0	0	0	0	0	1,223	0
2045	73	17,530	500	162	0	0	0	0	0	0	1,222	0
2046	73	17,530	500	162	0	0	0	0	0	0	1,222	0
2047	73	17,530	500	162	0	0	0	0	0	0	1,222	0
2048	74	17,530	500	162	0	0	0	0	0	0	1,222	0
2049	75	17,530	500	162	0	0	0	0	0	0	1,223	0
2050	75	17,530	500	162	0	0	0	0	0	0	1,223	0
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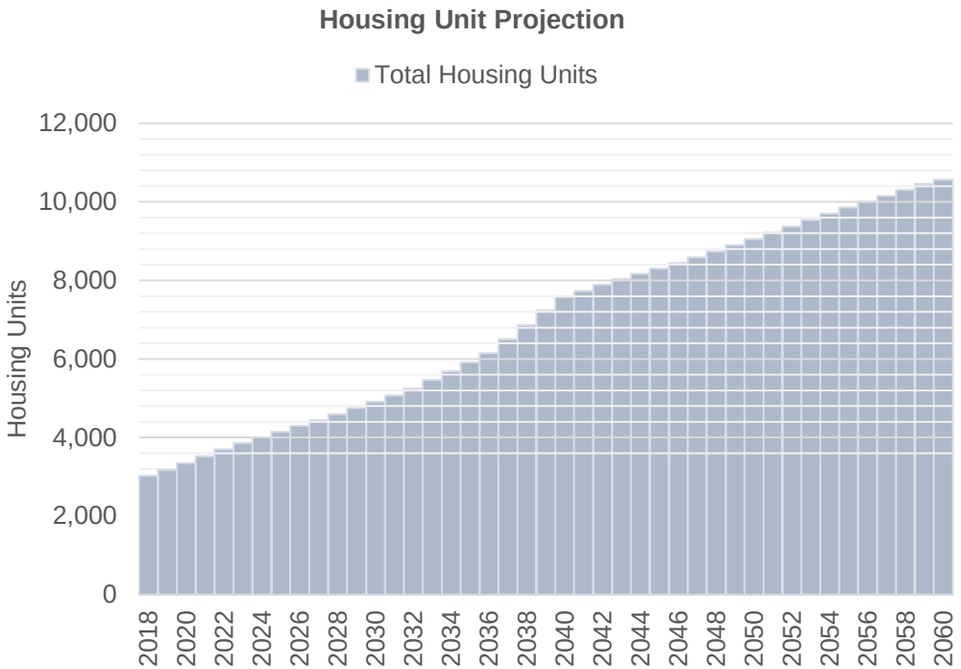
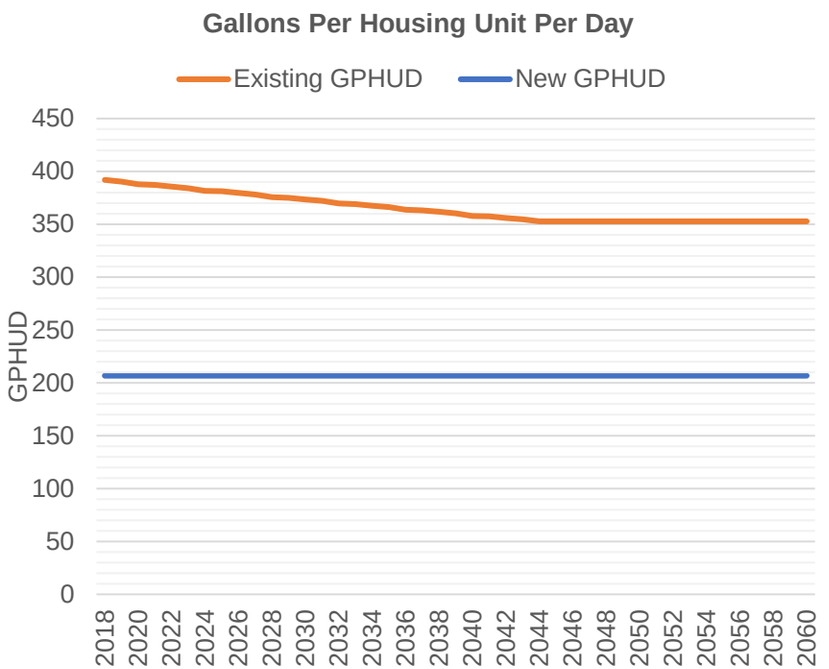
2058	76	17,530	500	162	0	0	0	0	0	0	1,224	0
2059	76	17,530	500	162	0	0	0	0	0	0	1,224	0
2060	76	17,530	500	162	0	0	0	0	0	0	1,224	0

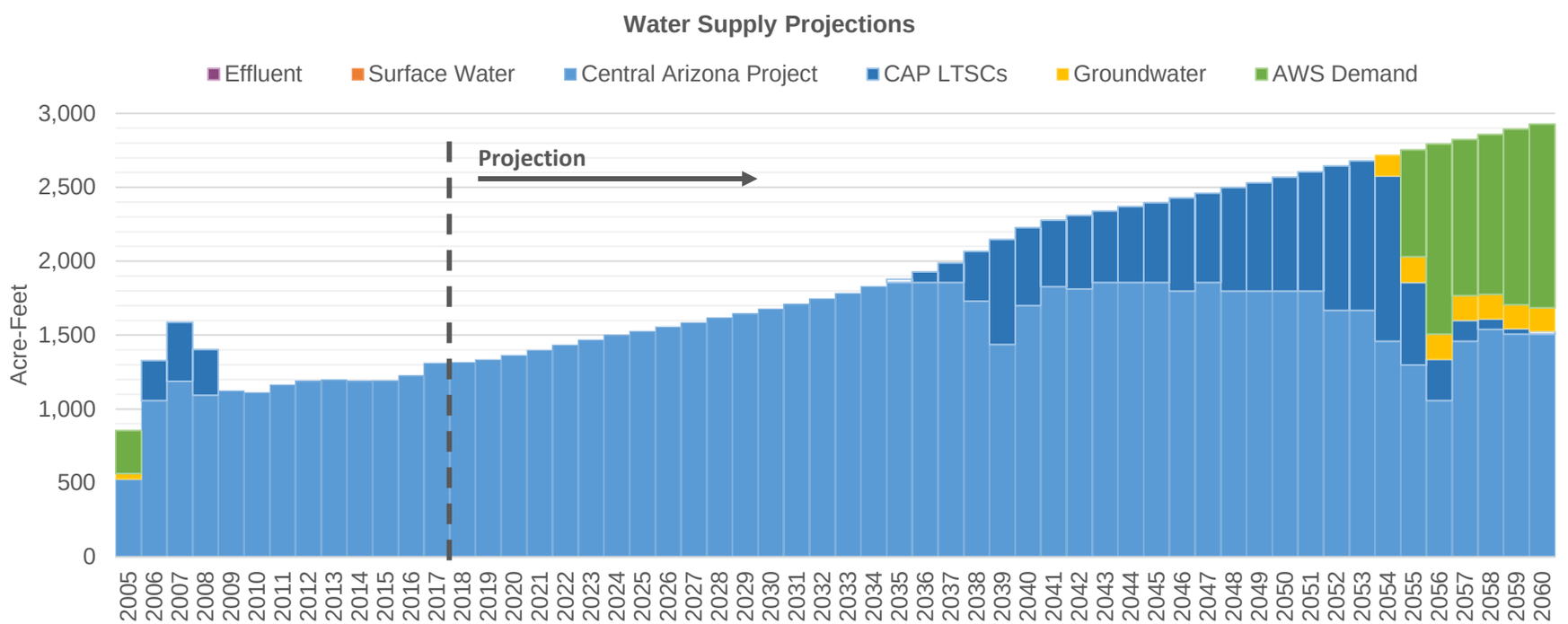
VailWC

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

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F. Rapid, Outward, Very Dry Climate [LSCRBS]

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Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	3,032	392	207	0	0	0	0	1,317	540	0	0	0
2019	3,177	390	207	0	0	0	0	1,334	523	0	0	0
2020	3,345	388	207	0	0	0	0	1,365	492	0	0	0
2021	3,521	387	207	0	0	0	0	1,399	458	0	0	0
2022	3,698	386	207	0	0	0	0	1,435	422	0	0	0
2023	3,864	384	207	0	0	0	0	1,469	388	0	0	0
2024	4,005	382	207	0	0	0	0	1,500	357	0	0	0
2025	4,149	381	207	0	0	0	0	1,528	329	0	0	0
2026	4,295	380	207	0	0	0	0	1,556	301	0	0	0
2027	4,445	378	207	0	0	0	0	1,585	272	0	0	0
2028	4,597	376	207	0	0	0	0	1,616	241	0	0	0
2029	4,753	375	207	0	0	0	0	1,646	211	0	0	0
2030	4,912	374	207	0	0	0	0	1,677	180	0	0	0
2031	5,074	372	207	0	0	0	0	1,710	147	0	0	0
2032	5,247	370	207	0	0	0	0	1,745	112	0	0	0
2033	5,466	369	207	0	0	0	0	1,784	73	0	0	0
2034	5,689	368	207	0	0	0	0	1,830	27	0	0	0
2035	5,917	366	207	0	0	0	0	1,857	0	20	0	0
2036	6,151	364	207	0	0	0	0	1,857	0	71	0	0
2037	6,506	363	207	0	0	0	0	1,857	0	132	0	0
2038	6,868	362	207	0	0	0	0	1,730	0	337	0	0
2039	7,239	360	207	0	0	0	0	1,437	0	711	0	0
2040	7,576	358	207	0	0	0	0	1,699	0	529	0	0
2041	7,733	357	207	0	0	0	0	1,828	0	449	0	0
2042	7,893	356	207	0	0	0	0	1,811	0	498	0	0
2043	8,037	355	207	0	0	0	0	1,857	0	483	0	0
2044	8,169	353	207	0	0	0	0	1,857	0	513	0	0
2045	8,305	353	207	0	0	0	0	1,857	0	540	0	0
2046	8,445	353	207	0	0	0	0	1,797	0	632	0	0
2047	8,587	353	207	0	0	0	0	1,857	0	604	0	0
2048	8,742	353	207	0	0	0	0	1,797	0	702	0	0
2049	8,897	353	207	0	0	0	0	1,797	0	734	0	0
2050	9,055	353	207	0	0	0	0	1,797	0	771	0	0
2051	9,216	353	207	0	0	0	0	1,797	0	808	0	0
2052	9,374	353	207	0	0	0	0	1,668	0	977	0	0
2053	9,536	353	207	0	0	0	0	1,668	0	1,011	0	0
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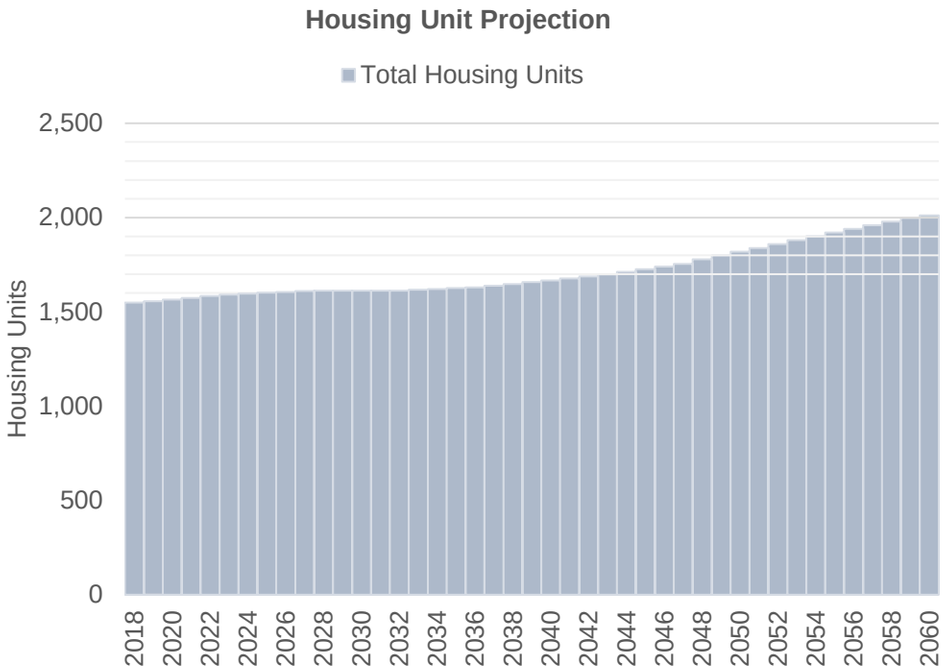
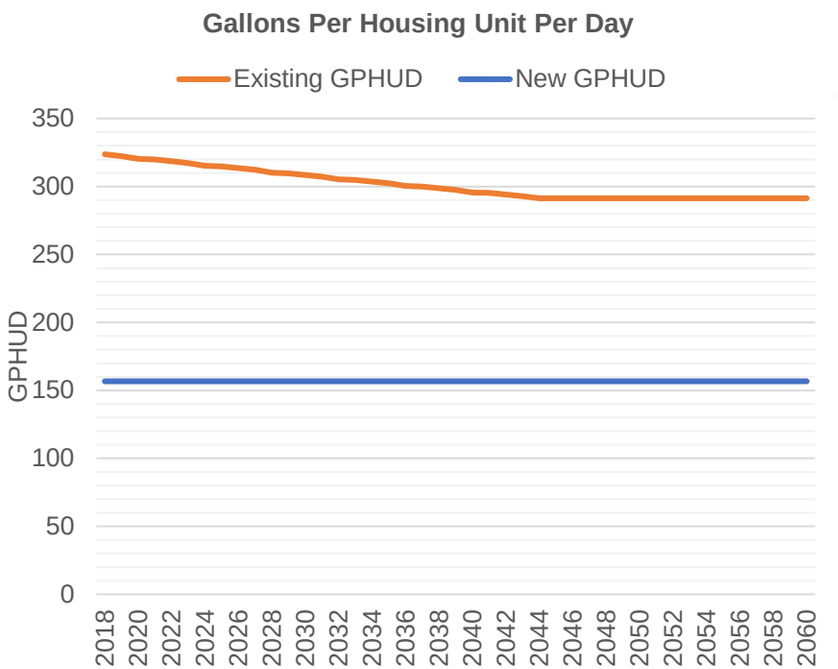
2055	9,858	353	207	0	0	0	0	1,298	0	559	175	722
2056	10,003	353	207	0	0	0	0	1,056	0	279	172	1,286
2057	10,151	353	207	0	0	0	0	1,459	0	140	168	1,056
2058	10,303	353	207	0	0	0	0	1,539	0	70	166	1,083
2059	10,459	353	207	0	0	0	0	1,507	0	35	163	1,188
2060	10,565	353	207	0	0	0	0	1,507	0	17	161	1,243

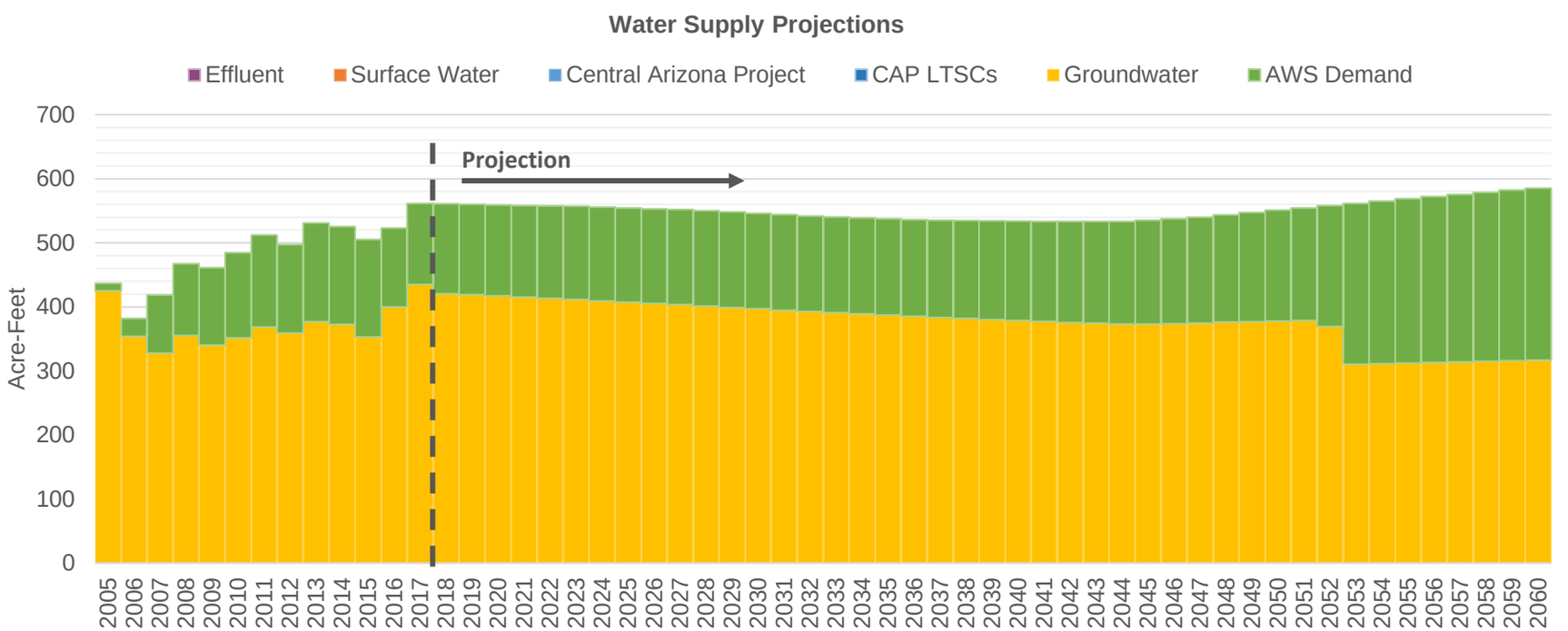
VoyagerWC

Central Arizona Project Service Area Model

F. Rapid, Outward, Very Dry Climate [LSCRBS]







Central Arizona Project Service Area Model

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Demand Assumptions | **Water Supply Projections** (Acre-Feet)

Date	Housing Units	GPHUD		Effluent	Surface Water		Central Arizona Project				Groundwater	
	Total	Existing	New		SRP	Non-SRP	Direct	ASR	Storage	Recovery	Non-AWS	AWS
2018	1,549	324	157	0	0	0	0	0	0	0	421	141
2019	1,557	322	157	0	0	0	0	0	0	0	419	141
2020	1,565	320	157	0	0	0	0	0	0	0	417	142
2021	1,574	320	157	0	0	0	0	0	0	0	415	143
2022	1,584	319	157	0	0	0	0	0	0	0	413	144
2023	1,591	317	157	0	0	0	0	0	0	0	411	146
2024	1,596	315	157	0	0	0	0	0	0	0	409	146
2025	1,601	315	157	0	0	0	0	0	0	0	407	147
2026	1,606	314	157	0	0	0	0	0	0	0	405	148
2027	1,610	312	157	0	0	0	0	0	0	0	403	148
2028	1,612	310	157	0	0	0	0	0	0	0	401	149
2029	1,612	310	157	0	0	0	0	0	0	0	399	149
2030	1,612	309	157	0	0	0	0	0	0	0	397	149
2031	1,612	307	157	0	0	0	0	0	0	0	395	149
2032	1,612	305	157	0	0	0	0	0	0	0	393	149
2033	1,617	305	157	0	0	0	0	0	0	0	391	149
2034	1,621	304	157	0	0	0	0	0	0	0	389	150
2035	1,626	302	157	0	0	0	0	0	0	0	387	150
2036	1,630	300	157	0	0	0	0	0	0	0	385	151
2037	1,639	300	157	0	0	0	0	0	0	0	384	152
2038	1,648	299	157	0	0	0	0	0	0	0	382	153
2039	1,657	298	157	0	0	0	0	0	0	0	380	154
2040	1,667	296	157	0	0	0	0	0	0	0	379	155
2041	1,677	295	157	0	0	0	0	0	0	0	377	156
2042	1,687	294	157	0	0	0	0	0	0	0	376	158
2043	1,699	293	157	0	0	0	0	0	0	0	374	159
2044	1,713	291	157	0	0	0	0	0	0	0	373	160
2045	1,726	291	157	0	0	0	0	0	0	0	373	162
2046	1,740	291	157	0	0	0	0	0	0	0	374	164
2047	1,754	291	157	0	0	0	0	0	0	0	374	166
2048	1,779	291	157	0	0	0	0	0	0	0	376	167
2049	1,799	291	157	0	0	0	0	0	0	0	377	170
2050	1,819	291	157	0	0	0	0	0	0	0	378	173
2051	1,839	291	157	0	0	0	0	0	0	0	379	176
2052	1,859	291	157	0	0	0	0	0	0	0	370	189
2053	1,880	291	157	0	0	0	0	0	0	0	310	251
2054	1,901	291	157	0	0	0	0	0	0	0	311	254
2055	1,921	291	157	0	0	0	0	0	0	0	312	256
2056	1,940	291	157	0	0	0	0	0	0	0	313	259
2057	1,959	291	157	0	0	0	0	0	0	0	314	261
2058	1,978	291	157	0	0	0	0	0	0	0	315	264
2059	1,998	291	157	0	0	0	0	0	0	0	316	266
2060	2,012	291	157	0	0	0	0	0	0	0	317	269

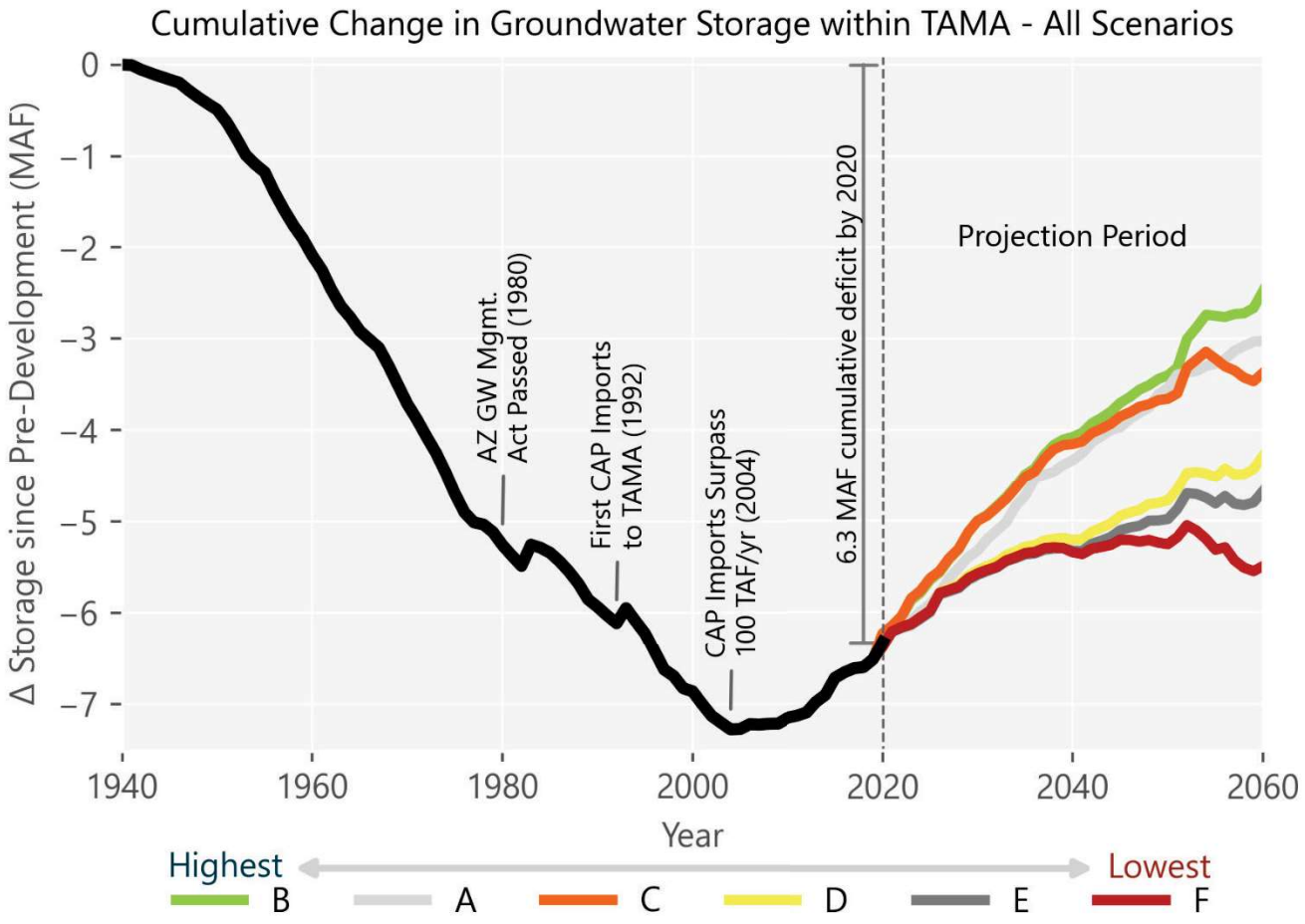
Appendix D

Groundwater Modeling Analysis

BUREAU OF RECLAMATION

Lower Santa Cruz River Basin Study Groundwater Analysis

Technical Memorandum ENV-2021-64



U.S. Department of the Interior

May 2022

Version 1.1

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Acknowledgements

The author gratefully acknowledges the input and review of members of the Lower Santa Cruz River Basin Study Project Team led by Eve Halper of Reclamation, Kathy Chavez of Pima County, and Wallace Wilson of Metro Water District. The author would also like to acknowledge the contributors and maintainers of Python and the open-source Python packages: FloPy, NumPy, Matplotlib, pandas, geopandas, and Project Jupyter.

On the Cover: Simulated change in groundwater storage by Basin Study supply-demand scenario

BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Technical Memorandum No. ENV-2021-64

Lower Santa Cruz River Basin Study Groundwater Analysis

Prepared for:

Phoenix Area Office

Lower Colorado Region
Bureau of Reclamation

May 2022

Prepared by:

Water, Environmental, and Ecosystems Division

Water Resources Engineering and Management Group (86-68210)

Brandon House - Civil Engineer (Hydrologic)

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Ian Ferguson – Civil Engineer (Hydrologic)

Acronyms and Abbreviations

ADWR	Arizona Department of Water Resources
afy	Acre-feet per year
AMA	Active Management Area
BAS	MODFLOW Basic Package
CAP	Central Arizona Project
CAP:SAM	Central Arizona Project Service Area Model
CAVSARP	Central Avra Valley Storage and Recovery Project
CDF	Cumulative probability distribution function
CDO	Cañada del Oro
cfs	cubic feet per second
CHD	MODFLOW Time-Variant Specified-Head Package
COOP	Cooperative Observation Network
DIS	MODFLOW Discretization Package
EVT	MODFLOW Evapotranspiration Package
FCAP	FICO CAP Line, LLC
FICO	Farmers Investment Company
GCM	Global Circulation Model
GHG	Greenhouse Gas
GIS	Geographic Information System
GSF	Groundwater Savings Facility
HD	Hybrid-delta
IGFR	Irrigation Grandfathered Right
K	Hydraulic conductivity
LSCR	Lower Santa Cruz River
M&I	Municipal and Industrial
MAF	million acre-feet
MGD	million gallons per day
mi	mile
MODFLOW	USGS MODular finite-difference groundwater FLOw modeling code
NWT	Newton formulation of MODFLOW

PAMA	Pinal Active Management Area
PCRFCD	Pima County Regional Flood Control District
RCH	MODFLOW Recharge Package
RCP	Representative Concentration Pathways
Reclamation	Bureau of Reclamation
Sac-SMA	Sacramento Soil Moisture Accounting
SAVSARP	Southern Avra Valley Storage and Recovery Project
SCAMA	Santa Cruz Active Management Area
SCR	Santa Cruz River
S-D	Supply-Demand
SECURE	Science and Engineering to Comprehensively Understand and Responsively Enhance
SHARP	Southeast Houghton Area Recharge Project
Study	Lower Santa Cruz River Basin Study
TAF	thousand acre-feet
TAMA	Tucson Active Management Area
UPW	MODFLOW Upstream Weighting (Groundwater Flow) Package
USF	Underground Storage Facilities
USGS	United States Geological Survey
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WEL	MODFLOW Well Package
WRF	Water Reclamation Facility
yr	year

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top of Big Wash in the CDO watershed over the projection period. Figures 34 to 38 share a color scale..... 67

Figure 35. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy CDO-2. CDO-2 includes 10 TAF/yr of reclaimed water diverted from the SCR being recharged near the top of Big Wash in the CDO watershed over the projection period. Figures 34 to 38 share a color scale. 68

Figure 36. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy CDO-3. CDO-3 includes 1.12 TAF/yr (1 MGD) of reclaimed water recharged near the top of Big Wash in the CDO watershed from a potential WRF over the projection period. Figures 34 to 38 share a color scale. 69

Figure 37. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy GV-1. GV-1 includes providing CAP surface water supplies in lieu of pumping groundwater to meet irrigation demands for FICO through the extension of the FCAP pipeline. This offsets about 10 TAF/yr of pumping starting in 2027 until the end of the projection period. Figures 34 to 38 share a color scale. 70

Figure 38. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy GV-2. GV-2 includes extension of a pipeline to the Canoa Ranch. Here, 2 TAF/yr of CAP water would be recharged when capacity in the pipeline was available (i.e., not during the growing season) over the projection period. Figures 34 to 38 share a color scale. 71

Executive Summary

This Technical Memorandum describes the groundwater modeling portion of the Lower Santa Cruz River Basin Study (Study). The Study aims to identify where physical water resources are needed to mitigate supply-demand imbalances due to climate change and other factors, and to develop strategies to improve water reliability for municipal, industrial, agricultural, and environmental sectors in the Lower Santa Cruz River (LSCR) Basin. The LSCR Basin Study area is focused within the Tucson Active Management Area (TAMA; Figure ES-1) as defined by the Arizona Department of Water Resources (ADWR).

The Study uses a scenario planning approach to evaluate a range of plausible water supply and demand projections between 2020 to 2060. The Study Project Team developed six supply-demand (S-D) scenarios that reflect the insight of local partners into water resource futures for the Study area.

This groundwater modeling portion of the Study relies on previous efforts including: development and calibration of the TAMA groundwater flow model by ADWR (Mason & Hipke, 2013; the active TAMA Model domain is shown in Figure ES-1), projections of future water supplies and demands by the Central Arizona Water Conservation District (commonly referred to as the Central Arizona Project, or CAP; CAP, 2021), recharge modeling provided by CAP (Montgomery and Associates, 2020), and projections of natural streamflow by the Bureau of Reclamation (Reclamation, 2021).

The six S-D scenarios developed by the Study Project Team are pairwise combinations of scenarios related to (1) the climate within the Lower Santa Cruz River Basin and the resulting natural recharge ("current", "best-case", and "worse-case") and (2) projected demand growth and pattern ("slow/compact", "medium/official", and "rapid/outward"). The "best-case" and "worse-case" climate scenarios are informed by results from global circulation models (GCMs) for greenhouse gas atmospheric concentration scenarios (i.e., Representative Concentration Pathways [RCP]) 4.5 and 8.5, respectively. For the "current" climate scenario, historic values were repeated over the projection period.

Table ES-1. Basin Study supply-demand scenario matrix. In general, water resource risk increases from the lower-left towards the upper-right.

Climate	Demand Growth: Slow, Compact	Demand Growth: Medium, Official	Demand Growth: Rapid, Outward
Worse Case	D	E	F
Best Case	B		C
Current Climate		A	

Higher Risk

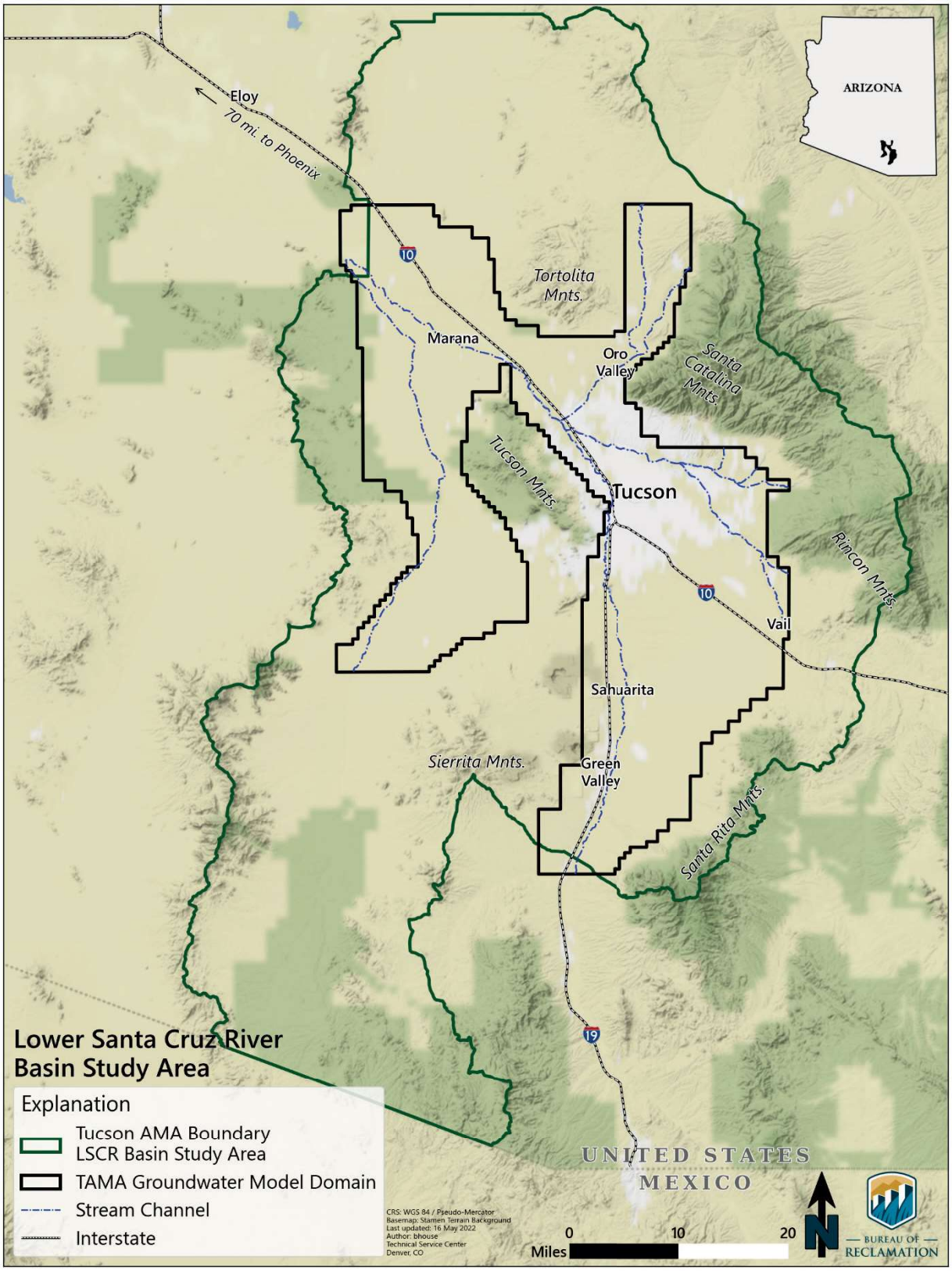


Figure ES-1. Lower Santa Cruz River Basin Study Area and modeling boundaries.

Demand growth scenarios relate to both the rate ("slow", "medium", or "rapid") and pattern ("compact", "official", or "outward") of growth. These demand growth scenarios also incorporated a range of shortages of Colorado River water imported via the CAP. More information on the demand growth scenarios is available in Appendix C of the *Lower Santa Cruz River Basin Study: Supply and Demand Assessment* report (CAP, 2021).

Table ES-1 presents a matrix of these climate and demand growth scenarios and identifiers (A-F) associated with each pairwise combination. In general, risk to water resources and the environment increases from the lower-left to the upper-right with B representing a lower risk and F a higher risk.

The enactment of Arizona's Groundwater Management Act in 1980 created several Active Management Areas (AMAs) in regions of Arizona with long-term groundwater storage declines—including the TAMA (LSCR Basin). The TAMA began receiving imports of Colorado River water via the CAP in 1992 with completion of the CAP. Importation of CAP water to the TAMA steadily increased until 2007 and has plateaued since. Prior to these imports, the TAMA relied almost exclusively on groundwater to meet its water demands. This led to significant groundwater overdraft and a declining groundwater table.

The TAMA's management goal is to achieve long-term "safe yield" by 2025 (ADWR, 2016). Safe-yield is defined under Arizona Revised Statutes Title 45 Section 561 as:

> "[A] groundwater management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management area."

The TAMA Groundwater Flow Model (TAMA Model) was used to evaluate impacts of the Study S-D scenarios and proposed adaptation strategies on groundwater resources within the Study area over the projection period, 2020-2060 (Mason & Hipke, 2013). It uses version 1.0.7 of the U.S. Geological Survey's (USGS) groundwater modeling code MODFLOW-NWT (Niswonger et. al., 2011). ADWR maintains the TAMA Model to support water resource planning and management in the TAMA, with the goal of being able to "evaluate relative changes within the regional system" (Mason & Hipke, 2013).

Groundwater pumping projections for each of the S-D scenarios were developed by a subset of the Project Team and CAP. Municipal, industrial and agricultural demands were translated into input files to the TAMA Model for each of the simulated S-D scenarios.

Simulated inflows to the groundwater model (in descending order of magnitude at the end of the modeled period) occur from:

- artificial recharge of CAP (Colorado River) water and reclaimed water[1]
- infiltration of natural and reclaimed water-derived streamflow
- mountain front recharge
- underflow from adjacent basins

[1] Reclaimed water, as defined by Arizona law, is water that has been treated or processed by a water reclamation facility.

- agricultural deep percolation
- seepage from mine tailings ponds.

Simulated outflows from the groundwater model (in descending order of magnitude at the end of the modeled period) occur from:

- municipal pumping
- agricultural pumping
- mining pumping
- underflow to an adjacent basin
- industrial pumping
- evapotranspiration.

Projections of Simulated Inflows

Inflows to the groundwater model over the projection period are summarized in Table ES-2, including the range of inflows from the various sources across all S-D scenarios and the MODFLOW package used to simulate each inflow. The rate columns (in thousands of acre-feet per year [TAF/yr]) provide insight into the impact of sources of inflow on the model results.

Table ES-2. Summary of TAMA Model inflows over the projection period and across all S-D scenarios. Development of each is described in the *Simulated Inflows* section of this Technical Memorandum.

Description	Rate (TAF/yr)			MODFLOW Package	Data Source(s)
	Min	Mean	Max		
Mountain Front Recharge*	-	28	-	RCH	Mason & Hipke (2013)
Underflow	27	28	29	WEL, CHD	Mason & Hipke (2013)
Mine Tailings Pond Seepage*	-	8	-	RCH	Mason & Hipke (2013)
Stream Channel Infiltration	54	121	382	RCH	Reclamation (2021), Mason & Hipke (2013), CAP (2021), Study Partners
Artificial Recharge Facilities	93	177	223	RCH	CAP (2021), Study Partners
Agricultural Deep Percolation	18	20	20	RCH	CAP (2021), Study Partners

*Inflow is constant over the projection period and across all S-D scenarios

The cumulative sum of groundwater inflows under each S-D scenario is shown in Figure ES-2. The apparent groupings of scenarios in Figure ES-2 highlight the impact of climate on inflows (Table ES-2). Cumulative inflows (recharge) under scenarios A, B, and C (current and best-case climates) are about 1.6 million acre-feet (MAF) greater over the projection period than under scenarios D, E, and F (worse-case climate). Differences in climate between the current and best-case scenarios and the worse-case scenario result in a difference in annual average recharge of about 40 TAF/yr over the projection period.

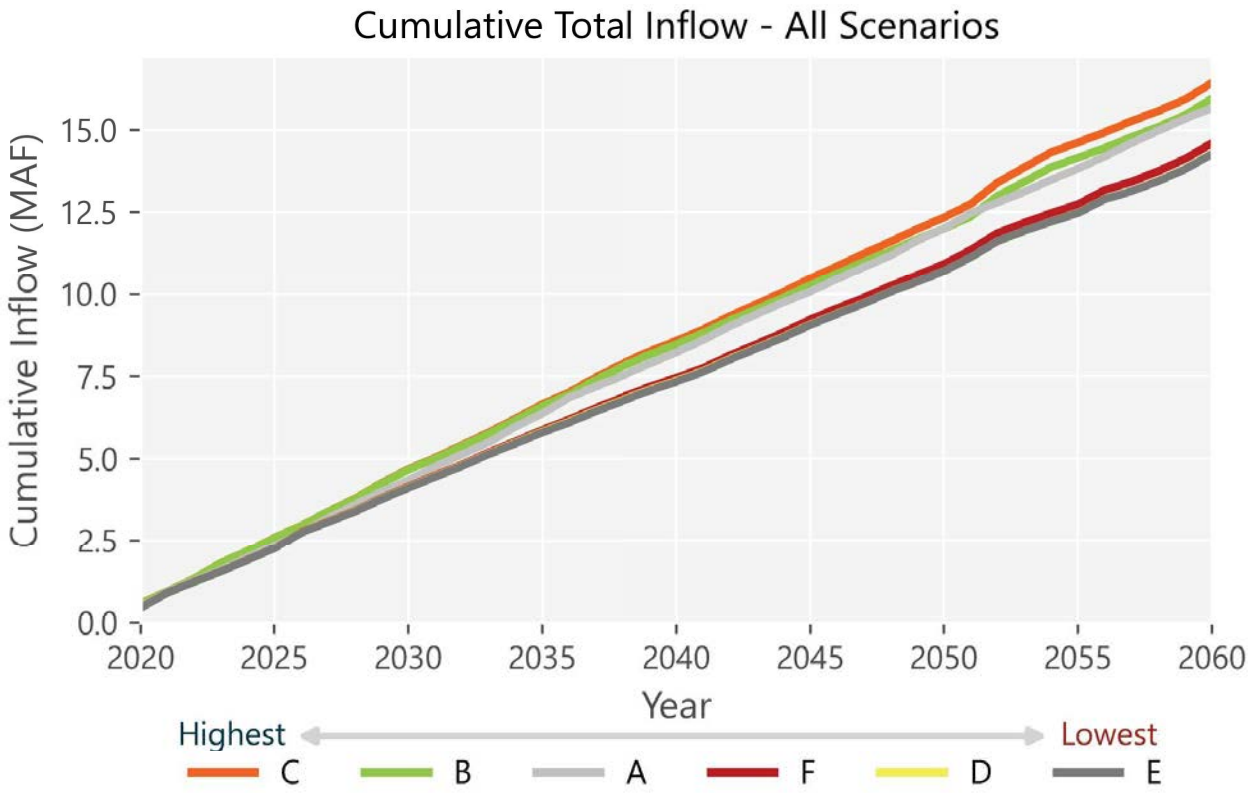


Figure ES-2. Cumulative sum of total annual simulated inflows to the TAMA groundwater model by S-D scenario.

Projections of Simulated Outflows

Outflows from the groundwater model over the projection period are summarized in Table ES-3, including the range of rates for each outflow across all S-D scenarios and the MODFLOW package that is used to simulate the outflow. The rate columns provide insight into the impact that each source of outflow has on the model results. Pumping accounts for an average of 92% of total outflows simulated from the TAMA Model over the projection period and across all S-D scenarios.

Table ES-3. Summary of groundwater model outflows over the projection period and across all S-D scenarios. Development of each is described in the section of this Technical Memorandum.

Description	Rate (TAF/yr)			MODFLOW Package	Data Source(s)
	Min	Mean	Max		
Evapotranspiration	0.4	4	16	EVT	Mason & Hipke (2013)
Underflow	17	20	26	CHD	Mason & Hipke (2013)
Pumping – Municipal	145	166	268	WEL	Mason & Hipke (2013), CAP (2021), Study Partners
Pumping – Ag	47	57	70	WEL	Mason & Hipke (2013), CAP (2021)
Pumping – Mining	29	34	46	WEL	Mason & Hipke (2013), Study Partners
Pumping – Industrial (Non-Mining)*	-	13	-	WEL	Mason & Hipke (2013)

*Outflow is constant over the projection period and across all S-D scenarios

Annual groundwater pumping for all sources is shown in Figure ES-3 for the projection period. For context, the historical simulated pumping is also shown. The rapid/outward demand growth projections (C and F) show significant increases over the projection period and, by 2060, reach rates similar to the peak abstraction period of the mid-1970s. All other S-D scenarios suggest only modest rises in pumping demands compared to the historical 1940-1960 period—with the lower risk scenario (B) being approximately constant. However, none of the projections suggest a decline in groundwater pumping.

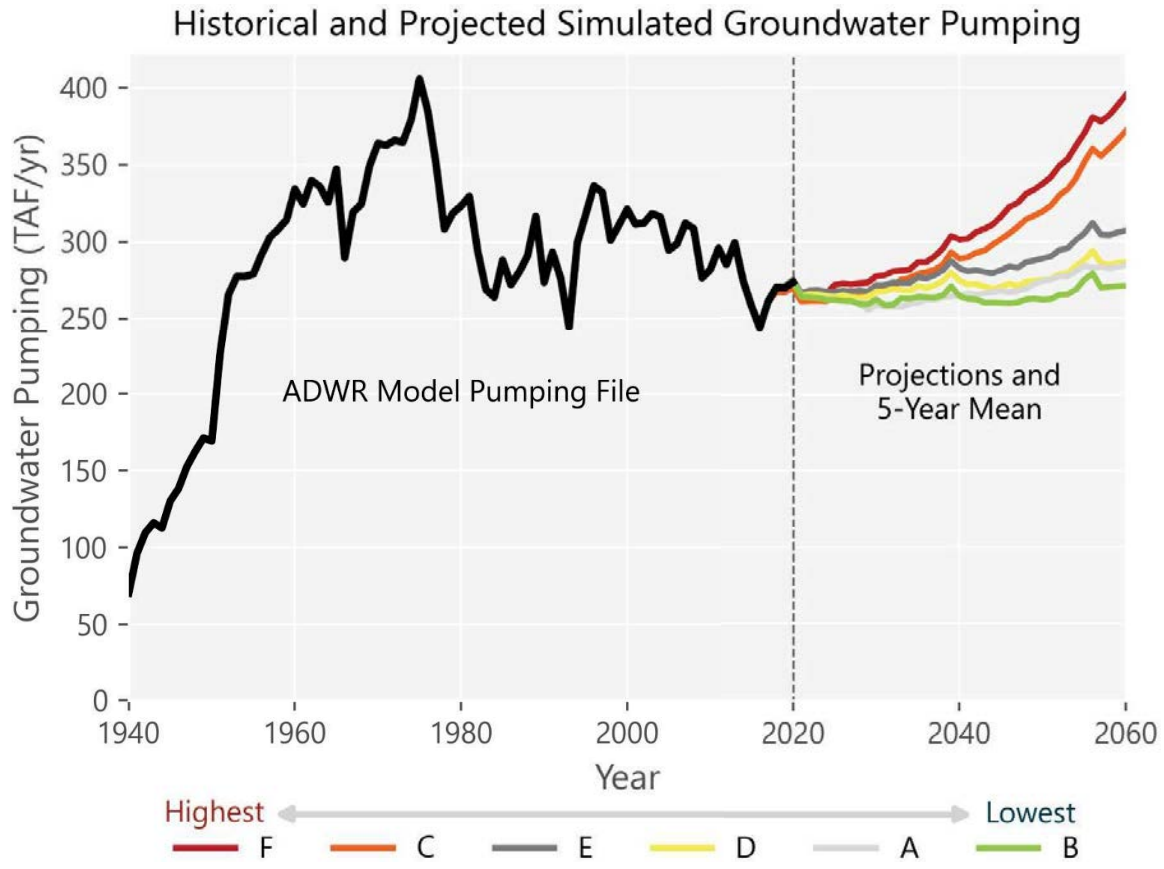


Figure ES-3. Historical and projected annual groundwater pumping simulated in the TAMA Model.

Summary: Results from All Supply-Demand Scenarios

Simulated changes in groundwater storage over the projection period under each S-D scenario are shown in the right portion of Figure ES-4. Projected changes in groundwater storage exhibit a general grouping by climate scenario. Groundwater storage increases for all S-D scenarios through the end of 2030s. By 2060 scenarios A, B, and C (current and best-case climates) result in a notably greater increase in groundwater storage than scenarios D, E, and F (worse-case climate). Separation between scenarios D, E, and F in the later portion of the projection period suggests that differences in demand growth have a more significant impact over time.

While the higher risk scenario (F) is generally in overdraft for the final 10-years of the projection period, all other S-D scenarios are generally in surplus (Figure ES-4). This result suggests that under the range of water supply and demand growth considered in the Study S-D scenarios, the LSCR Basin as a whole has increasing groundwater storage throughout most of the projection period. However, this result does not mean that groundwater storage increases in all areas of the LSCR Basin; some areas exhibit declines in groundwater storage while others experience increases.

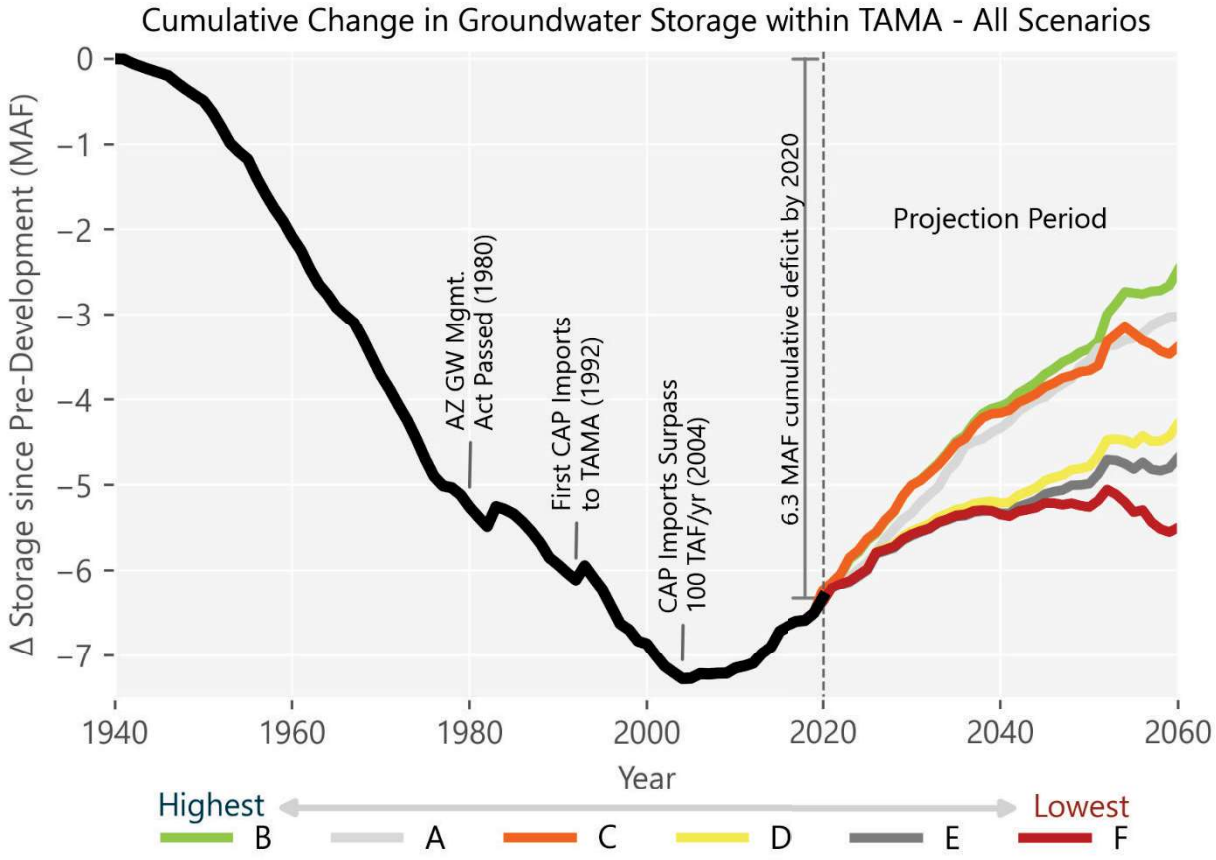


Figure ES-4. Simulated cumulative change in groundwater storage within the TAMA Model since pre-development (1940). Historical period is in black with results from Study S-D scenarios branching out at the start of the projection period (2020).

Maps of the simulated change in the groundwater table over the projection period—i.e., the difference in water table elevation between 2060 and 2020—provide insight into the spatial

distribution of projected changes in groundwater heads and storage. Total hydraulic head of groundwater is a combination of both pressure from the weight of the water and the elevation of the water. The head at a point in an aquifer (in three-dimensions) is the elevation that water will rise to within a pipe screened or open to that point. For this broad-scale Study, groundwater head can generally be considered to be the elevation of the water table.

The spatial distribution of projected changes in groundwater heads under each S-D scenario is presented in Figure ES-5. The color scale is the same across all panels in Figure ES-5, with blue areas indicating an increase in groundwater levels and red areas indicating a decrease. All panels of Figure ES-5 show blue shading near and along the Santa Cruz River (SCR) northwest of Tucson, indicating a rise in groundwater levels in this portion of the LSCR Basin under all S-D scenarios. This is a result of increased discharge and infiltration of reclaimed water from two metropolitan Water Reclamation Facilities (WRFs) along the SCR.

Darker blue shading under scenarios B and C, compared to scenarios D, E, and F, indicate projected increases in streamflow in the Tanque Verde and Rillito Creek area under the best-case climate (Reclamation, 2021). Figure ES-5 also shows continued propagation of the groundwater mounds created by recharge at the Central Avra Valley Storage and Recovery Project (CAVSARP) and the Southern Avra Valley Storage and Recovery Project (SAVSARP) facilities in the Avra Valley subbasin under all S-D scenarios.

Areas of groundwater table rise related to new recharge facilities are also shown under all S-D scenarios. Three new facilities (two of which are operating as of 2022) are included in the projections. These are the Southeast Houghton Area Recharge Project (SHARP) to the east, Project RENEWS in the Green Valley area, and the Santa Cruz River Heritage Project in central Tucson. Recharge of reclaimed water from the Green Valley WRF also contributes to the rise in the Green Valley area across all S-D scenarios.

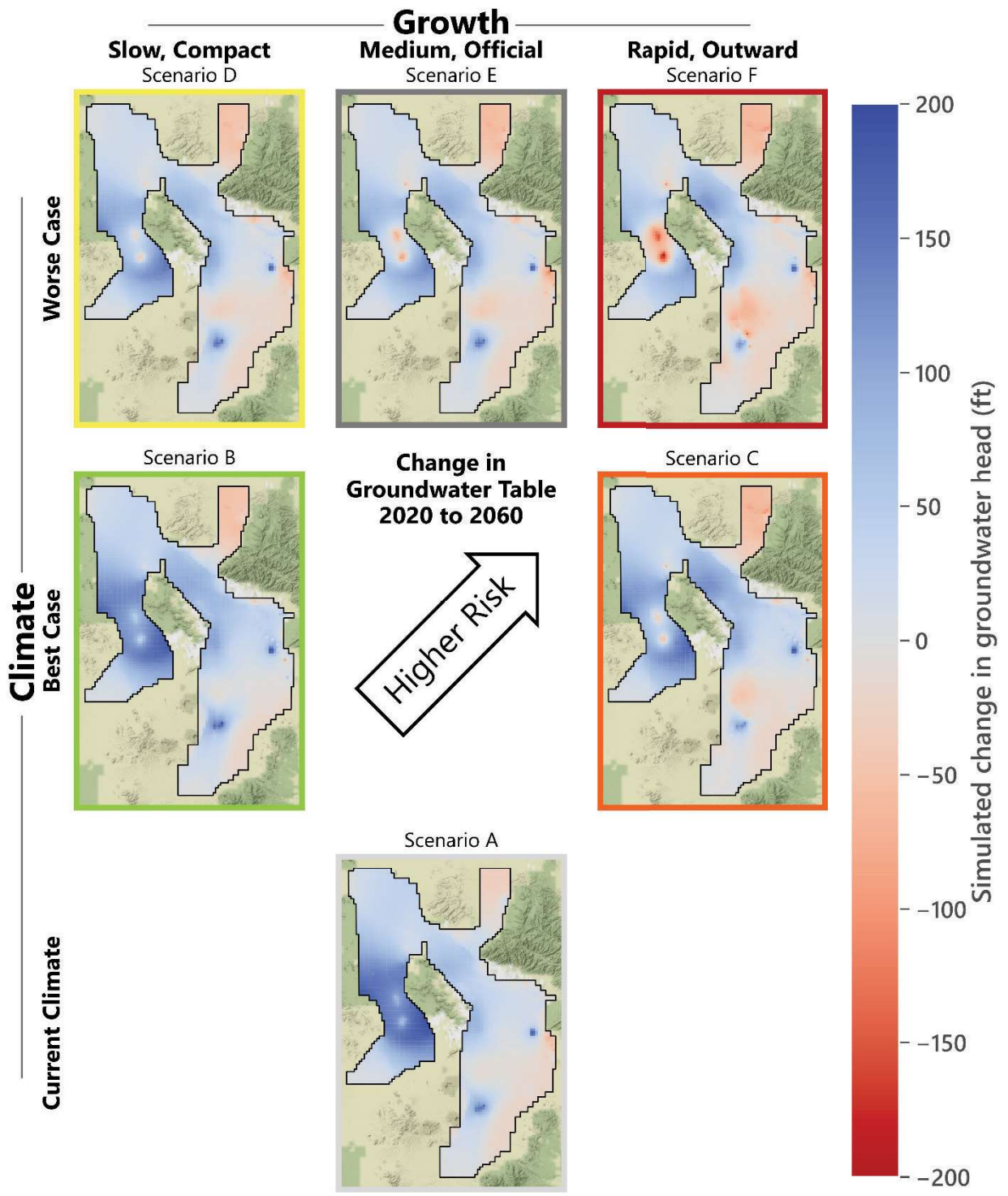


Figure ES-5. Change in simulated head by model cell over the projection period for each Study S-D scenario. Maps are positioned in the layout of Table ES-1. Color scale is shared between all maps.

Five adaptation strategies were simulated with the TAMA Model to evaluate the impact each would have on the groundwater table by the end of the projection period. Simulations were conducted as if a given adaptation strategy was implemented for the duration of the projection period (40 years). All simulations were conducted under scenario F, which reflects the higher risk to water resources for this Study. Results suggest that all five strategies simulated are effective at increasing the simulated groundwater table by at least a foot over large portions of the Study area. In generally, the greater the rate of recharge or pumping offset, the greater the benefit to groundwater table.

1. Introduction

The Bureau of Reclamation (Reclamation) conducts the Basin Study Program to evaluate future water supply and demand imbalances and develop strategies to address these imbalances. The Basin Study Program is part of the U.S. Department of the Interior WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program[2], which addresses 21st-century water supply challenges such as population growth, increased competition for finite water supplies, and climate change.

Reclamation, in partnership with six local non-federal cost-share partners, began the Lower Santa Cruz River Basin Study (Study) in southeastern Arizona in 2016. Non-federal cost-share partners include the Southern Arizona Water Users Association, the Pima Association of Governments, the Cortaro-Marana Irrigation District, the Arizona Department of Water Resources (ADWR), the Central Arizona Water Conservation District (also known as the Central Arizona Project or CAP), and the University of Arizona.

As defined in the *Plan of Study* (Reclamation, 2016), the overarching goal of this Study is to identify where physical water resources are needed to mitigate supply-demand imbalances due to climate change and other factors and to develop strategies to improve water reliability for municipal, industrial, agricultural, and environmental sectors in the Lower Santa Cruz River Basin. In this Technical Memorandum, supply-demand imbalances will generally be referred to as "risk to water resources". Low risk to water resources correlates with minimal need for adaptation, while high risk correlates to a greater need for adaptation. The future projection period for the Study is 2020 to 2060.

The Study area is focused within the Tucson Active Management Area (TAMA; Figure 1), as defined by ADWR. The Study uses a scenario planning approach to evaluate a range of future LSCR Basin-wide climate conditions, as well as a range of population growth rates and development patterns. Scenarios are based on projected climate conditions and a combination of population growth rate and development pattern (demand/growth) out to the 2060 planning horizon. For this Study, six scenarios with pairwise combinations of climate conditions and demand/growth were evaluated (scenarios are lettered A-F).

This Technical Memorandum describes the groundwater modeling portion of the Study and relies on previous efforts including: development and calibration of the TAMA groundwater flow model by ADWR (Mason & Hipke, 2013; the active TAMA Model domain is shown in Figure 1), projections of future water supplies and demands by CAP (CAP, 2021), recharge modeling provided by CAP (Montgomery and Associates, 2020) and projections of natural streamflow by Reclamation (Reclamation, 2021). CAP used the Central Arizona Project Service Area Model (CAP:SAM) to develop projections of most water supplies and demands within the Study area.

Projections of water supply and demand growth were translated into groundwater inflows and outflows for input into the TAMA groundwater flow model by Study Partners with expert

[2] https://www.usbr.gov/watersmart/

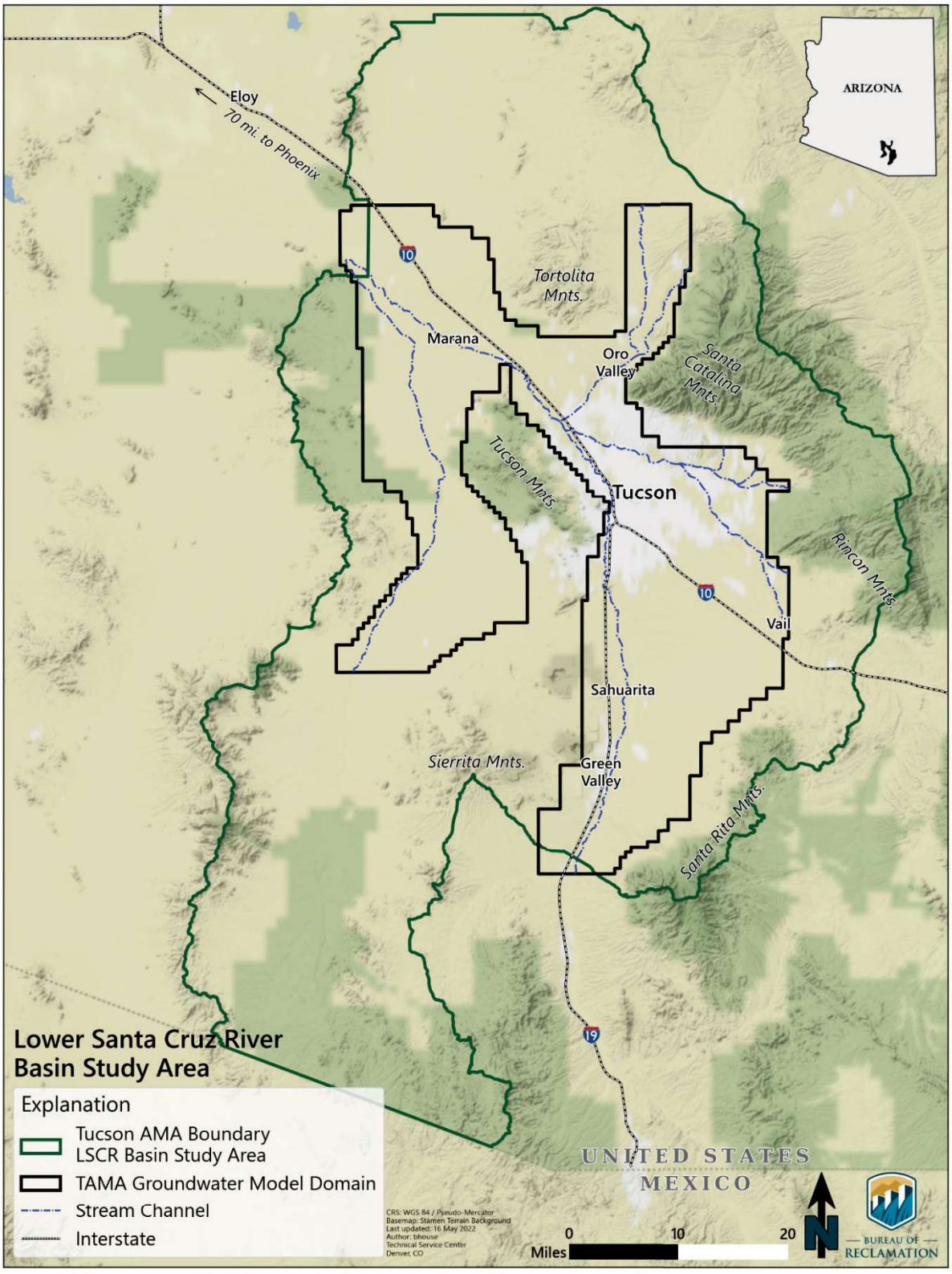


Figure 1. Lower Santa Cruz River Basin Study Area and the TAMA groundwater model boundary.

knowledge. Results from the groundwater model projection period (2020-2060) provide insight into the range of plausible future conditions for the groundwater resources in the Study area. Results were also used to inform adaptation strategies that address areas of supply-demand imbalances and declining groundwater heads/storage. Finally, five proposed adaptation strategies are simulated in the groundwater flow model to evaluate the impact each would have on the groundwater table by the end of the projection period.

1.1. Basin Study Background and Overview

The Basin Study Program is part of the U.S. Department of the Interior WaterSMART (Sustain and Manage America's Resources for Tomorrow) Program, which addresses 21st-century water supply challenges such as population growth, increased competition for finite water supplies, and climate change. The establishment of the WaterSMART Program addresses the authorities within the SECURE (Science and Engineering to Comprehensively Understand and Responsively Enhance) Water Act (Subtitle F of the Omnibus Public Land Management Act of 2009, Public Law 111-11), enacted into law on 30 March 2009. The SECURE Water Act provides authority for federal water and science agencies to work with state and local water managers to plan for climate change and other threats to water supplies, and to take action to secure water resources for the communities, economies, and ecosystems they support.

In 2009, Reclamation initiated the WaterSMART Basin Study Program to fund comprehensive studies that evaluate options for meeting future water demands within river basins in the West where imbalances in supply and demand exist or are projected. A Basin Study is conducted as a collaborative, cost-share partnership with non-Federal partners to: quantify current and future water supply and demand imbalances, assess the resulting risks to the basin resources, develop strategies to resolve those imbalances, and perform a trade-off analysis. In this technical memorandum, supply-demand imbalances will generally be referred to as “risk to water resources”. Low risk to water resources correlates with a lesser need for adaptation while high risk correlates to a greater need for adaptation.

The enactment of Arizona’s Groundwater Management Act in 1980 created several Active Management Areas (AMAs) in regions of Arizona with long-term groundwater storage declines. AMAs are subject to intensive water resource management by ADWR. The Study area coincides with the Tucson Active Management Area (TAMA) boundary (Figure 1). The TAMA’s management goal is to achieve long-term “safe-yield” by 2025 (ADWR, 2016). Safe-yield is defined under Arizona Revised Statutes Title 45 Section 561 as:

“[A] groundwater management goal which attempts to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial recharge in the active management area.”By this statute, safe-yield is achieved on an AMA-wide basis. Early on, it was recognized that as safe-yield conditions were attained on an AMA-wide basis, some areas could be depleted, some areas of active recharge could be in surplus, and other areas could achieve a localized balance between the amount of water recharged and pumped (ADWR, 1999).

The Study Area began receiving imports of Colorado River water in 1992 with completion of the CAP—a series of canals and pipelines stretching over 360 miles (mi) from Lake Havasu, AZ and terminating just south of the San Xavier District of the Tohono O’odham Nation, within the Study Area. Importation of CAP water to the TAMA steadily increased through 2007 and has

plateaued since. Prior to these imports, the TAMA relied almost exclusively on groundwater to meet its water demands. This led to significant groundwater overdraft and a declining groundwater table.

Municipal CAP water entitlements are either recharged into the aquifer for storage and recovered for treatment and use or substituted for groundwater that would otherwise be pumped by agriculture. In addition to CAP water deliveries, the region has seen a marked reduction in per capita water use, as well as declines in agricultural groundwater use. As a result, groundwater levels have rebounded in many areas, despite the population growing to over 1 million people in 2020. However, there are still local supply-demand imbalances within the Study area due to a lack of transmission infrastructure, a lack of recharge and recovery facilities in up-groundwater-gradient parts areas, and the cost of constructing new facilities.

The Study uses a scenario planning approach to evaluate a plausible range of projections of water supply and demand over the projection period—2020 to 2060. The Study Project Team developed six supply-demand (S-D) scenarios that reflect the insight of local partners regarding the range of water resource futures for the Study area (Figure 1). These include pairwise combination of three scenarios related to climate ("best-case", "current", and "worse-case") and three related to demand growth and pattern ("slow/compact", "medium/official", and "rapid/outward").

Climate scenarios generally correlate with water supply within the Study area. The "best-case" and "worse-case" climate scenarios for the Study area were developed using results from global circulation models (GCMs) for two greenhouse gas atmospheric concentration scenarios (i.e., Representative Concentration Pathways [RCP]) 4.5 and 8.5, respectively. The "best-case" and "worse-case" climate scenarios represent opposing ends of the spectrum of risk to water resources for the Study area. However, they do not describe the full extent of the possible range of impacts from changes in climate (i.e., "best-case" [*sic*] does not represent the best possible future nor "worse-case" the worst possible future).

A "current" climate scenario was also used to provide comparisons with products from other organizations that do not formally include the impacts of climate change in their projections of supply and demand. For the "current" climate scenario, historic values were repeated over the projection period.

The "best-case", "current", and "worse-case" climate scenarios for the Study area align with plausible sequences of shortages to imported Colorado River water supplies conveyed via the CAP. While the Study's specific climate scenarios were only modeled within the LSCR Basin (see *Lower Santa Cruz River Basin Study Hydroclimate Analysis* [Reclamation, 2021]), the CAP delivery supply sequences from CAP (2021; Figure 2) correspond to the same emissions levels: RCP 4.5, current climate, or RCP 8.5 levels of emissions.

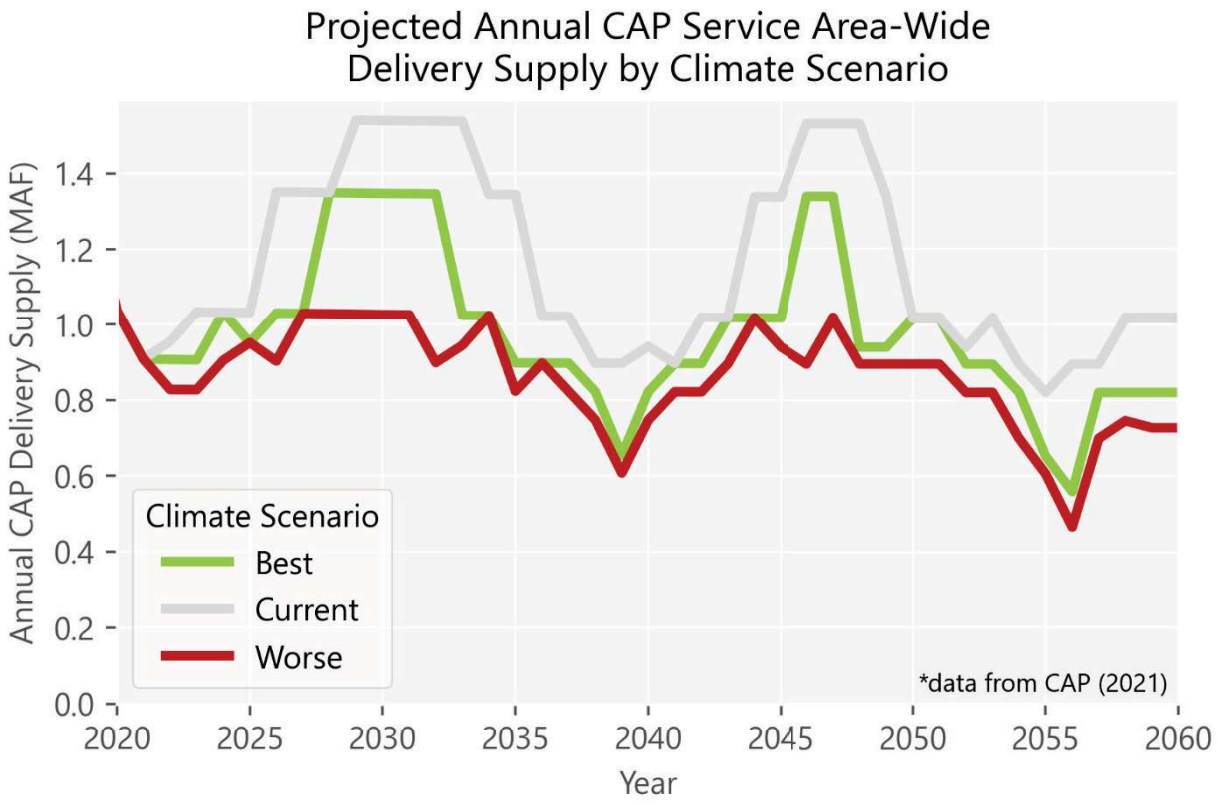
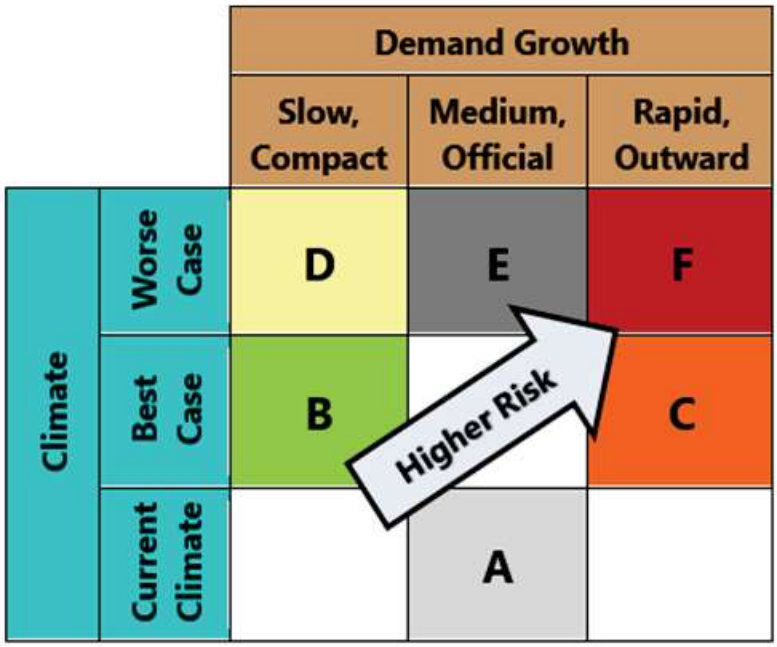


Figure 2. CAP (Colorado River water) service area-wide delivery supply by climate scenario. Data from CAP (2021).

Demand growth scenarios relate to both the rate ("slow", "medium", or "rapid") and pattern ("compact", "official", or "outward") of municipal and industrial growth. Detailed information on these scenarios can be found in Section 4 of the CAP Supply and Demand Assessment (2021).

Table 1 presents a matrix of these climate and demand growth scenarios and identifiers (A-F) associated with each pairwise combination. Based on Study Partner input, not all combinations of climate and demand growth were evaluated. In general, the risks to water resources and the environment increases from the lower-left to the upper-right with scenario B representing a lower and F a higher risk.

Table 1. Lower Santa Cruz River Basin Study supply-demand (S-D) scenario matrix



1.2. TAMA Groundwater Flow Model

The TAMA Groundwater Flow Model (TAMA Model) was used to evaluate impacts of the S-D scenarios and proposed adaptation strategies on groundwater resources within the Study area over the projection period (2020-2060). The first groundwater models of the Tucson and Avra Valley basins were developed in 1972 using an electronic analog system (Anderson, 1972 and Moosburner, 1972). Since then, approximately five iterations of groundwater flow models have been developed for the Study area. The current version of the TAMA Model, which is used in this Study, was released by ADWR in 2013. It uses version 1.0.7 of the U.S. Geological Survey's (USGS) groundwater modeling code MODFLOW-NWT (Mason & Hipke, 2013; Niswonger et. al., 2011). ADWR maintains the TAMA Model to support water resource planning and management in the TAMA, with the goal of being able to "evaluate relative changes within the regional system" (Mason & Hipke, 2013).

The TAMA Model domain encompasses two main subbasins: the Avra Valley Subbasin to the west and the Upper Santa Cruz Subbasin to the east (Figure 3). The subbasins are separated by the Tucson Mountains. The model simulates groundwater conditions over the period 1940-2010 using an annual stress period (i.e., produces a simulated distribution of groundwater heads annually). General parameter ranges and characteristics of the model are summarized in Table 2. In general, hydraulic conductivities (K) are higher in the upper layers and near major streams and washes.

Simulated inflows to the groundwater model (in descending order of magnitude at the end of the modeled period) occur from:

- artificial recharge of CAP (Colorado River) water and reclaimed water
- infiltration of natural and reclaimed water-derived streamflow

- mountain front recharge
- underflow from adjacent basins
- agricultural deep percolation
- seepage from mine tailings ponds

Simulated outflows from the groundwater model(in descending order of magnitude at the end of the modeled period) occur from:

- municipal pumping
- agricultural pumping
- mining pumping
- underflow to an adjacent basin
- industrial pumping
- evapotranspiration

Prior to 1900, groundwater pumping within the TAMA was minimal and used for meeting domestic and stock animal demands (Mason & Bota, 2006). Agricultural development began in the early 1900s, with the first high capacity well installed in 1937. According to a number of groundwater modeling efforts, the TAMA groundwater system was, "still in a state of dynamic equilibrium until about 1940" (Mason & Bota, 2006)—where Mason & Bota defined dynamic equilibrium as, "long-term natural recharge balanced by long-term natural discharge" (2006). Simulated groundwater heads from 1940 (pre-development) indicate groundwater generally flows from south to north and out of the model domain in the northwest corner (Figure 3). This general flow pattern has not been altered with development.

Groundwater abstractions increased significantly from an estimated 70 thousand acre-feet per year (TAF/yr) in 1940 to a peak of over 400 TAF/yr in 1975 (Mason & Hipke 2013). Groundwater abstractions subsequently declined to approximately 280 TAF/yr in 2010–the final year of the TAMA Model simulation period. Groundwater pumping during much of this period far exceeded recharge, resulting in a near-continuous decline in groundwater storage from the mid-1940s to the mid-2000s. Mason & Hipke (2013) estimated that at its low in 2004, there had been a 6.8 million acre-foot (MAF) decline in groundwater storage within the model domain. The importation of Colorado River water via CAP had offset some pumping demands and supplied artificial recharge, resulting in minor groundwater storage recovery since the mid-2000s. The TAMA Model estimates that groundwater storage increased by approximately 0.2 MAF between 2004 and 2010 (Mason & Hipke, 2013).

There is an interim period between the end of the TAMA Model simulation period (2010) and the start of the Study projection period (2020). Updated MODFLOW Well package (WEL) and MODFLOW Recharge package (RCH) input files were provided by ADWR though 2017 (ADWR, 2019; ADWR, 2020a). WEL includes groundwater stresses from pumping and underflow from adjacent basins. RCH includes all sources of recharge to the groundwater system except underflow from adjacent basins. An interim period of 2018 to 2019 for the WEL and RCH remains before the start of the projection period in 2020. Actual pumping rates by well for these years were provided by CAP (CAP, 2021). RCH for 2018 to 2019 were handled on a source-by-source basis with either a constant rate, data provided by CAP (CAP, 2021) or a

constant median historic rate. Details on this by source of recharge are included in the *Simulated Inflows* section of this technical memorandum. Evapotranspiration and some groundwater underflow processes are implemented in the TAMA Model with the MODFLOW Evapotranspiration package (EVT) and MODFLOW Time-Varying Specified-Head package (CHD), respectively. Extended periods for these packages were not available. The most recent model input values for these packages (2010) were held constant over the interim period (2010-2020).

It should also be noted that the TAMA Model domain is not coincident with the TAMA boundary. The groundwater model encompasses small portions of the Santa Cruz AMA (SCAMA) to the south and the Pinal AMA (PAMA) to the northwest (Figure 3). To avoid confusion, many of the TAMA Model outputs were constrained to include only those model cells located within the TAMA boundary—thereby excluding those in the PAMA or SCAMA.

Table 2. TAMA groundwater model general parameters and characteristics (Mason & Hipke, 2013)

Model Component	Description	Values/Units
Simulation: Combined Steady-State-Transient	Years: 1940-2010; Steady-State: 1940: Transient: 1941-2010	Time = days Length = feet
Model Grid	130 Rows x 100 Columns; 3,200 $mile^2$	Model Cells = 0.5 $mile^2$ DELR = DELC = 2640 feet
Model Origin (Lower Left)	UTM, Zone 12, HARN 1983, feet	X = 1488661.47638 Y = 11494611.8537
Model Cell Types	No Flow, Constant Head, Variable Head, Specified Flux	
Boundary Conditions	Constant Head and Specified Flux	
UPW Package	Allows resaturation of cells that go dry	LAYWET = 0
Layer 1 – 3,105 active cells	Layer Type 1 – Unconfined Aquifer	Horizontal K; Min = 0.5 feet/day, Max = 250, Average = 35.3
Layer 2 – 4,524 active cells	Layer Type 3 – Confined / Unconfined Aquifer	Horizontal K; Min = 0.5 feet/day, Max = 110, Average = 16.5
Layer 3 – 4,954 active cells	Layer Type 3 – Confined / Unconfined Aquifer	Horizontal K; Min = 0.1 feet/day, Max = 55, Average = 3.8
Vertical Conductivity	Assigned as a ratio between horizontal K and vertical K values	Layer 1 = 10:1 Layer 2 = 10:1 to 20:1 Layer 3 = 15:1 to 30:1
Specific Yield	Volume of water yielded per unit area per unit change of water level in unconfined aquifer	Layer 1 = 0.08% to 20% Layer 2 = 0.05% to 0.18% Layer 3 = 0.05% to 0.12%
Specific Storage	Volume of water yielded per area per unit change in a confined aquifer's potentiometric surface	Layer 1 = N/A (Unsaturated) Layer 2 = 1.0×10^{-6} Layer 3 = 1.0×10^{-6}
Pumping	Assigned to all simulated well locations	$feet^3$ / day
Recharge	Applied to uppermost active cells	feet / day
Evapotranspiration	Assigned rates per cell; Extinction Depth 30 feet	feet / day
Numerical Solver	Generalized-Minimum-Residual (GMRES)	Head Closure Criteria: 0.01 feet Budget Error 864 $feet^3$/day

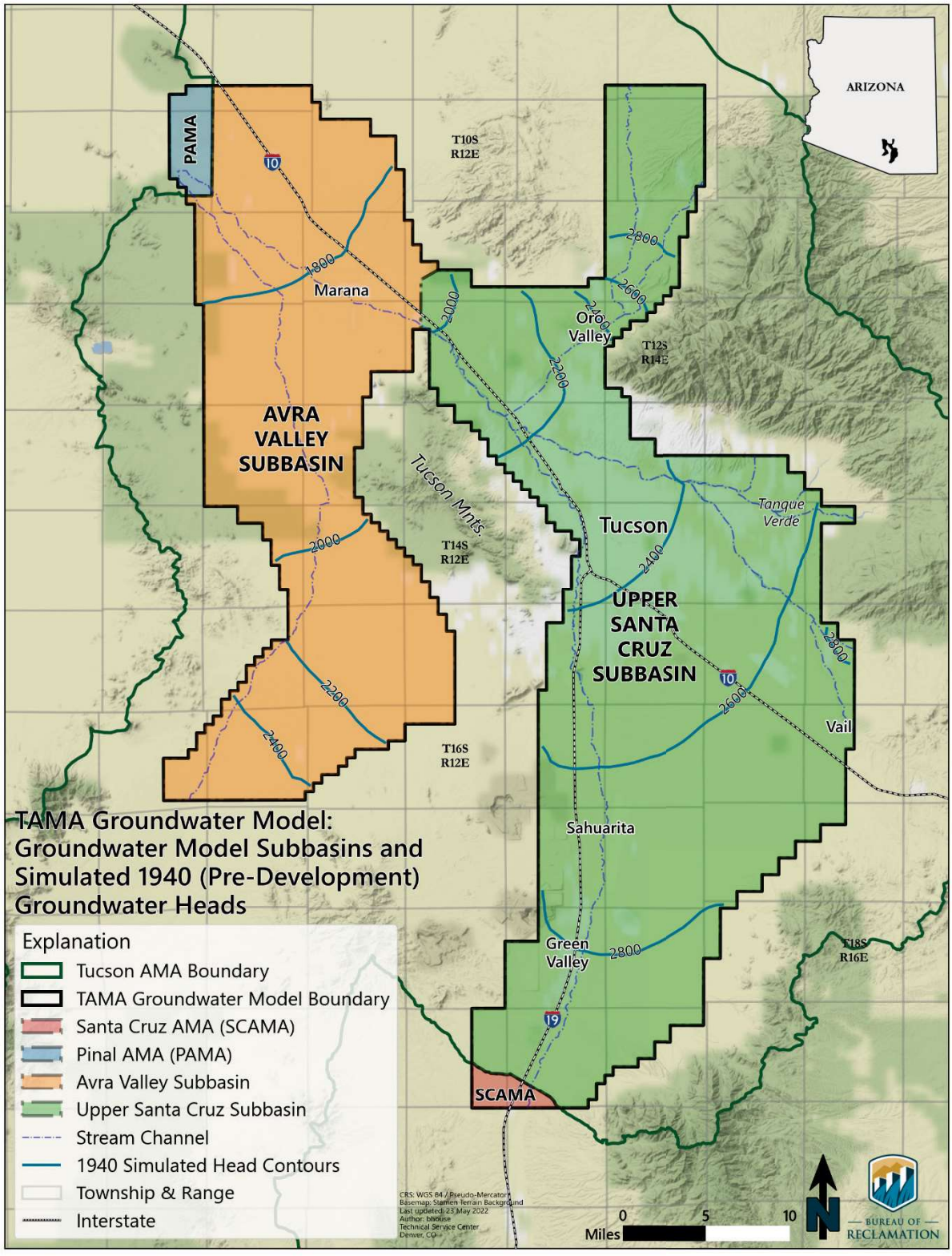


Figure 3. TAMA groundwater model subbasins and portions located outside the TAMA boundary. Contours of simulated groundwater head from 1940 (pre-development) in feet of elevation.

2. Groundwater Model Updates

The ADWR TAMA Model was updated for application to the Study. The active model domain was expanded in layers 1 and 2. The domain expansion allowed for wetting of model cells that were dry over the historical period (1940-2010). Section 2.1 provides details on this change. TAMA Model groundwater stresses were updated to fill the interim period (2010-2019 or 2018-2019) and incorporate projections of future stresses (2020-2060). Section 2.2 provides detail on updates to inflows (recharge) to the model while Section 2.3 provides detail on updates to outflows.

2.1. Active Model Domain

The TAMA Model active domain and hydrogeologic properties were developed by Mason & Hipke (2013). Personal communication with Dale Mason of ADWR indicated that the active domain for layers 1 and 2 was curtailed during model development where model cells in these layers were dry for the duration of the historical period (ADWR, 2018b). Model cells in these areas were set inactive to improve computational performance, not because aquifer material does not exist.

According to Mason (2018b), the active domains of layers 1 and 2 should be coincident with layer 3. These inactive cells in layers 1 and 2 should be activated if there were potential for wetting of historically dry cells. For example, the Avra Valley has experienced a significant change from its natural state with the construction of two major artificial recharge facilities (CAVSARP and SAVSARP). Though much of this change occurred during the period modeled by Mason & Hipke (2013), there remains potential for future wetting of historically dry cells as artificial recharge persists in the area and the resulting groundwater mounds continue to propagate outward from the facilities. Therefore, it was necessary to expand the active domain of layers 1 and 2 for this Study.

Hydrogeologic properties (i.e., hydraulic conductivity and storage parameters) were not assigned to these potentially active cells in the original TAMA Model input files from Mason & Hipke (2013). Groundwater modeling work commissioned by CAP (Montgomery and Associates, 2020) addressed this issue previously by activating cells in layers 1 and 2 to match the extent of layer 3. This work also assigned hydrogeologic properties to these activated cells. The MODFLOW input files containing these changes (BAS, DIS, and UPW) were provided by CAP for implementation in this Study (Montgomery and Associates, 2020). The updated active model boundaries and horizonal K values for model layers 1 and 2 are presented in Figures 4 and 5, respectively. The area between the original (blue) and updated (black) layer boundaries in Figures 4 and 5 are where the active domain was expanded. Hydrogeologic properties for model layer 3 were not changed from Mason & Hipke (2013).

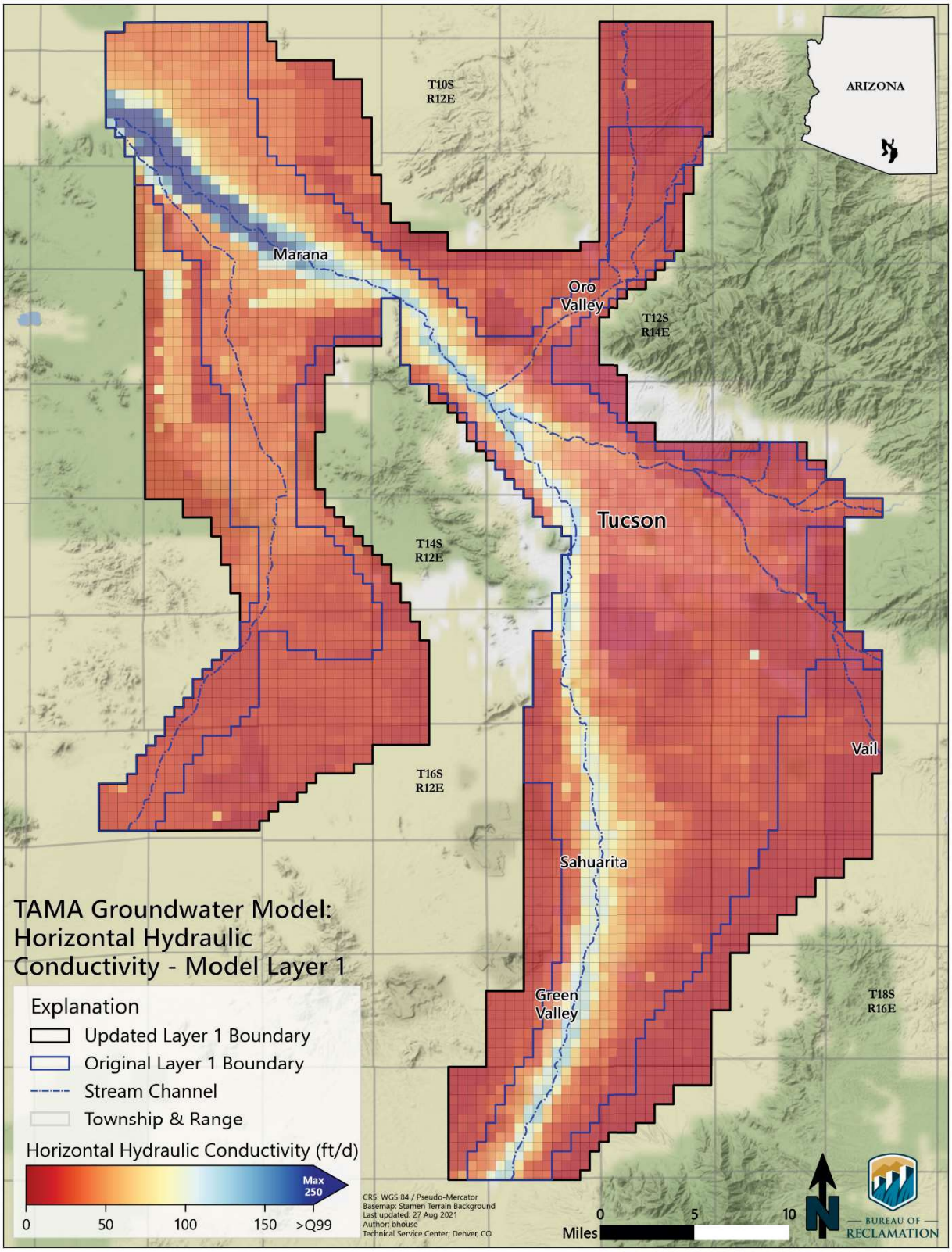


Figure 4. Updated horizontal hydraulic conductivity distribution for the TAMA Model layer 1. To provide detail in the expanded domain areas, the maximum value on the color bar was set to the 99th quantile. The area between the blue and black boundaries indicates where the active domain was expanded.

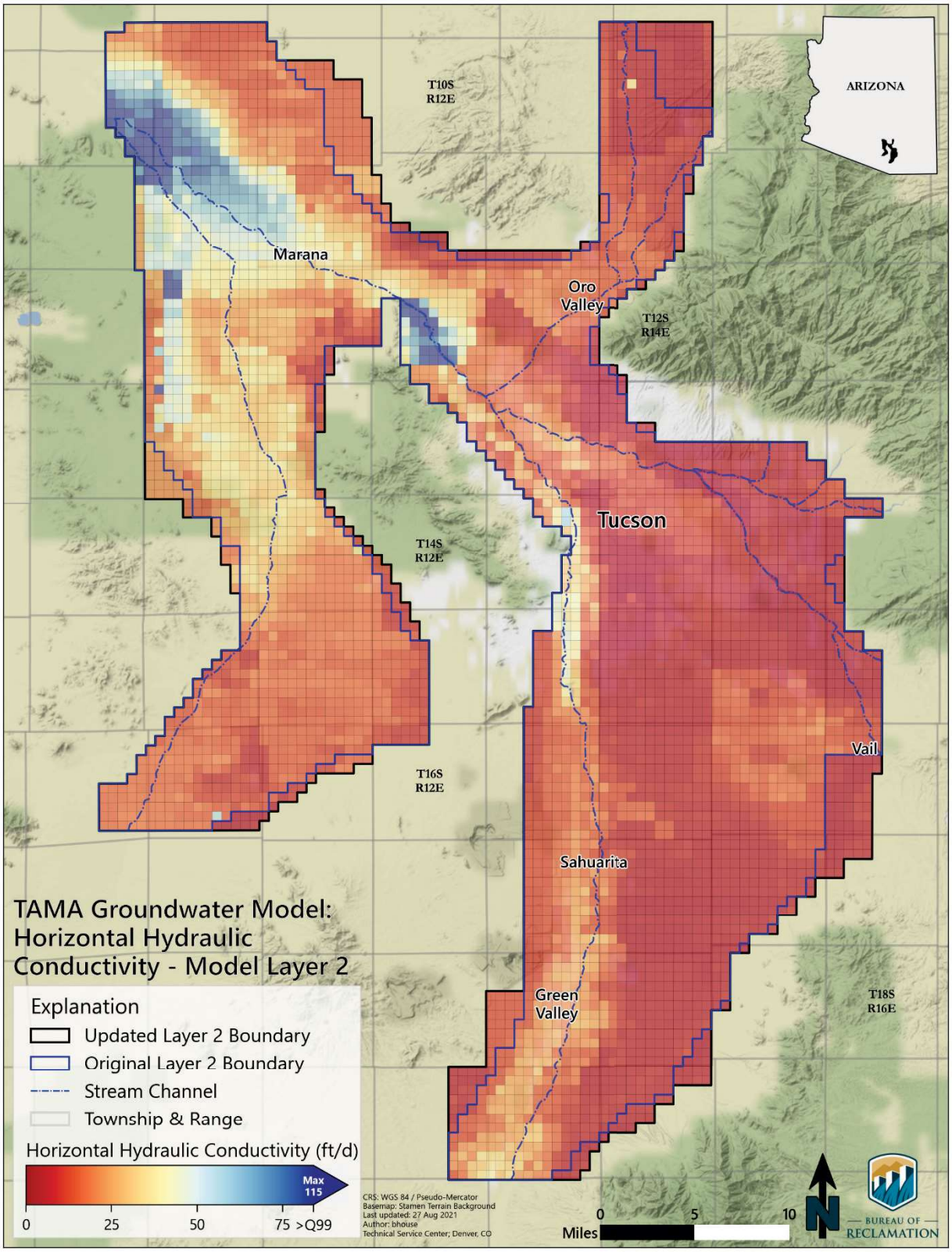


Figure 5. Updated horizontal hydraulic conductivity distribution for the TAMA Model layer 2. To provide detail in the expanded domain areas, the maximum value on the color bar was set to the 99th quantile. The area between the blue and black boundaries indicates where the active domain was expanded.

2.2. Simulated Inflows

Simulated inflows to the groundwater model (in order of descending magnitude) occur from: artificial recharge of CAP water and reclaimed water; infiltration of natural and reclaimed water-derived streamflow; mountain front recharge; underflow from adjacent basins; agricultural deep percolation; and seepage from mine tailings ponds. Each will be discussed below.

2.2.1. Artificial Recharge

Just under half of the total recharge within the Study Area over the projection period occurs at constructed artificial recharge facilities—legally designated as underground storage facilities (USFs). ADWR differentiates USFs as either "constructed" or "managed" (ADWR, 2022). Constructed facilities recharge water via percolation basins, etc. Managed facilities recharge water through discharge to a natural channel. Supplies for recharge include reclaimed water from water reclamation facilities (WRF; a.k.a. wastewater treatment plants) or Colorado River water imported via the CAP. Projections of recharge for these facilities within the Study Area were provided by CAP for 2018-2060 (CAP, 2021). This section of the Technical Memorandum covers the area's constructed facilities, as well as the small managed Santa Cruz Heritage Recharge Project. Managed recharge projects for reclaimed water discharges from the region's two metropolitan WRFs into the Santa Cruz River is covered in Section 2.2.3.

An extended RCH input file was provided by ADWR though 2017, which includes historical annual recharge rates from these facilities (ADWR, 2020a). Projections vary based on the Study climate and demand growth scenarios and include varying degrees of shortages of CAP water across the tiers identified in the *2019 Lower Basin Drought Contingency Plan*[3] (CAP, 2021). Projections were provided for the 17 permitted recharge facilities within the TAMA Model domain, listed in Table 3, for each S-D scenario. The locations of the recharge facilities listed in Table 3 are shown in Figure 7.

[3] https://www.usbr.gov/dcp/finaldocs.html

Table 3. Permitted recharge facilities within the project area.

USF Permit Number	Facility Name	Type
71-211276	SOUTHERN AVRA VALLEY STORAGE AND RECOVERY (SAVSARP) USF	Constructed
71-211284	PCRWRD CORONA DE TUCSON RECHARGE FACILITY USF	Constructed
71-221721	SADDLEBROOKE WATER RECLAMATION PLANT CONSTRUCTED USF	Constructed
71-222410	PROJECT RENEWS CONSTRUCTED UNDERGROUND STORAGE FACILITY	Constructed
71-224073	BLACK WASH USF – PIMA COUNTY RWRD	Constructed
71-224578	MARANA WRF RECHARGE PROJECT USF	Constructed
71-225060	TUCSON WATER SHARP USF	Constructed
71-228412	SANTA CRUZ RIVER HERITAGE PROJECT MANAGED USF	Managed
71-231174	GREEN VALLEY RECHARGE PROJECT USF	Constructed
71-520083	SWEETWATER RECHARGE FACILITIES USF	Constructed
71-561366	LOWER SANTA CRUZ REPLENISHMENT PROJECT USF	Constructed
71-563876	MARANA HIGH PLAINS EFFLUENT RECHARGE PROJECT USF	Constructed
71-564896	AVRA VALLEY RECHARGE PROJECT (FULL SCALE) USF	Constructed
71-577501	PIMA MINE ROAD FULL SCALE USF	Constructed
71-578806	CAVSARP FULL SCALE USF	Constructed
71-581379	ROBSON RANCH QUAIL CREEK, LLC USF	Constructed
71-595209	TOWN OF SAHUARITA	Constructed

Mason & Hipke (2013) found that temporal lagging of recharge at facilities to account for travel time through the vadose zone improved model calibration. Lagging over a three-year period with 30% the first year, 40% the second, and 30% the third year was found to yield reasonable results (Mason & Hipke, 2013). Figure 6 shows the historical and projected total annual lagged recharge by S-D scenario. Projected recharge was distributed spatially over groundwater model cells using the footprint of each recharge facility provided by ADWR. Where a recharge facility's footprint overlapped with multiple model cells, the proportion of the footprint overlap with a given cell was used to distribute the total recharge volume. Figure 7 presents a map of average recharge rates from artificial recharge facilities over the projection period and S-D scenarios. Recharge from facilities was implemented in the TAMA Model using RCH.

Most recharge from artificial recharge facilities occurs in the Avra Valley subbasin at the SAVSARP, CAVSARP, AVRP, and LSCRP facilities (Figure 7). The Pima Mine Road facility north of Sahuarita is projected to recharge the majority of water in the Upper Santa Cruz subbasin. For all S-D scenarios, recharge at facilities is projected to decline over the projection period due to reductions in available CAP supplies (Figure 6).

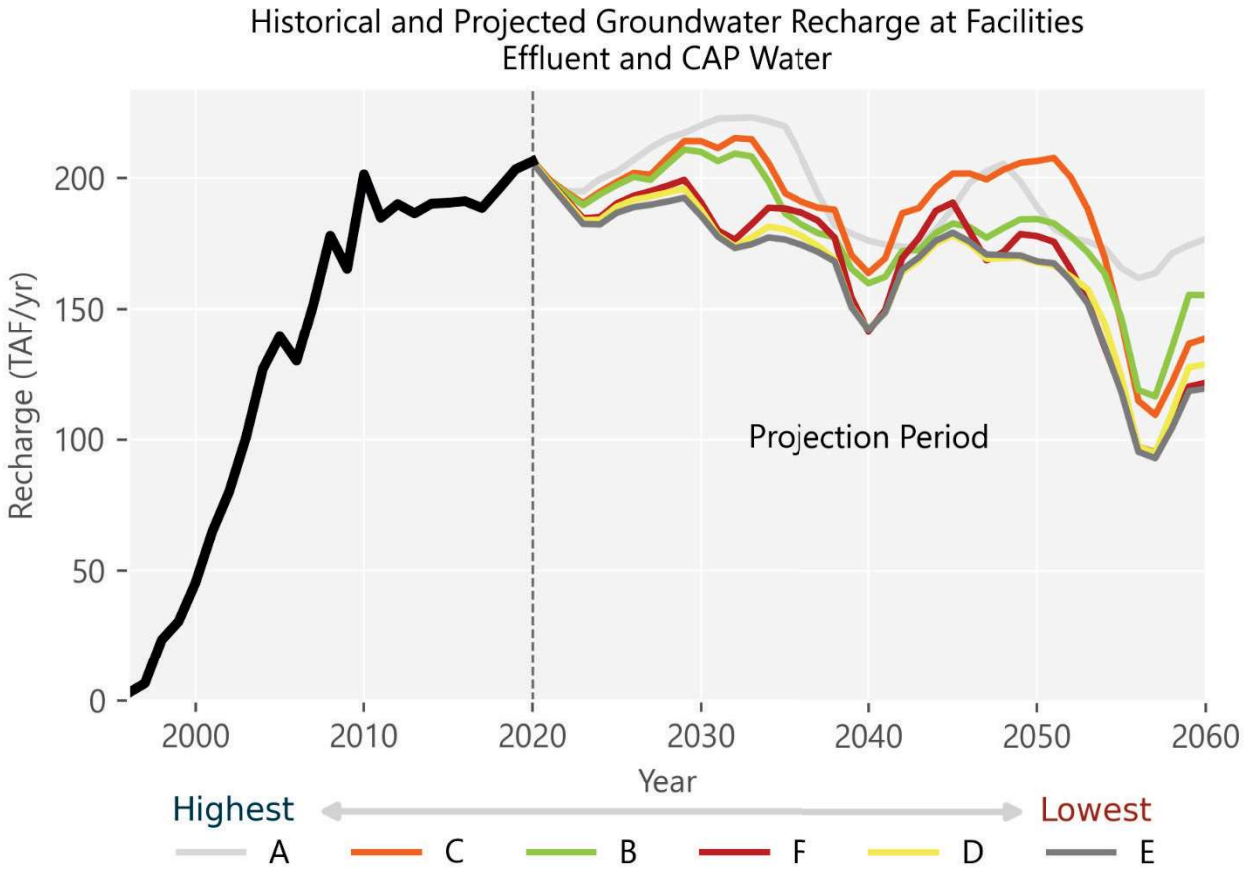


Figure 6. Historical and projected annual groundwater recharge at recharge facilities within the TAMA groundwater model boundary. Values are temporally lagged over a three-year period.

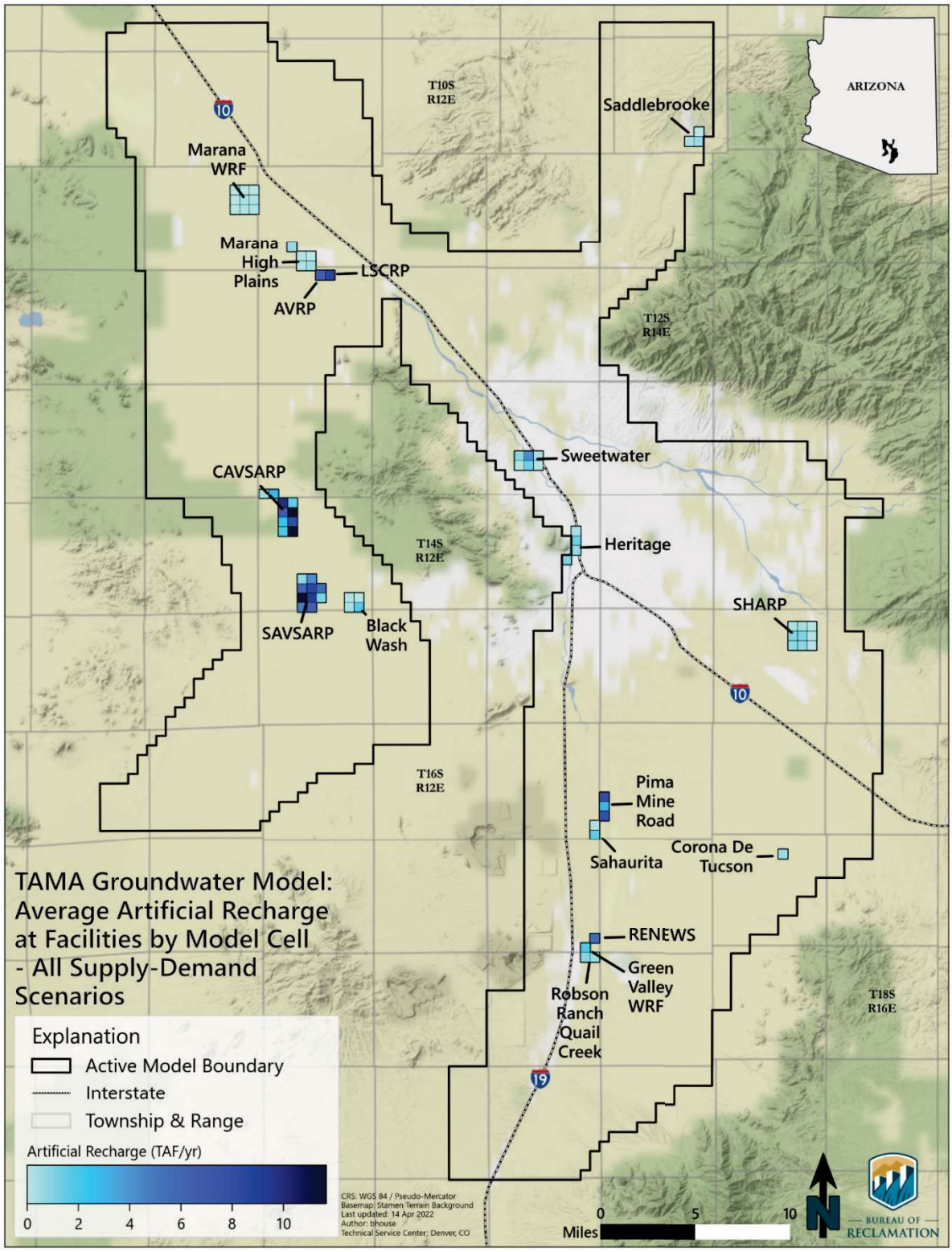


Figure 7. Map of average groundwater recharge from facilities over the projection period (2020-2060) and all S-D scenarios. Note that this map does not include the Santa Cruz Managed USF and the Lower Santa Cruz River Managed USF that receive reclaimed water from the Agua Nueva and Tres Rios WRFs. These managed recharge facilities are depicted in Figure 15.

2.2.2. Streamflow Infiltration

Infiltration of streamflow along natural channels constitutes a significant source of groundwater recharge within the TAMA. Mason & Hipke (2013) estimated that under pre-development conditions, streamflow infiltration accounted for 37% of recharge within the TAMA Model domain. Streamflow infiltration can vary greatly from year-to-year. Estimated annual streamflow infiltration during the historical period (1940-2010) ranges from a minimum of 15 TAF to a maximum of 450 TAF (Mason and Hipke, 2013).

Mason & Hipke (2013) calculated initial estimates of groundwater recharge from streamflow infiltration using a method developed by Burkham (1970). This method uses a power-law relationship between mean monthly streamflow discharge at a given gage (in cubic feet per second [cfs]) and mean monthly infiltration (cfs):

$$Infiltration\ Rate = C \times Mean\ Monthly\ Discharge^{0.8} \qquad \text{Equation 1}$$

where C is a reach-specific fitting parameter.

Burkham (1970) assigned C parameters for the major streams and washes within the Study area based on analysis of measured discharge data from flow events (Figure 8). Given the length of a reach, the $C_{per\ mile}$ (1/mile) was calculated for several reaches by Burkham (1970). Those reaches for which Burkham (1970) did not calculate the $C_{per\ mile}$ were calculated as part of this Study. The Burkham (1970) reaches and $C_{per\ mile}$ parameters are presented in Figure 8.

Current Climate Scenario

Streamflow infiltration is implemented in the TAMA Model with RCH. An RCH input file with an extended period (1940-2017) was provided by ADWR (2020a). An interim period of 2018 to 2019 remains before the start of the projection period in 2020. Inflows from all sources (except underflow) are combined in the RCH for a given year and cell. This complicates parsing inflows by source. An RCH with streamflow infiltration removed was provided by ADWR for 1940 to 2010 (ADWR, 2018a). The difference between this and the RCH from Mason & Hipke (2013) provided an approximation of historic streamflow infiltration by model cell. The median streamflow infiltration between 2000 and 2010 was applied for the years 2018 and 2019. This results in approximately 71.7 TAF/yr of streamflow infiltration recharge for these years.

As the Study progressed, a dataset of streamflow infiltration rate by year and model cell became available from ADWR with a period of 1940 to 2015 (ADWR, 2020b). The period 1999 to 2013 is identified in the TAMA Fourth Management Plan as, "…generally representative of 'normal' (streamflow) conditions" (ADWR, 2016). There is a 2% difference in the median total streamflow infiltration over this period and the result above; therefore, streamflow infiltration for 2018 and 2019 were not changed when this new dataset became available.

Streamflow infiltration rates for the current climate scenario reflect the period 1999 to 2013. As stated above, these years are "generally representative of 'normal' (streamflow) conditions" (ADWR, 2016). Data for these years were extracted from the streamflow infiltration rate dataset by year and model cell discussed above (ADWR, 2020b). Streamflow infiltration rates for the projection period (2020-2060) were defined by repeating rates for the period 1999-2013 in sequence.

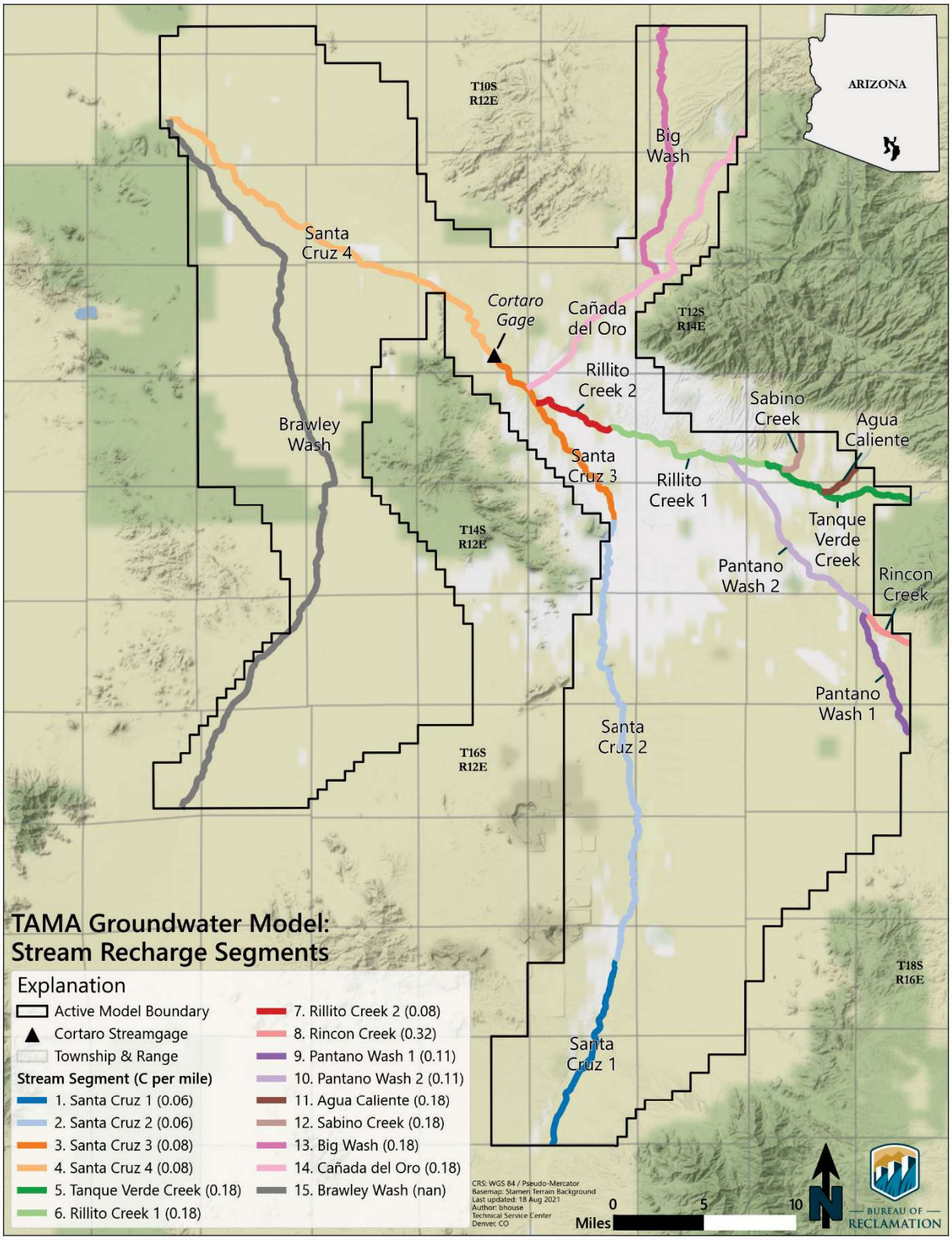


Figure 8. Study area stream recharge segments. Where available, Burkham (1970) $C_{per\ mile}$ values are included in the legend. General flow directions are south to north and out the northwest corner of the model domain. Location of the Cortaro Gage noted. Brawley Wash was not evaluated in Burkham (1970).

Best-case and Worse-case Climate Scenarios

Streamflow infiltration for the best-case and worse-case future climates was developed from projections of mean monthly streamflow. Infiltration to the groundwater was computed using the projected mean monthly streamflow and Equation 1. Projected changes in streamflow were developed based on a combination of future climate projections from GCMs, a stochastic weather generator, and rainfall-runoff modeling (Reclamation, 2021).

Downscaled climate projections were first used to inform a stochastic weather generator based on projected changes in precipitation and temperature under the best-case (RCP 4.5) and worse-case (RCP 8.5) climates (see Table 1). A stochastic weather generator was then used to generate a suite of one hundred realizations of daily precipitation and temperature under each climate scenario. Realizations of precipitation and temperature were used as input to the Sacramento Soil Moisture Accounting (Sac-SMA) rainfall-runoff model to generate corresponding realizations of daily streamflow (Reclamation, 2021). In addition to realizations of the best-case and worse-case climates, a historical case was also developed by forcing the Sac-SMA model with observed historical precipitation and temperature.

Reclamation (2021) grouped the climate analysis into 30-year periods. These included 2020-2049, referend to as the “near future”, and 2050-2079, referred to as the “far future”. To align with the projection period (2020-2060) of this analysis, the complete near future period (2020-2049) and the initial third of the far future period (2050-2060) were used. More information on the downscaled climate projections and development of weather and streamflow realizations are detailed in the *Lower Santa Cruz River Basin Study Hydroclimate Analysis* Technical Memorandum ENV-2020-056 (Reclamation, 2021).

Sac-SMA discretizes the Study area into subbasins and simulates streamflow discharge at each subbasin outlet. Subbasin outlets align with existing streamflow gage stations (Figure 9; Table 4). USGS streamgage locations are used in most cases. The Pima County Regional Flood Control District (PCRFCD) also maintains a series of streamgages throughout the Study area known as the ALERT System. The Sac-SMA gages are aligned with ALERT System gages in several locations where USGS gages are not present.

Table 4. Summary of Sac-SMA streamflow projection locations

Sac-SMA Gage Id	Gage Name	USGS Gage Id	Burkham (1970) Reach Name	$C_{per\ mile}$
STB	Santa Cruz River at Tubac, AZ	09481740	Santa Cruz 1	0.06
SCC	Santa Cruz River at Continental, AZ	09482000	Santa Cruz 2	0.06
SBC	Sabino Creek near Tucson	09484000	Sabino Creek	0.18
ACH	Agua Caliente Wash near La Milagrosa	2253*	Agua Caliente Wash	0.18
TQR	Tanque Verde Creek near Tucson, AZ	09483100	Tanque Verde Creek	0.18
RIN	Rincon Creek near Tucson	09485000	Rincon Creek	0.32
PNT	Pantano Wash near Vail	09484600	Pantano Wash 1	0.11
PWB	Pantano Wash at Broadway Blvd.	09485450	Pantano Wash 2	0.11
TVC	Tanque Verde at Tucson, AZ	09484500	Rillito Creek 1	0.18
RIL	Rillito Creek Tucson at Dodge Blvd.	09485700	Rillito Creek 1	0.18
BWC	Big Wash Canada Del Oro	1174*	Big Wash	0.18
CDO	Canada Del Oro below Ina Rd, near Tucson	09486350	Canada Del Oro	0.18
GRB	Canada Del Oro Golder Road Bridge	1103*	Canada Del Oro	0.18
RIC	Rillito Creek at La Cholla Blvd	09486055	Rillito Creek 2	0.08
CSC	Santa Cruz River at Cortaro	09486500	Santa Cruz 4	0.08
TSC	Santa Cruz River at Tucson	09482500	Santa Cruz 3	0.08
SCT	Santa Cruz River at Trico Rd, near Marana	09486520	Santa Cruz 4	0.08

*PCRFCD ALERT system streamgage number

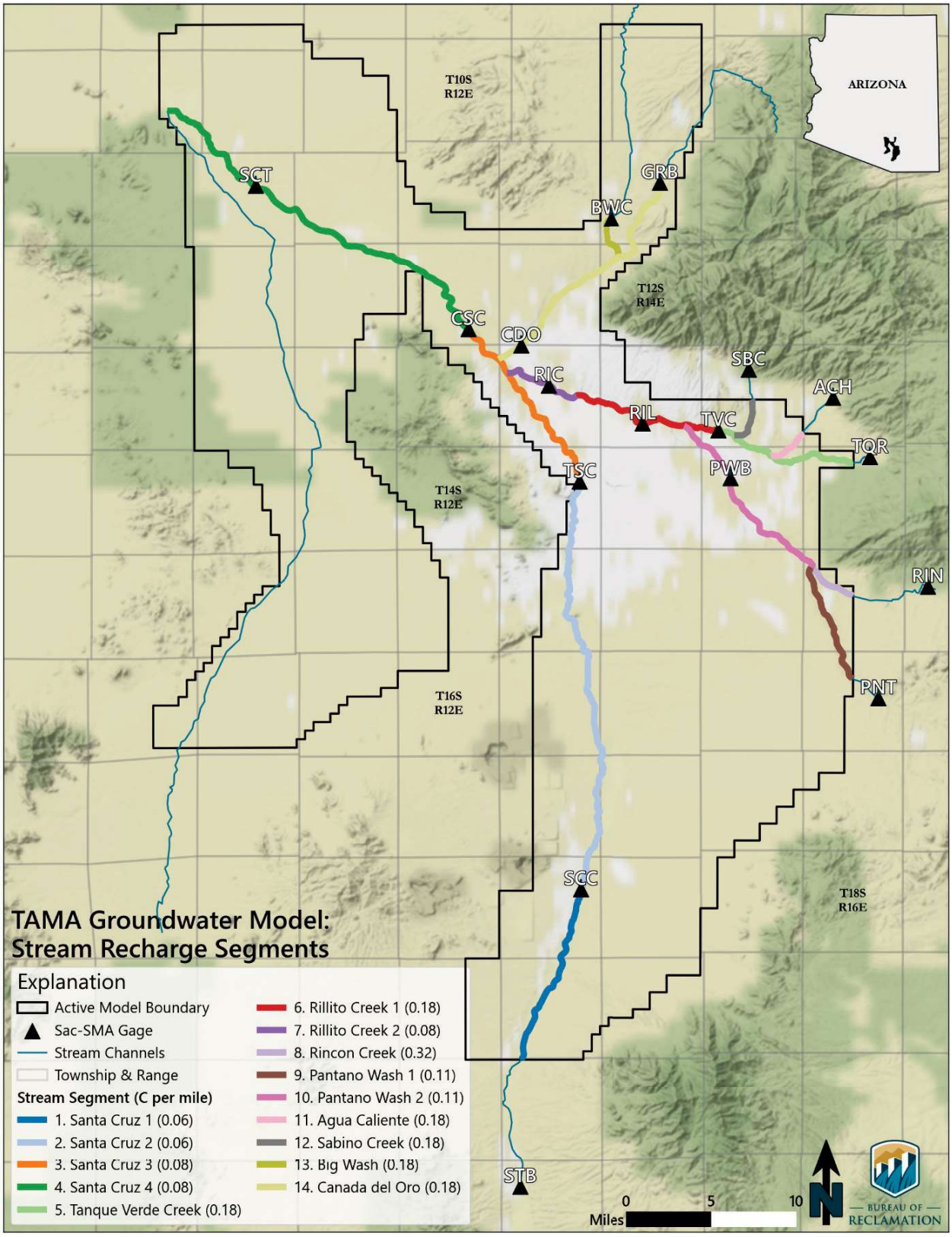


Figure 9. Sac-SMA subbasin outlet locations along stream channels within the project area. Sac-SMA subbasins are assigned a three-letter ID. This ID is located above each outlet location (black triangle) on the map.

The downscaled climate projections used to force the Sac-SMA model in Reclamation (2021) were not bias-corrected; instead, streamflow projections were bias-corrected to the observed streamflow record. The purpose of bias-correction is to correct for systematic biases in the model simulations—in this case, both in the GCMs and Sac-SMA. For this Study, bias-correction is based on the relationships between simulated streamflows from the Sac-SMA model when forced with historical or future climate conditions and the observed streamflow record. The approach uses the cumulative probability distribution function (CDF) of mean monthly streamflow (by month) from the observed record (blue line in Figure 10), Sac-SMA historical simulation (green dashed line in Figure 10), and Sac-SMA projection simulation (red dashed line in Figure 10) to produce a transformed version of the observed record (black line in Figure 10).

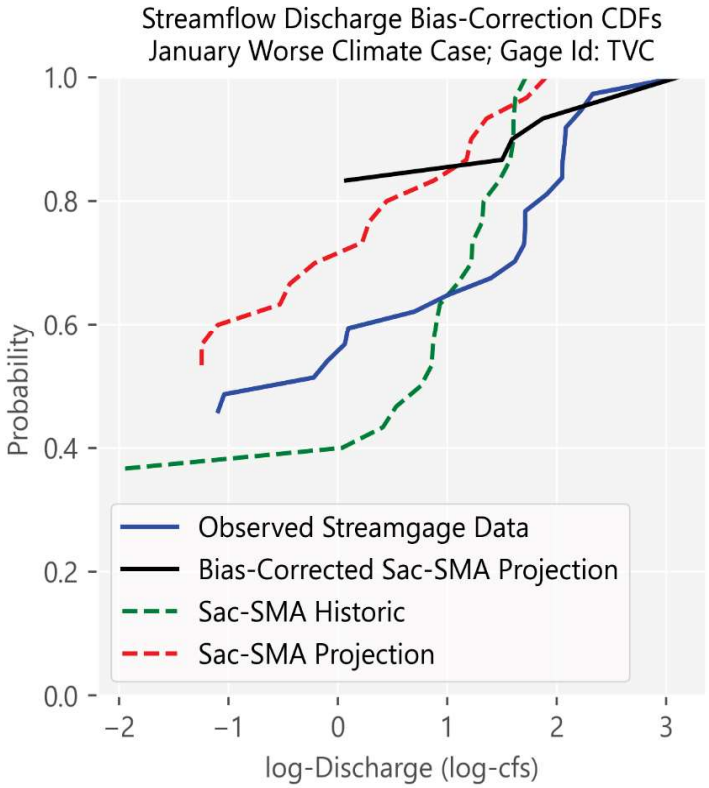


Figure 10. Illustrative CDFs for streamflow bias-correction process. Data are from January of the worse-case climate for Sac-SMA gage TVC.

The relationship between the simulated historical CDF and simulated projected CDF (the difference between the green and red dashed lines in Figure 10) is imposed on the observed record through quantile (exceedance probability) mapping. This preserves the range of observed streamflow magnitudes but transforms the probability of a particular flow occurring. This transformation represents the simulated change in streamflows between the historic and projected conditions. The sequencing of flows from the Sac-SMA projections is preserved through the projection period. The result is a magnitude bias-corrected monthly mean streamflow with temporal sequencing from the Sac-SMA projections (black line in Figure 10). Additional details on the streamflow bias-correction method are discussed further in Appendix A of this technical memorandum.

Comparison of the historic simulated streamflow infiltration (ADWR, 2020b) and the projected streamflow infiltration under the best-case climate (Figure 11) and worse-case climate (Figure 12) indicate reasonable temporal sequencing and magnitude over the projection period. The best-case climate includes greater streamflow infiltration than the worse-case climate. The final 10-years (2050-2060 of the “far future”) of the projection period includes greater streamflow infiltration compared to the initial 30-years (2020-2049 or “near future”) for both climate scenarios. These characteristics are in-line with the results of Reclamation (2021). Note: The projected time series of streamflow infiltration in Figures 11 and 12 represent a single plausible future out of the many plausible futures generated in Reclamation (2021). These results do not represent a prediction of streamflow infiltration for a given future year.

Where streamflow observation data had a short period of record, calculated recharge for the projection period was sometimes found to deviate significantly from what had been applied in Mason & Hipke (2013). In these cases, gaps in the observed record were filled based on a monthly disaggregation of the annual recharge from streamflow infiltration applied in Mason & Hipke (2013). These values were then added to the observed data during bias-correction.

A potential limitation of this bias-correction method is that the maximum observed mean monthly streamflow cannot be exceeded during the projection period. As a result, a projected increase in mean monthly streamflow could be muted. The potential impact of this limitation is reduced given that streamflow is aggregated to monthly mean. Also, many of the streamgages in the Study area were active during the high precipitation events in 1983 and 1993 which resulted in catastrophic flooding and significant groundwater recharge (Roeske, et al. 1985; House 1993; Mason & Hipke, 2013 RCH file). The method also assumes that the biases present in the historical simulation period are representative of biases in the projected simulation period.

An alternative method of bias-correction that repeats the historic sequencing of flow events is possible. This would entail perturbing the observed streamflow record based on the difference between the historical and projected simulated streamflow. For application to this Study, a reconstruction of the “observed” streamflow record would be necessary, as many streamgages in the Study area have gaps in the period of record. Some methodological uncertainty in the projections of streamflow infiltration is present in these results due to the selection of the quantile-mapping method described above for bias-correction. This uncertainty could be constrained by evaluating the impact on the results based on which method is applied.

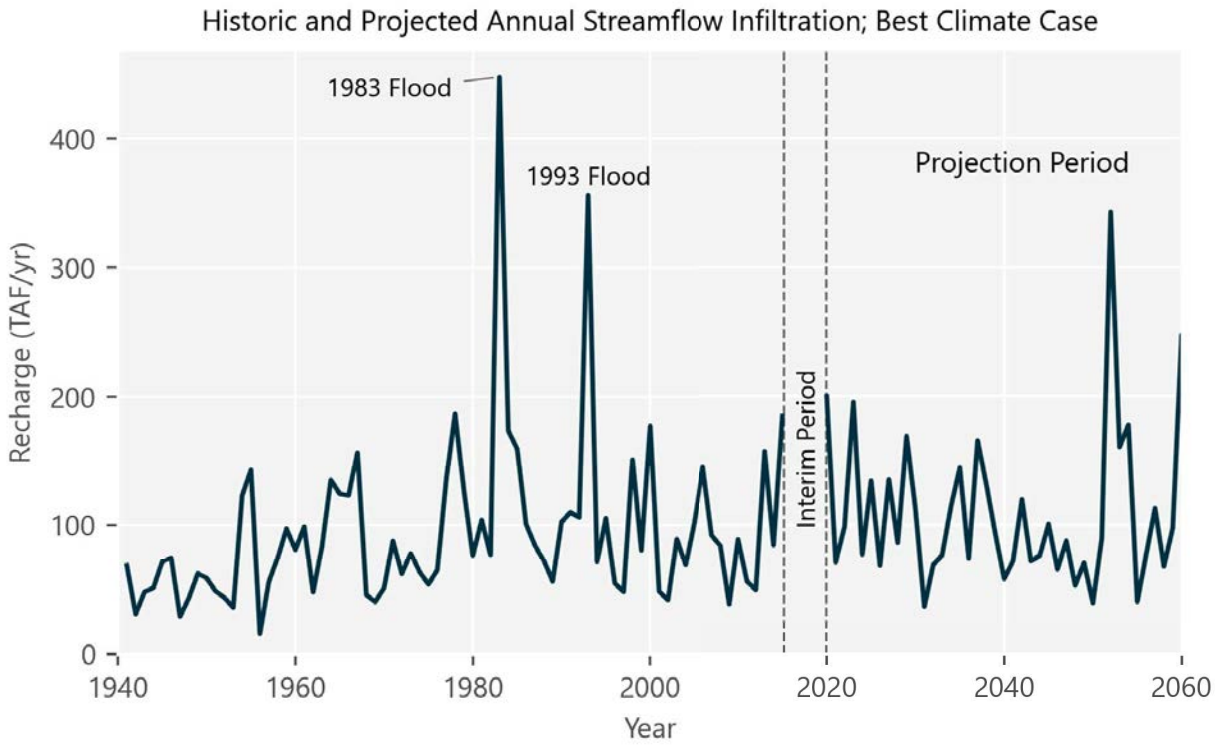


Figure 11. Historic and best-case climate projected annual streamflow infiltration simulated in the TAMA Model.

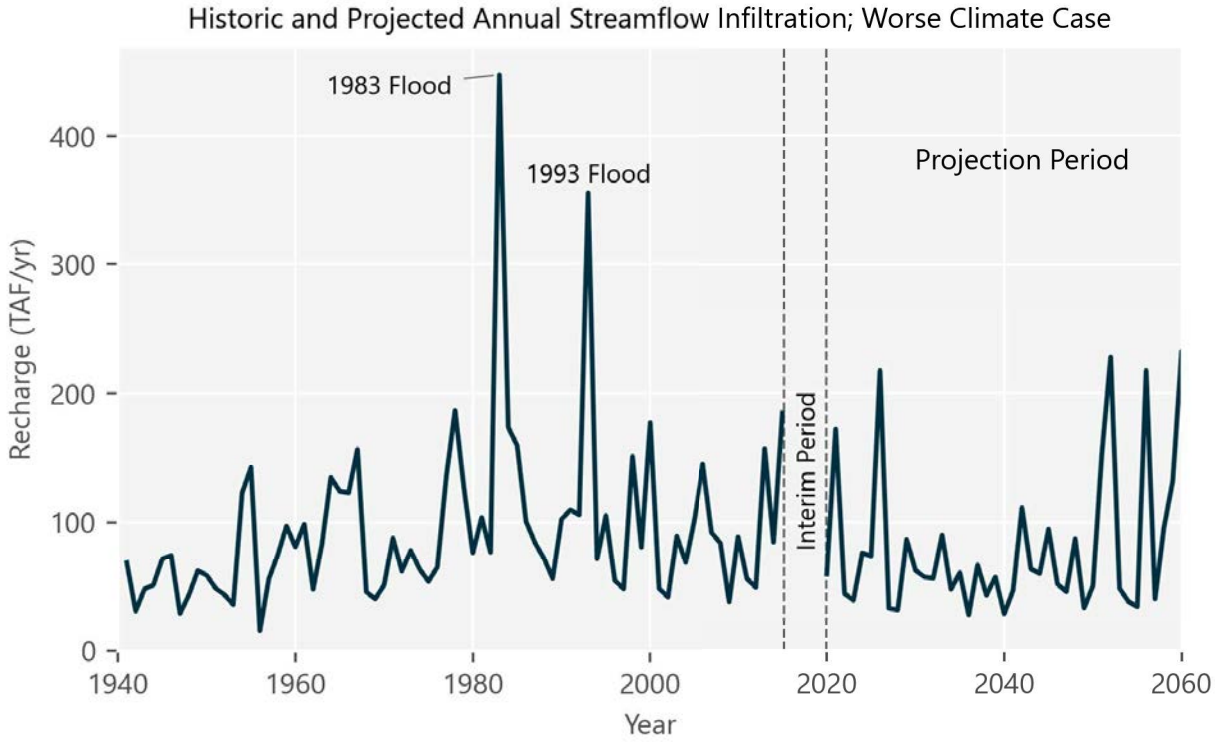


Figure 12. Historic and worse-case climate projected annual streamflow infiltration simulated in the TAMA Model.

The Tres Rios and Agua Nueva water reclamation facilities (WRFs), which are located within the Tucson metropolitan area, discharge reclaimed water to the reach of Santa Cruz River near Tucson (SCR; "Santa Cruz 3" in Figure 8). Above the Cortaro streamgage (Sac-SMA ID: CSC; USGS ID: 09486500; Figure 8), Mason & Hipke (2013) calculate recharge from this reclaimed water separately from natural streamflow. (Details on this processing are discussed below in the *Reclaimed Water Discharge to Santa Cruz River* section of this Technical Memorandum.) Below the Cortaro gage, no distinction is made between natural streamflow and reclaimed water. The Sac-SMA model accounts for this reclaimed water with a constant additional discharge of 53 cfs at the CSC/Cortaro gage (Figure 9). To account for expected future changes in reclaimed water discharged to the SCR, the CSC gage discharge was adjusted based on the reclaimed water remaining in the stream channel that had not infiltrated above the gage.

Equation 1 was applied to the transformed (bias-corrected) version of the projected mean monthly streamflow timeseries to produce estimates of future groundwater recharge from streamflow infiltration. Data from each Sac-SMA gage shown in Figure 10 was processed in turn—starting with the upstream gages and working downward. Recharge was distributed to cells underlying the stream segments by applying Equation 1 on a cell-by-cell basis and routing the remaining flow to the next downstream cell/reach. Where a confluence occurs mid-segment, the outflow of the tributary segment was added during the routing process. Multiple Sac-SMA gages are located outside the TAMA Model domain. In these cases, Equation 1 was applied to the portion of the segment outside the domain first and the remaining flow routed within the model.

Groundwater recharge from streamflow infiltration was processed for each of the 100 Sac-SMA realizations for both the best-case and worse-case climates. Though the groundwater model is capable of producing results for all realizations, a single realization was selected to align with the methodology applied by CAP for the data provided for the Study. The median of the 100 recharge realizations for each climate scenario was selected for use in the modeling analysis. Prior to applying the selected realizations in the TAMA Model, the realizations were inspected to ensure that they exhibited reasonable temporal sequencing compared to the historic period (Figures 11 and 12).

Note that Burkham (1970) did not address recharge along Brawley Wash in Avra Valley and Big Wash in Falcon Valley (locations in Figure 8). Mason & Hipke (2013) developed a time series of streamflow infiltration for Brawley Wash based on limited stream gage data and precipitation; however, documentation on the methodology is limited. For Big Wash, long-term average recharge rates from the previous iteration of the TAMA Model were adjusted based on precipitation data and observed groundwater heads during calibration (Mason & Hipke, 2013). Communication with Dale Mason at ADWR indicated that in future iterations of the model ADWR planned to forgo temporal variation in recharge along Brawley and Big Wash for a long-term mean constant rate as it did not have significant impact on simulated groundwater conditions (ADWR, 2018c).

For this Study, recharge along Brawley and Big Wash was assigned a constant rate through both the interim (2018-2019) and projection periods (2020-2060). Mason & Hipke (2013) developed a relationship between local precipitation data and streamflow to fill gaps in records at several streamgages in these areas. The recharge rates along Brawley and Big Wash were set to the simulated recharge assigned by Mason & Hipke (2013) for the year with median precipitation at

the Cooperative Observation Network (COOP[4]) Anvil Ranch station (ID: USC00020287) over the period 1946-2010. Combined, recharge along Brawley and Big Wash accounts for 2.9 TAF/yr.

Streamflow infiltration was implemented in the TAMA Model using RCH. Maps of mean recharge rates by model cell along stream channels from both natural and reclaimed water sources for each climate scenario are shown in Figures 15 (best-case), 16 (current), and 17 (worse-case). Results from the *Reclaimed Water Discharge to Santa Cruz River* section of this Technical Memorandum contribute to the recharges rate shown in these figures.

2.2.3. Reclaimed Water Discharge to Santa Cruz River

Reclaimed water from WRFs is an important a source of recharge within the Study area. A portion of the reclaimed water within the basin is discharged to the Santa Cruz River (SCR), where it contributes to streamflow infiltration. Most of the remaining reclaimed water is routed to artificial recharge facilities. This section addresses recharge from reclaimed water discharged to the SCR; recharge from reclaimed water routed to artificial recharge facilities is addressed above in the *Artificial Recharge* section of this Technical Memorandum. Note that the managed Santa Cruz Heritage Recharge Project is also discussed in the *Artificial Recharge* section because it is a small, controlled project and is not associated with a WRF.

The Agua Nueva WRF (replacement for the former Roger Road WRF) and Tres Rios WRF (replacement for the former Ina Road WRF) both discharge reclaimed water to the SCR near Tucson (Figure 15). Recharge along the reach of the SCR between the WRFs' respective discharge points and the Cortaro gage ("Santa Cruz 3" in Figure 8) is calculated separately from streamflow infiltration from natural flows. Downstream of the Cortaro gage ("Santa Cruz 4" in Figure 8), recharge from infiltration of natural and reclaimed water flows are calculated jointly.

Mason & Hipke (2013) based initial estimates of recharge above the Cortaro gage on an infiltration study by Galyean (1996); however, details of how the analysis of Galyean (1996) was applied to the TAMA Model are unclear. Galyean (1996) estimated reclaimed water infiltration along the SCR with data collected from 1990 to 1993. At that time reclaimed water was discharged in the SCR from the Roger and Ina Road WRFs. Beginning in 2013, reclaimed water was discharged from the new Agua Nueva and Tres Rios WRFs. Reclaimed water discharge from the older Roger and Ina Road WRFs was of a lower quality and stimulated the development of a biological sealing layer (*schmutzdeche*) along the streambed. This layer reduced infiltration and groundwater recharge from the reclaimed water. With completion of the Agua Nueva and Tres Rios WRFs in 2013, and subsequent decommissioning of the Roger and Ina Road WRFs, the quality of reclaimed water discharged to the SCR increased and no longer stimulates *schmutzdeche* development. This has resulted in a state change in reclaimed water infiltration in the SCR since 2013; therefore, the results of Galyean (1996) are not applicable to the interim (2018-2019) and projection (2020-2060) periods evaluated in this Study.

Instead, recharge from reclaimed water discharged to the SCR from the Agua Nueva and Tres Rios WRFs was estimated using a method provided by the Study Partners that is used for recharge accounting purposes. This method estimates a percentage of the total daily reclaimed water discharge that infiltrates in the SCR above the Cortaro gage (USGS ID: 09486500) on days where no other measurable inflows to the reach occur. A period of record from 2008 to 2018 of

[4] https://climate.usu.edu/mapServer/mapGUI/index.php

daily WRF discharge data was available for this analysis. Days where flow was measured at either Santa Cruz at Tucson (09482500), Rillito at La Cholla (09486055), or Cañada Del Oro (09486350) were eliminated from the analysis. The percentage of reclaimed water infiltrated was then calculated as:

$$\%\ Infiltration = \left(1 - \frac{Daily\ WRF\ Discharge\ to\ SCR - Daily\ Discharge\ at\ Cortaro}{Daily\ WRF\ Discharge\ to\ SCR}\right) \times 100\%$$

According to this analysis, prior to the increase in reclaimed water quality (2008-2012), an estimated 19% of total daily WRF discharge to the SCR infiltrated above the Cortaro gage (n=2147). Following the increase in reclaimed water quality (2013-2018) an estimated 28% of total daily WRF discharge to the SCR infiltrated above the Cortaro gage (n=1828). These results support the assumed state change (increase) in reclaimed water recharge in the SCR when the older Roger and Ina Road WRFs were replaced by the Agua Nueva and Tres Rios WRFs.

The method used to spatially distribute recharge from natural streamflow infiltration over the TAMA Model cells was also applied to distribute recharge from infiltration of reclaimed water (Burkham, 1970; see the *Streamflow Infiltration* section above for more detail). The $C_{per\ mile}$ parameter was calibrated such that 28% of WRF discharged to the SCR infiltrates above the Cortaro gage, as estimated from the available data. The 2008-2018 mean daily WRF discharge to the SCR was used for the calibration. A $C_{per\ mile}$ of 0.288 was found to be satisfactory. Over the projection period of this Study, Equation 1 with a $C_{per\ mile}$ of 0.288 was used to calculate infiltration above the Cortaro gage from Agua Nueva and Tres Rios WRFs discharges to the SCR.

Projections of annual reclaimed water discharge to the SCR from the Agua Nueva and Tres Rios WRFs were provided by CAP (CAP, 2021). Projected annual reclaimed water discharge was disaggregated to monthly values for consistency with projected streamflows from Reclamation (2021). The percentage of annual total discharge in a given month was estimated from daily WRF discharge data (aggregated to monthly) for the period 2008-2018. For the analysis, data for Agua Nueva WRF were combined with data for Roger Road WRF, and data for Tres Rios WRF with data for Ina Road WRF. These monthly percentages were then used to disaggregate the annual total projections provided by CAP to monthly totals.

With the annual projections of WRF discharge to the SCR disaggregated to monthly values and the calibrated $C_{per\ mile}$ (0.288), groundwater recharge above the Cortaro gage was calculated by model cell over the projection period for all S-D scenarios (see Table 1). Recharge from WRF discharge to the SCR during the interim period is included with the streamflow infiltration, discussed above in the *Streamflow Infiltration* section of this Technical Memorandum. Infiltration of WRF discharge to the SCR was implemented in the TAMA Model using RCH. The resulting annual total recharge over the projection period by S-D scenario is presented in Figure 13. Figure 13 indicates that the scenarios tend to group based on demand growth case (e.g., scenarios F and C include rapid/outward demand growth). Note that recharge below the Cortaro gage is incorporated within the natural streamflow recharge calculation.

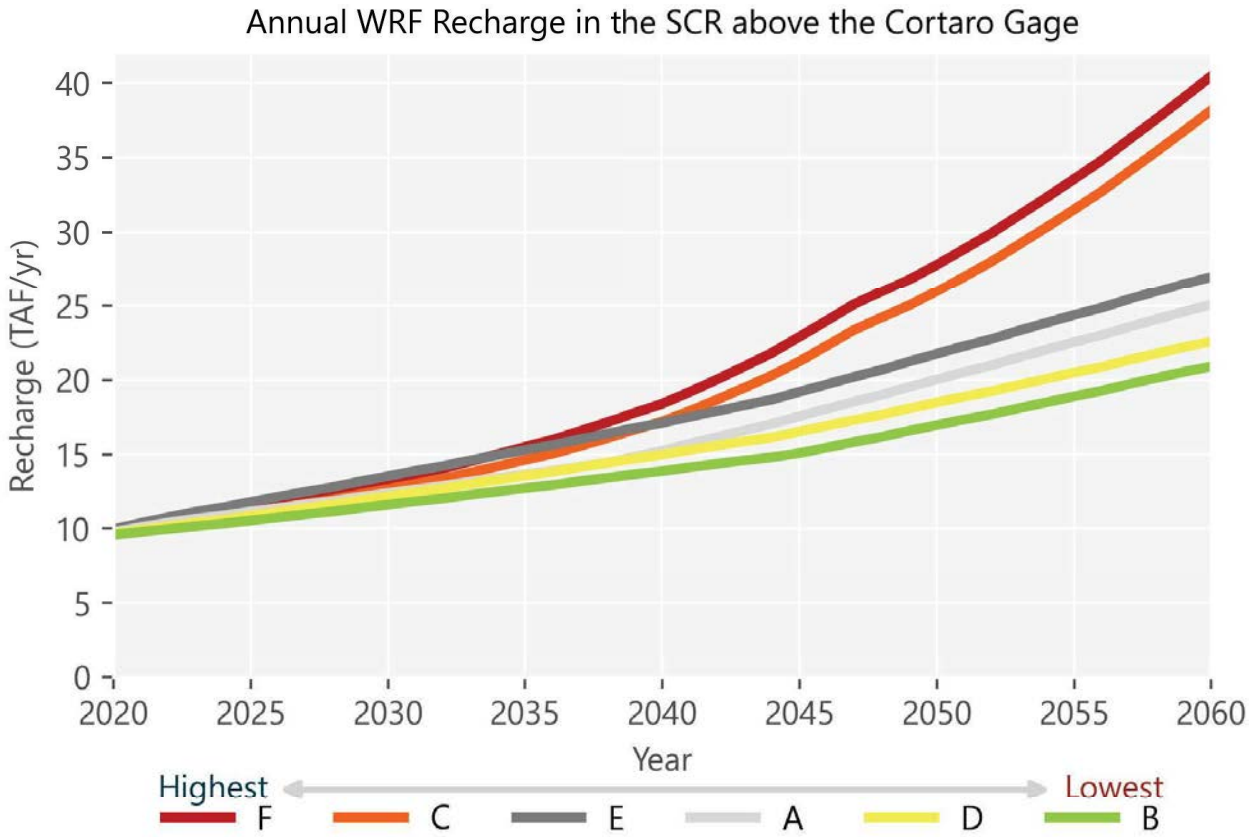


Figure 13. Projected annual groundwater recharge from WRF discharge to the SCR above the Cortaro gage. Note S-D scenarios tend to group based on demand/growth cases case due to similar population growth projections (e.g., F and C are rapid/outward demand growth scenarios).

Combining the recharge from reclaimed water discharge to the SCR above the Cortaro gage (described in this section) and the recharge from natural and reclaimed water streamflow occurring instream channels (described in the *Streamflow Infiltration* section above), yields estimates of total recharge occurring from infiltration along stream channels within the TAMA Model domain. The cumulative sum of annual infiltration along stream channels (from both natural and reclaimed water sources) by S-D scenario is shown in Figure 14. An apparent grouping by climate scenario highlights the impact of climate on recharge along stream channels. This is due to the impact of climate on natural streamflow, which in turn impacts streamflow infiltration, and not due to a significant relationship with demand growth as was seen in Figure 13.

The impact of demand growth on infiltration along stream channels can be seen by comparison of S-D scenarios with identical climate but different demand growth scenarios (e.g., scenario C [orange] vs. B [green]). The magnitude of this difference is markedly smaller than that related to different climate scenarios. The best-case climate is also shown to have more recharge overall than the current climate scenario. This is due to projected increases in natural streamflow above historical rates in some areas of the Sac-SMA model during the projection period (Reclamation, 2021).

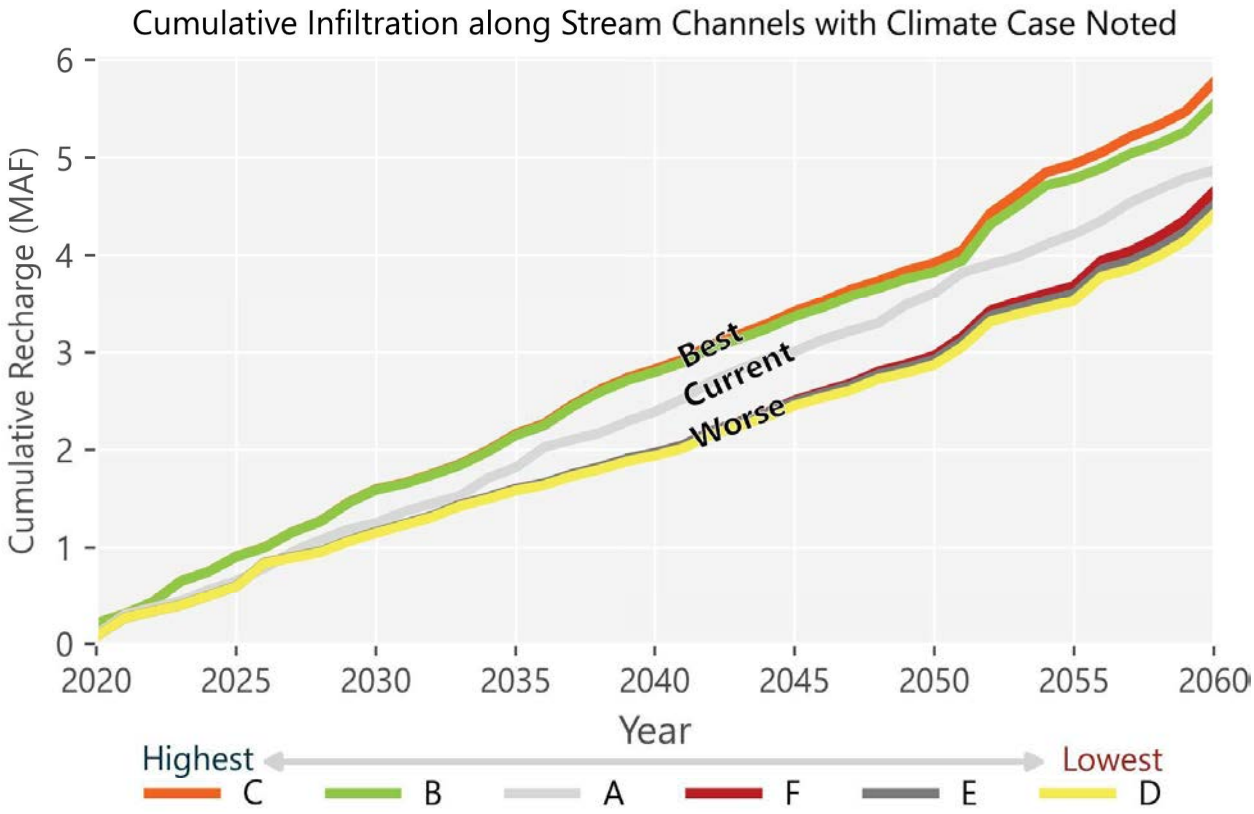


Figure 14. Cumulative sum of annual infiltration along stream channels from natural and reclaimed water sources. Study climate scenario is noted atop the related S-D scenarios.

Maps of average annual recharge rates by model cell along stream channels (from both natural and reclaimed water sources) for each climate scenario are shown in Figures 15 (best-case), 16 (current), and 17 (worse-case). The impact of reclaimed water discharge to the SCR is apparent in all climate scenarios in cells along the stream channel to the northwest of the WRF discharge locations. These figures indicate that most stream channel recharge occurs in the Tanque Verde area, Rillito Creek, and SCR northwest of Tucson.

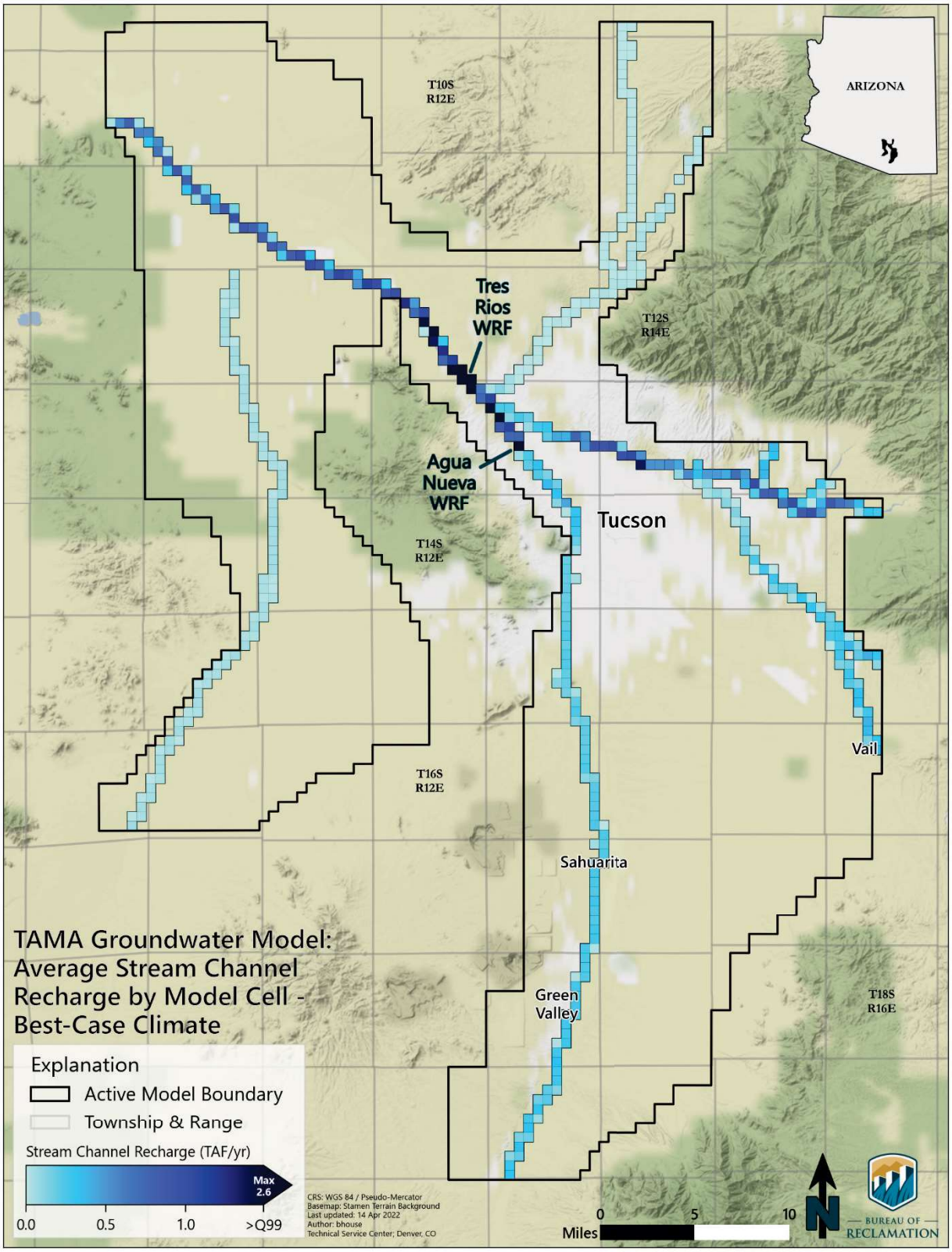


Figure 15. Average annual groundwater recharge from streamflow (both natural and reclaimed water) for the best-case climate S-D scenarios (B and C) over the projection period. For clarity, the maximum value on the color scale was set to the 99th quantile. Figures 15, 16, and 17 share a color scale.

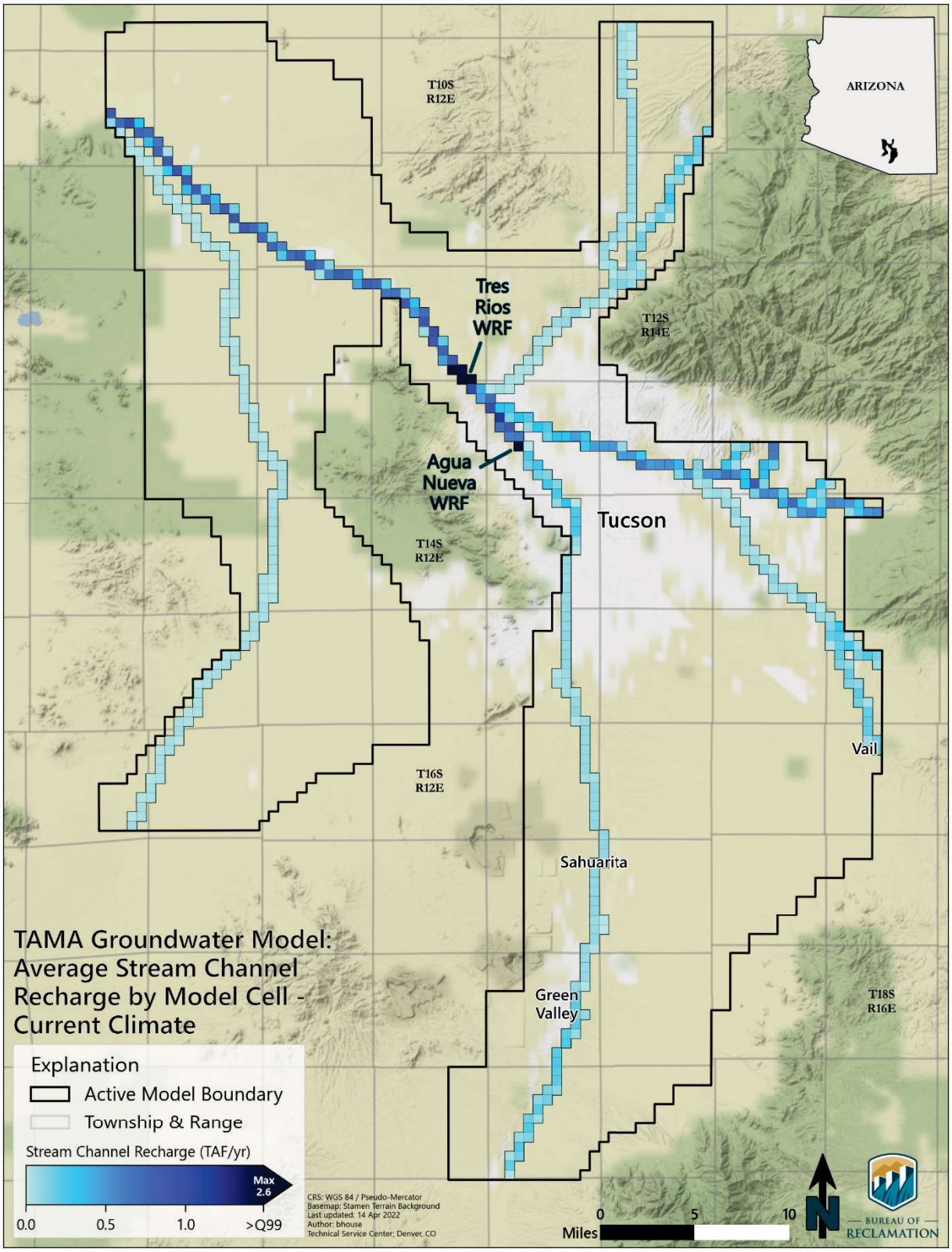


Figure 16. Average annual groundwater recharge from streamflow (both natural and reclaimed water) for the current climate S-D scenario (A) over the projection period. For clarity, the maximum value on the color scale was set to the 99th quantile. Figures 15, 16, and 17 share a color scale.

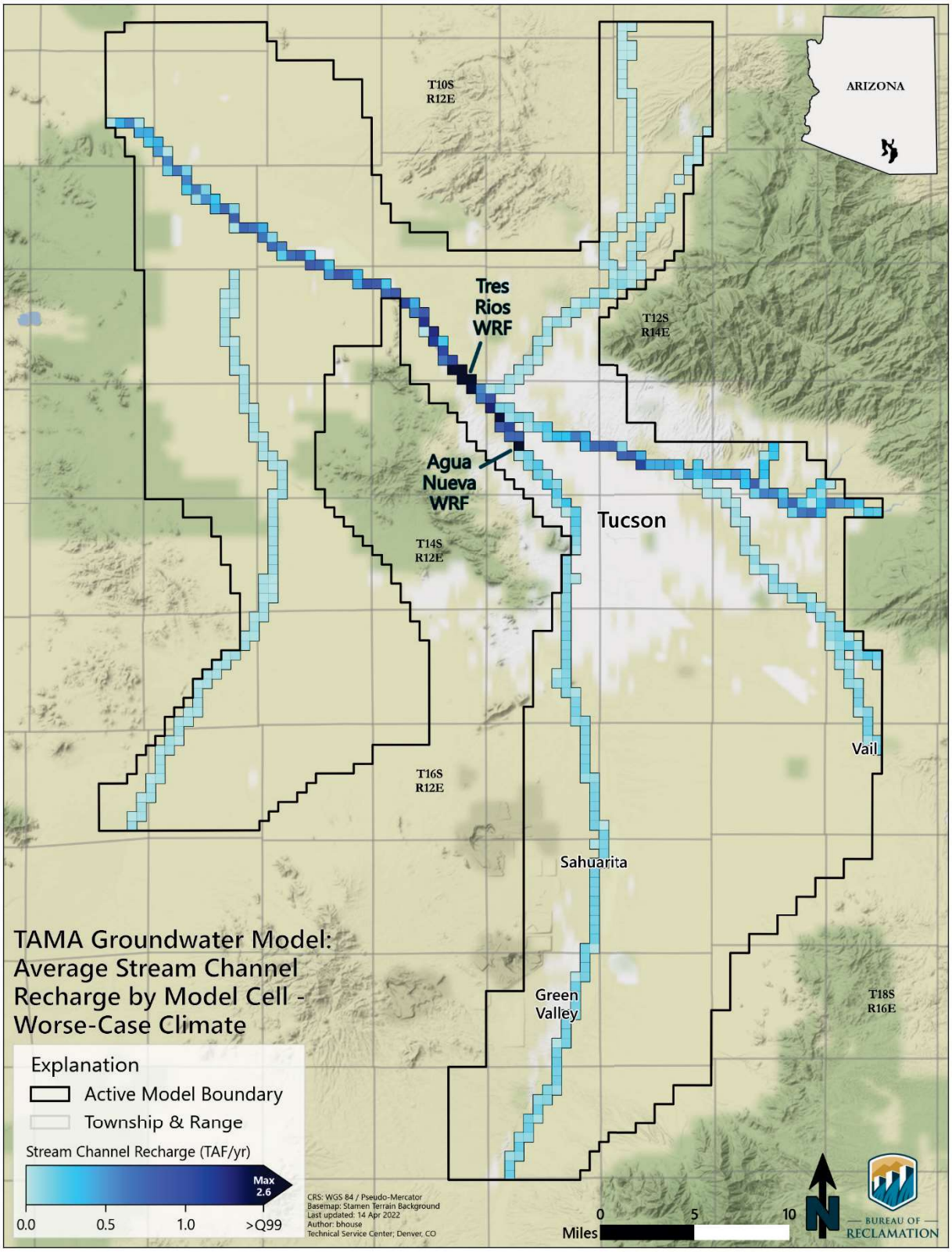


Figure 17. Average annual groundwater recharge from streamflow (both natural and reclaimed water) for the worse-case climate S-D scenarios (D, E, and F) over the projection period. For clarity, the maximum value on the color scale was set to the 99th quantile. Figures 15, 16, and 17 share a color scale.

2.2.4. Mountain Front Recharge

Mountain front recharge is implemented in the RCH. Mountain front recharge for the historical period (1940-2010) was estimated by Mason & Hipke (2013) during model development. Estimated mountain front recharge is spatially and temporally constant over the historical simulation period (Mason & Hipke, 2013). This does not include recharge due to seepage and infiltration from the major streams fed by runoff from the mountains discussed in the *Streamflow Infiltration* section of this Technical Memorandum.

The magnitude and spatial distribution of mountain front recharge are assumed to remain constant over the interim (2018-2019) and projection periods (2020-2060). Mountain front recharge rates for the historical simulation period (1940-2010) were extracted from the RCH input file developed by Mason & Hipke (2013). The RCH input file includes recharge from multiple sources. The location and rates of mountain front recharge were manually compiled using geographic information system (GIS) software and the map of mountain front recharge cells provided in Mason & Hipke (2013, Figure 21). In cells containing both mountain front and streamflow recharge, the mode of the simulated recharge for that cell was used—exploiting the fact that mountain front recharge is constant and during drier years no streamflow recharge occurs. This method resulted in a total of 28 TAF/yr of mountain front recharge with the spatial distribution indicated in Figure 18. This is consistent with what was reported in Mason & Hipke (2013) and was held constant for the interim and projection periods. This assumption is reasonable given its relatively small magnitude compared to other model inflows, it is consistent with the model configuration during calibration, and that changes in recharge from streams emanating from the major drainage basins is accounted for in streamflow infiltration.

2.2.5. Underflow from Adjacent Basins

Groundwater underflow into the TAMA Model domain occurs along the boundaries with SCAMA to the south, Altar Valley to the southwest, and Falcon Valley to the northeast (Figure 18). Underflow from each adjacent basin was estimated by Mason and Hipke (2013) during model development.

Underflows into the TAMA Model from Altar and Falcon Valleys are represented as constant fluxes of 10,200 and 70 acre-feet per year (afy), respectively. Underflow from these basins is implemented using the WEL. The spatial distributions and rates of underflow are held constant during the simulated historic period (1940-2010; Mason & Hipke, 2013). The historic distribution and rates of underflow developed by Mason & Hipke (2013) are also applied for the duration of the interim (2018-2019) and projection periods (2020-2060). This assumption is reasonable given its relatively small magnitude compared to other model inflows and its consistency with the model configuration during calibration,

Underflow into the TAMA Model from SCAMA is represented as a constant groundwater head boundary implemented using the Time-Varying Specified-Head (CHD) Package (Figure 18). The CHD Package allows flow across the boundaries to vary depending on the groundwater gradient between active model cells and constant-head cells. Mason & Hipke (2013) assigned varying values of head based on recent head contours of the area. The varying heads in the CHD allow for representing changes in groundwater heads in SCAMA, near the TAMA-SCAMA boundary. A CHD with an extended period was not available from ADWR.

This Study is focused within the TAMA and does not consider projections of groundwater conditions for adjoining basins. The most recent head values (2010) were held constant for the

duration of the interim (2010-2019) and projection periods. This assumes that groundwater heads in SCAMA near the TAMA-SCAMA boundary remain consistent over the interim and projection periods. Underflow from SCAMA accounts for an average of 16 TAF/yr into the TAMA Model over the projection period. This assumption is reasonable given its relatively small magnitude compared to other model inflows.

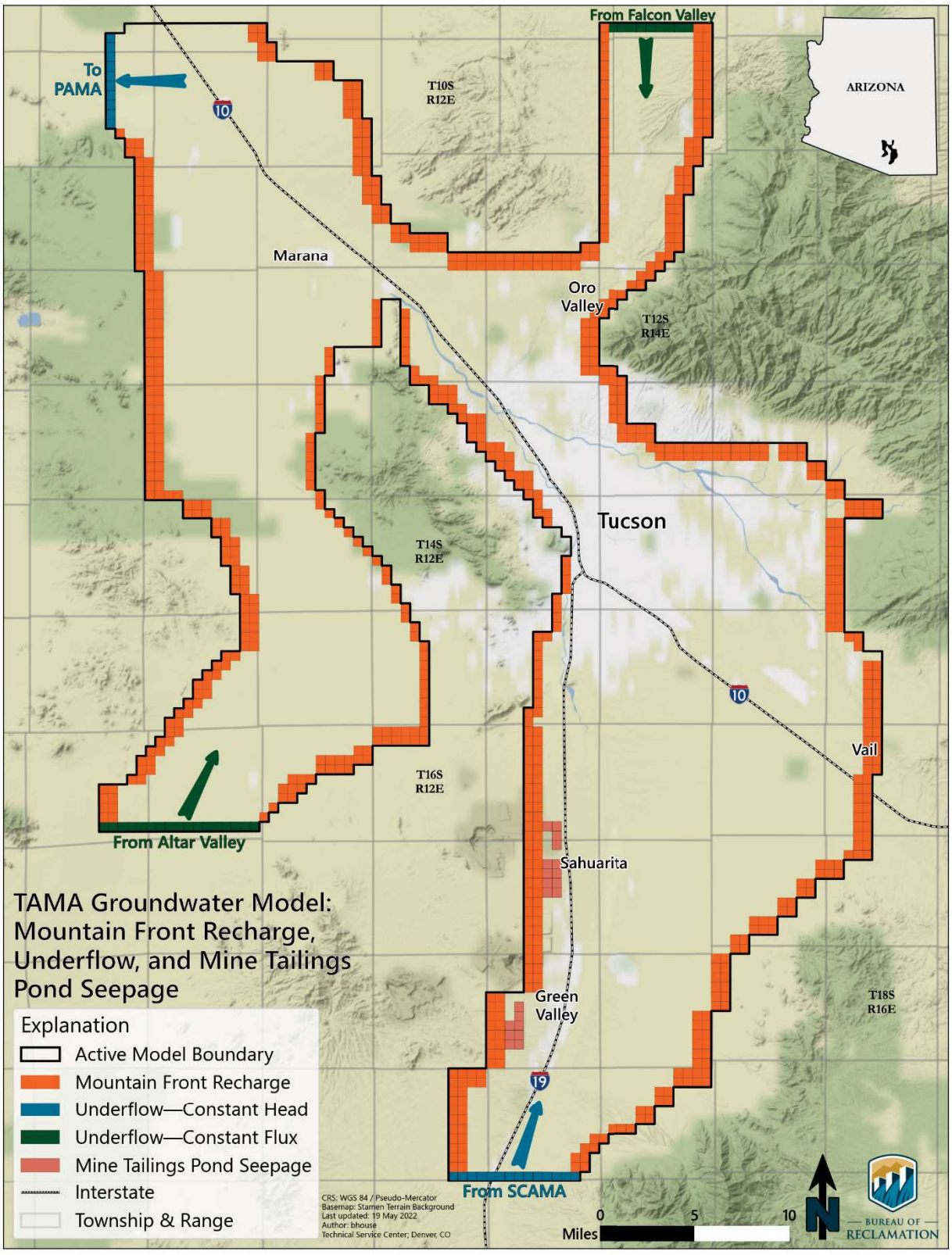


Figure 18. Constant flux and head inflows and outflows to the TAMA groundwater model. These include mountain front recharge, underflow to PAMA, underflow from SCAMA, underflow from Falcon Valley, underflow from Altar Valley, and mine tailings pond seepage.

2.2.6. Agricultural Deep Percolation

Irrigation of agricultural lands results in limited groundwater recharge from deep percolation of irrigation water past the plant root zone. The rate of deep percolation can be calculated based on the total irrigation water demand and irrigation efficiency by:

$$Deep\ Percolation = Total\ Irrigation\ (1 - Irrigation\ Efficiency)$$

In this case, total irrigation water demand is the volume of water used for irrigation, not the plant consumptive use. Based on discussions with the Study Partners and a site visit, a relatively high irrigation efficiency of 0.85 was applied for commercial agriculture and 0.65 for agriculture on tribal lands. Projections of agricultural irrigation water demands were provided by CAP for 2018-2060 in three groups: irrigation districts, irrigation grandfathered rights (IGFR), and irrigation on tribal agricultural lands (CAP, 2021).

CAP projects variations in irrigated acreage within irrigation districts under projected changes in climate and CAP supplies. Irrigated acreage varies with the available water supply, with more land being fallowed in years with lower supply and less in years with higher supply. CAP provided values for "irrigation intensity" by TAMA Model cell and irrigation district as an estimate of the amount of irrigation occurring within a given cell (CAP, 2021).

Projections of total annual agriculture irrigation water demands for four farms/irrigation districts, from 2018-2060, were provided for all S-D scenarios and include: BKW Farms, Cortaro-Marana Irrigation District, Farmers Investment Co., and Kai Avra. (Projections were also provided for Kai Red Rocks; however, these irrigated lands are located outside the TAMA Model domain.) Total deep percolation was subsequently calculated using an irrigation efficiency of 0.85 for all farms/irrigation districts. Deep percolation was then distributed over the TAMA Model cells based on the projected irrigation intensity of the farms/irrigation districts in a given cell. Based on Study Partner input, a constant 500 afy of agricultural demand was also applied at the Bridle Bit Ranch near Marana, AZ. Water is reported to be applied via sprinkler at this location. An irrigation efficiency of 0.7 was applied to this demand.

Projections of total annual agricultural irrigation water demands on tribal lands were also provided by CAP for the San Xavier and Schuk Toak Districts of the Tohono O'odham Nation (CAP, 2021). (Projections were also provided for Pascua Yaqui tribe; however, these irrigated lands are located outside the TAMA Model domain.) Total deep percolation from irrigation of tribal lands was then calculated using an irrigation efficiency of 0.65. Delineation of irrigated fields within the District boundaries was not attempted, and recharge was distributed based on the proportion of the overlapping District area with a given model cell. Only portions of the District located inside the active model domain were considered.

Some groundwater pumping within the TAMA occurs from wells having an IGFR and is assumed to be used for irrigation. Pumping projections for these wells were also provided by CAP (CAP, 2021). An irrigation efficiency of 0.85 was applied to these pumping projections to estimate deep percolation. The location of use was assumed to be near the well site, so recharge was applied to the model cell that the pumping well was located within.

Mason & Hipke (2013) employed an iterative method of temporally lagging the recharge to account for travel times through the vadose zone based on historical depth to groundwater. Sufficient details were not available to reproduce the iterative lagging method for this Study. Instead, the temporal lagging method applied to artificial recharge facilities was applied to recharge from agricultural deep percolation. This lagged the recharge over a three-year period

applying 30% the first year, 40% the second, and 30% the final, third year (Mason & Hipke, 2013).

Total recharge from deep percolation of irrigation from these three sources (farms/irrigation districts, IGFR, and tribal agriculture) varies over S-D scenario from an average of 19.0 TAF/yr under scenario A to 20.3 TAF/yr under scenario D. Figure 19 presents the average spatial distribution of agricultural deep percolation across all S-D scenarios over the projection period. Recharge from agricultural deep percolation was implemented in the TAMA Model using RCH.

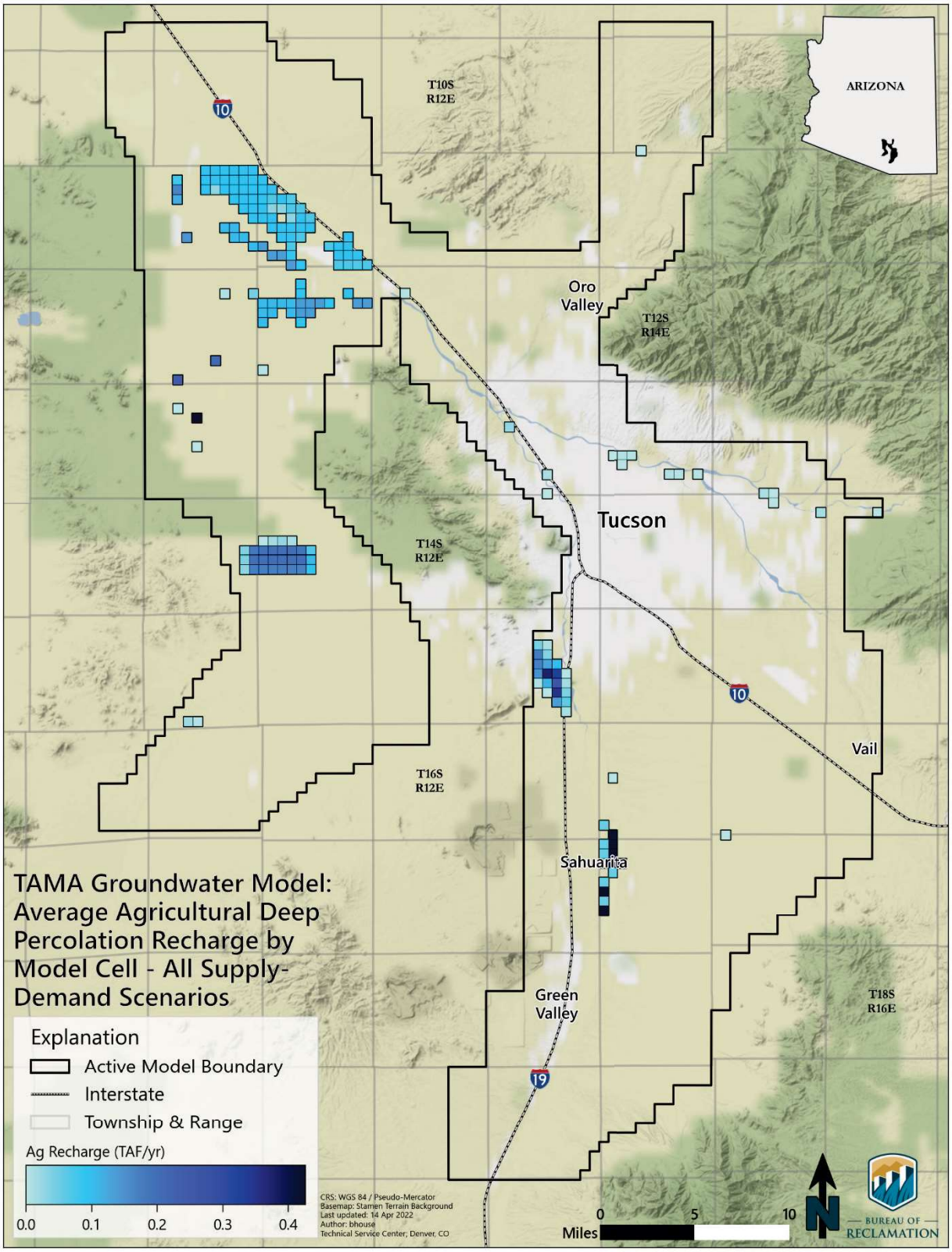


Figure 19. Average annual distribution of recharge from deep percolation of agricultural irrigation averaged over the projection period and S-D scenarios.

2.2.7. Mine Tailings Ponds Seepage

Seepage from mine tailings ponds contributes to groundwater recharge within the TAMA Model domain. This includes seepage from tailings ponds associated with the ASARCO Mission mine near the town of Green Valley and the Freeport-McMoran Sierrita mine near the town of Sahuarita. Seepage from tailings ponds has historically varied with the transitioning of mining operations in the area. Recharge from mine tailings ponds was estimated by Mason and Hipke (2013) during model development and is implemented using RCH. Recharge from tailings ponds over the interim (2018-2019) and projection periods (2020-2060) was assumed to be constant and equal to recharge from tailings ponds during the final year of the historical period. This results in a total of approximately 8 TAF/yr of recharge over the cells indicated in Figure 18.

2.2.8. Summary of Simulated Inflows

Inflows to the TAMA Model over the projection period are summarized in Table 5. Table 5 includes the range of inflows from the various sources across all S-D scenarios and the MODFLOW package that is used to simulate each inflow. The rate columns provide insight into the relative impact of changes to a given source of inflow on the groundwater model results.

Table 5. Summary of groundwater model inflows over the projection period and across all S-D scenarios. Development of each is described in the *Simulated Inflows* section of this Technical Memorandum.

Description	Rate (TAF/yr)			MODFLOW Package	Data Source(s)
	Min	Mean	Max		
Mountain Front Recharge*	-	28	-	RCH	Mason & Hipke (2013)
Underflow	27	28	29	WEL, CHD	Mason & Hipke (2013)
Mine Tailings Pond Seepage*	-	8	-	RCH	Mason & Hipke (2013)
Stream Channel Infiltration	54	121	382	RCH	Reclamation (2021), Mason & Hipke (2013), CAP (2021), Study Partners
Artificial Recharge Facilities	93	177	223	RCH	CAP (2021), Study Partners
Agricultural Deep Percolation	18	20	20	RCH	CAP (2021), Study Partners

*Inflow is constant over the projection period and across all S-D scenarios

The cumulative sum of groundwater inflows under each S-D scenario is shown in Figure 20. The apparent groupings of S-D scenarios in Figure 20 highlights the impact of climate on inflows (see Table 1). Cumulative inflows (recharge) under scenarios A, B, and C (current and best-case climates) are about 1.6 million acre-feet (MAF) greater over the projection period than under scenarios D, E, and F (worse-case climate). Differences between the current and best-case climates and the worse-case climate result in a difference in annual average recharge of about 40 TAF/yr over the projection period.

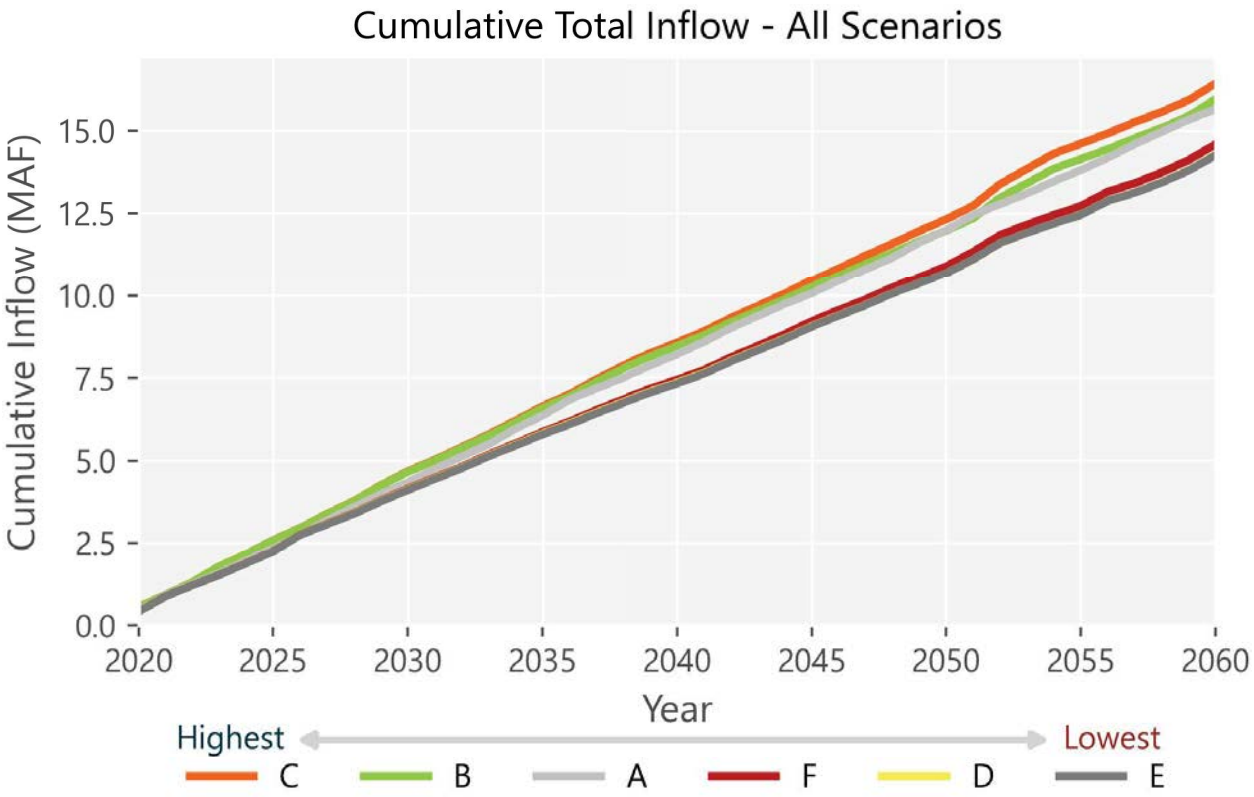


Figure 20. Cumulative sum of total annual simulated inflows to the TAMA groundwater model by S-D scenario.

Comparison of inflow projections between scenarios B and F provides insight into the range of risk to water resources covered by this Study. Scenario B combines the best-case climate with slow/compact demand growth and represents an S-D scenario with a lower risk to water resources; scenario F combines the worse-case climate with rapid/outward demand growth and represents an S-D scenario with a higher risk to water resources.

Recharge projections by source for these two S-D scenarios are shown in Figures 21 and 22. Shaded areas in Figures 21 and 22 represent the annual volume of recharge from a given source. From these figures it is evident that inflows from recharge facilities (violet area) and natural and reclaimed water streamflow infiltration (brown area) account for the majority of total recharge within the TAMA Model domain. The annual variability of streamflow infiltration recharge is also evident in both S-D scenarios (brown area). Annual variability in streamflow infiltration accounts for the majority of annual variability in total recharge. While difficult to observe at the scale of the figures, variability in agricultural deep percolation is present (red area) and has minimal impact on recharge to the TAMA as a whole.

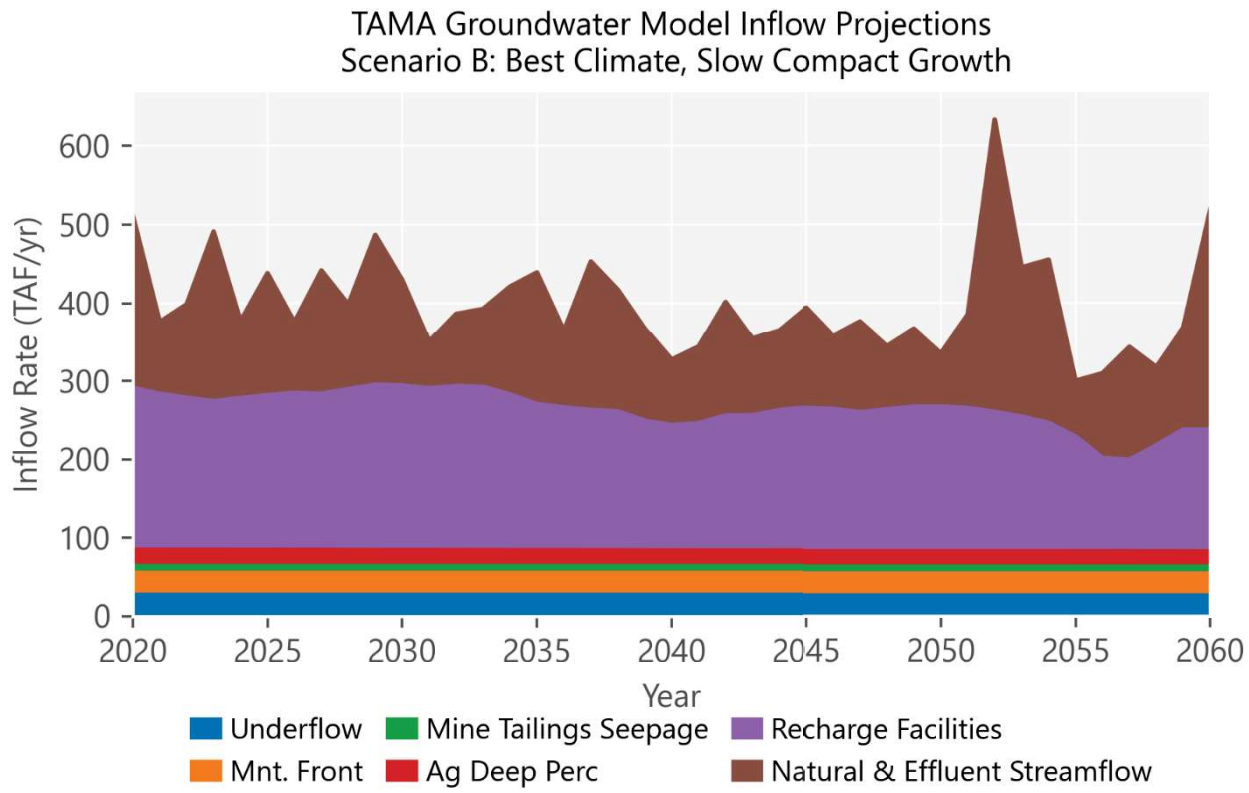


Figure 21. Inflow projections by type for the lower risk S-D scenario (B).

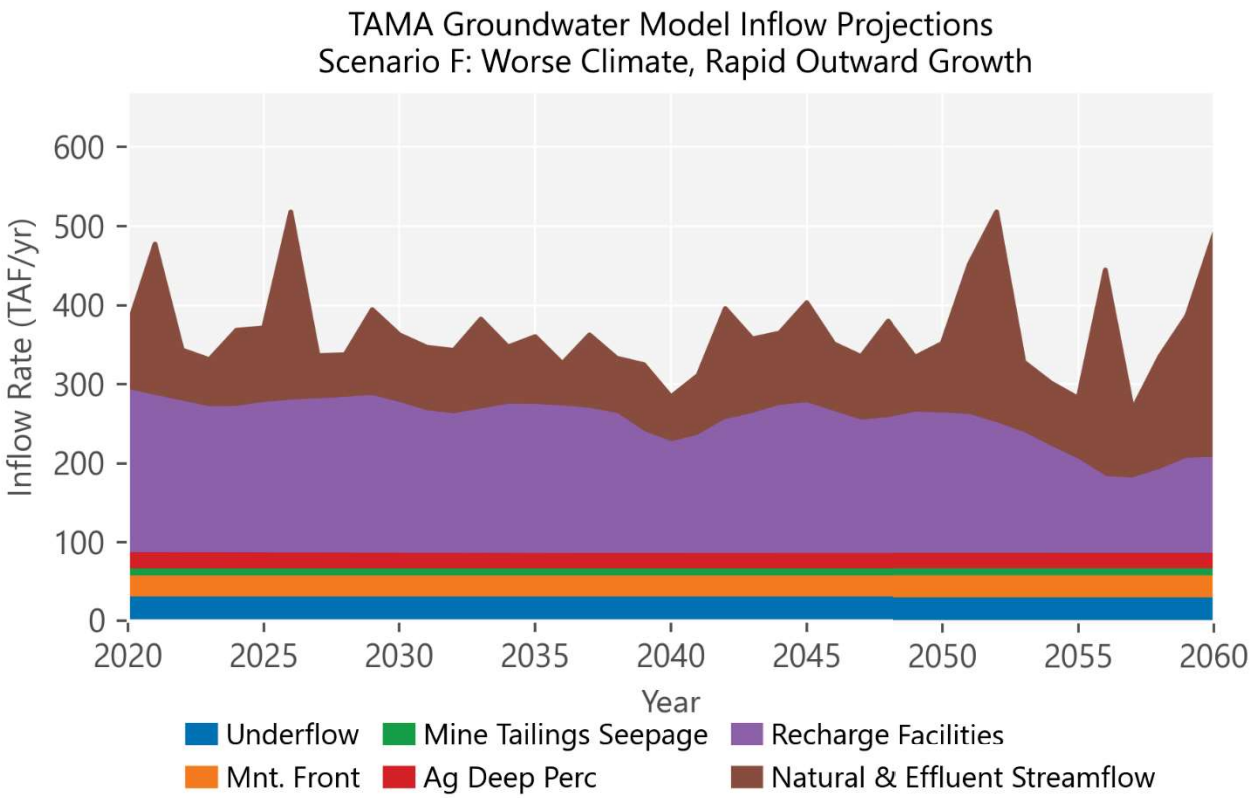


Figure 22. Inflow projections by type for the higher risk S-D scenario (F).

2.3. Simulated Outflows

Simulated outflows from the groundwater model (in order of descending magnitude) occur from: municipal pumping, agricultural pumping, mining pumping, underflow to an adjacent basin, industrial pumping, and evapotranspiration. Each will be discussed below.

2.3.1. Groundwater Pumping

Groundwater pumping constitutes the vast majority of outflow from the TAMA Model. From a low of about 70 TAF/yr in 1940, pumping reached a peak of over 400 TAF/yr in 1975. Pumping subsequently declined to about 280 TAF/yr in 2010—the final year of the simulation by Mason & Hipke (2013). Agricultural, municipal, and industrial uses are the major sectors of pumping, with agricultural pumping having declined significantly since the mid-1970s and municipal pumping steadily rising. Historical pumping was provided by ADWR for 1940-2017 (ADWR, 2019). From 1940 to 1983, pumping rates are informed by limited records and groundwater model calibration. Enactment of Arizona's Groundwater Management Act mandated reporting of annual pumping volumes to ADWR for recording. These reported volumes used by ADWR to assign pumping rates from 1984 to 2017.

Municipal Sector Pumping

Projections of municipal groundwater demands were generated by CAP for all S-D scenarios (CAP, 2021). Staff from local water providers (Study Partners) then distributed these demands to specific groundwater pumping wells. Most of these wells were already constructed, in the ADWR Wells 55 database[5], and assigned to cells in the TAMA Model. In cases where a new well was assigned pumping, a cadastral location was specified by the water provider, and the new well was assumed to be at the center of the finest cadastral discretization provided (e.g., section, sub-section, etc.). Layers were assigned to these new wells by comparison to other nearby wells of similar pumping capacity. Municipal pumping demands over the projection period range from an average of 152 TAF/yr under the slow/compact demand growth case to 184 TAF/yr under the rapid/outward demand growth case.

Agricultural Sector Pumping

Projections of farm/irrigation district agricultural pumping were provided by CAP for all S-D scenarios (CAP, 2021). Projections include pumping to meet water irrigation demands for BKW Farms, Cortaro-Marana Irrigation District, Farmers Investment Company, and Kai Avra. Demands were distributed between wells by CAP based on the historic pumping distribution. Projections of annual pumping demands for agriculture on tribal lands were also provided by CAP (CAP, 2021) for the San Xavier and Schuk Toak Districts of the Tohono O'odham Nation—though CAP does not project any pumping demand for the San Xavier District. (Projections were also provided for Pascua Yaqui tribe; however, these irrigated lands are located outside the TAMA groundwater model domain.) Study Partners did not assign projected agricultural pumping on tribal lands to specific wells; instead, pumping was distributed based on the proportion of the overlapping district area with a given model cell. Irrigated areas outside the TAMA Model domain were not considered. Agricultural pumping demands over the projection period range from an average of 51 TAF/yr under scenario A to 61 TAF/yr under scenario D.

[5] https://gisweb.azwater.gov/waterresourcedata/WellRegistry.aspx

Mining Sector Pumping

For the rapid/outward demand growth S-D scenarios (i.e., scenarios C and F), groundwater pumping associated with mining was increased over the projection period. Projections from CAP do not include mining demands. Instead, projections of mining pumping demands under the rapid/outward demand growth scenario included both an incremental increase of 30% by 2060 from the 2013-2017 mean pumping (or 0.75% per year) and a step increase of 5 TAF/yr starting in 2025 to meet demand for a new mine. Mining pumping demands over the projection period range from an average of 32 TAF/yr under scenarios A, B, D, and E to an average of 38 TAF/yr under scenarios C and F.

Other Pumping

The TAMA boundary does not coincide with the TAMA Model domain (Figure 3). The TAMA Model boundary covers portions of SCAMA to the south and PAMA to the northwest. Projections from CAP are applicable to the TAMA and do not cover pumping in these other areas. CAP projections also do not account for industrial, mining, turf grass, and some municipal demands. Therefore, additional pumping to fill these gaps was necessary for congruency between the historic, interim, and projection periods of the model. Using the 1940-2017 pumping data provided by ADWR, wells that were not included in the CAP projections, but had reported pumping in the previous three years, were assigned their five-year mean pumping for the final two years of the interim period (2018 and 2019) and for the duration of the projection period. Some exceptions were made in cases where all demand for a specific sector or water provider had been accounted for by CAP. This resulted in an additional 64 TAF/yr of pumping applied to the groundwater model over the projection period. Over half of this pumping is associated with mining operations.

Summary of Pumping

Annual groundwater pumping for all sources is shown in Figure 23 for the projection period. For context, the historical simulated pumping is also shown. The rapid/outward demand growth scenarios (C and F) show significant increases over the projection period and, by 2060, reach rates similar to the peak abstraction period of the mid-1970s. All other S-D scenarios suggest only modest rises in pumping demands compared to the historical 1940-1960 period—with the lower risk scenario (B) being approximately constant. None of the projections suggest a decline in groundwater pumping. The average spatial distribution of pumping, summed over model layers, across all S-D scenarios over the projection period is shown in Figure 24. The high pumping rates in Avra Valley near the CAVSARP and SAVSARP facilities indicate recovery of stored CAP water to meet municipal demands. Areas of high pumping demand in the Green Valley area to the south are primarily associated with mining operations.

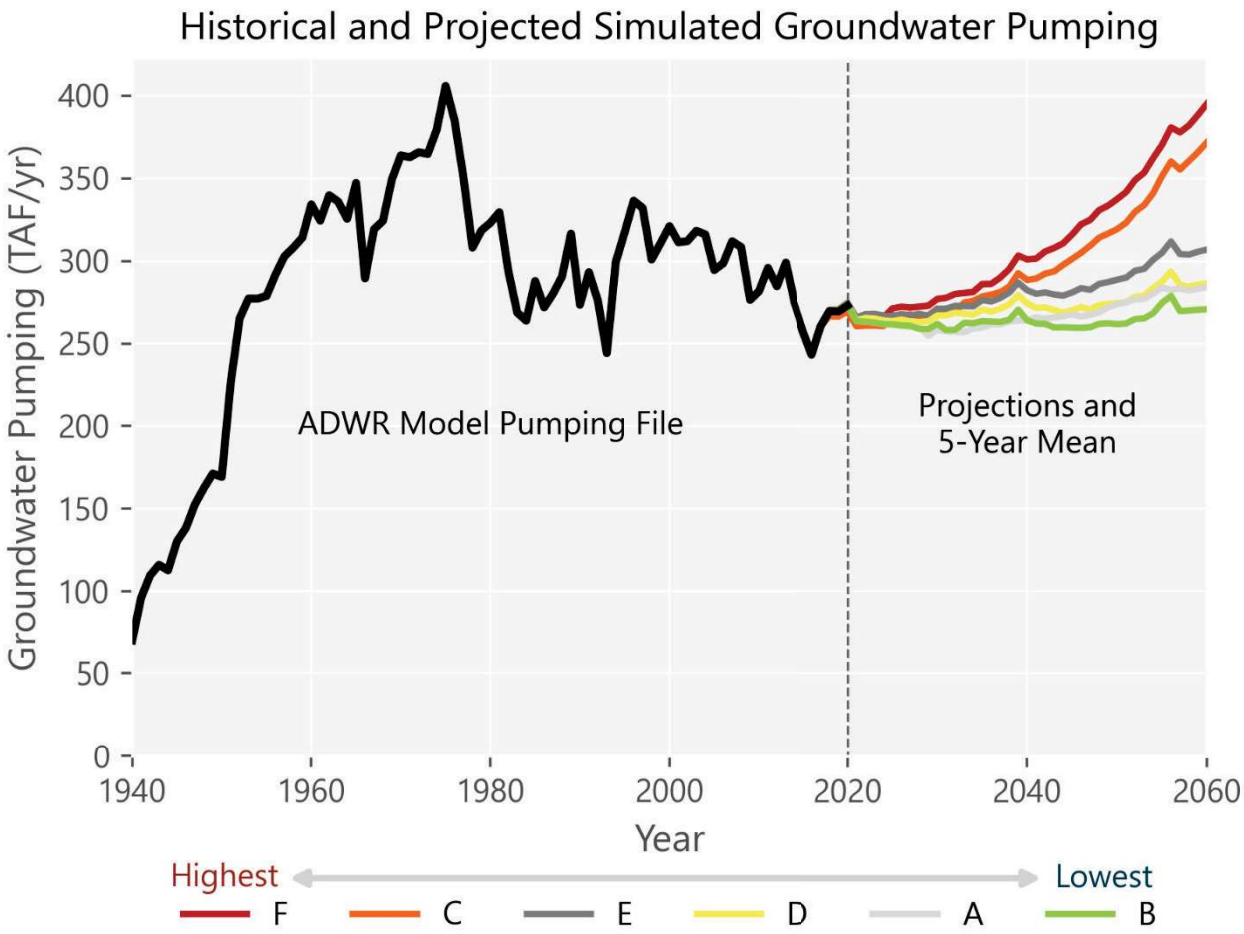


Figure 23. Historical and projected total annual groundwater pumping simulated in the TAMA Model.

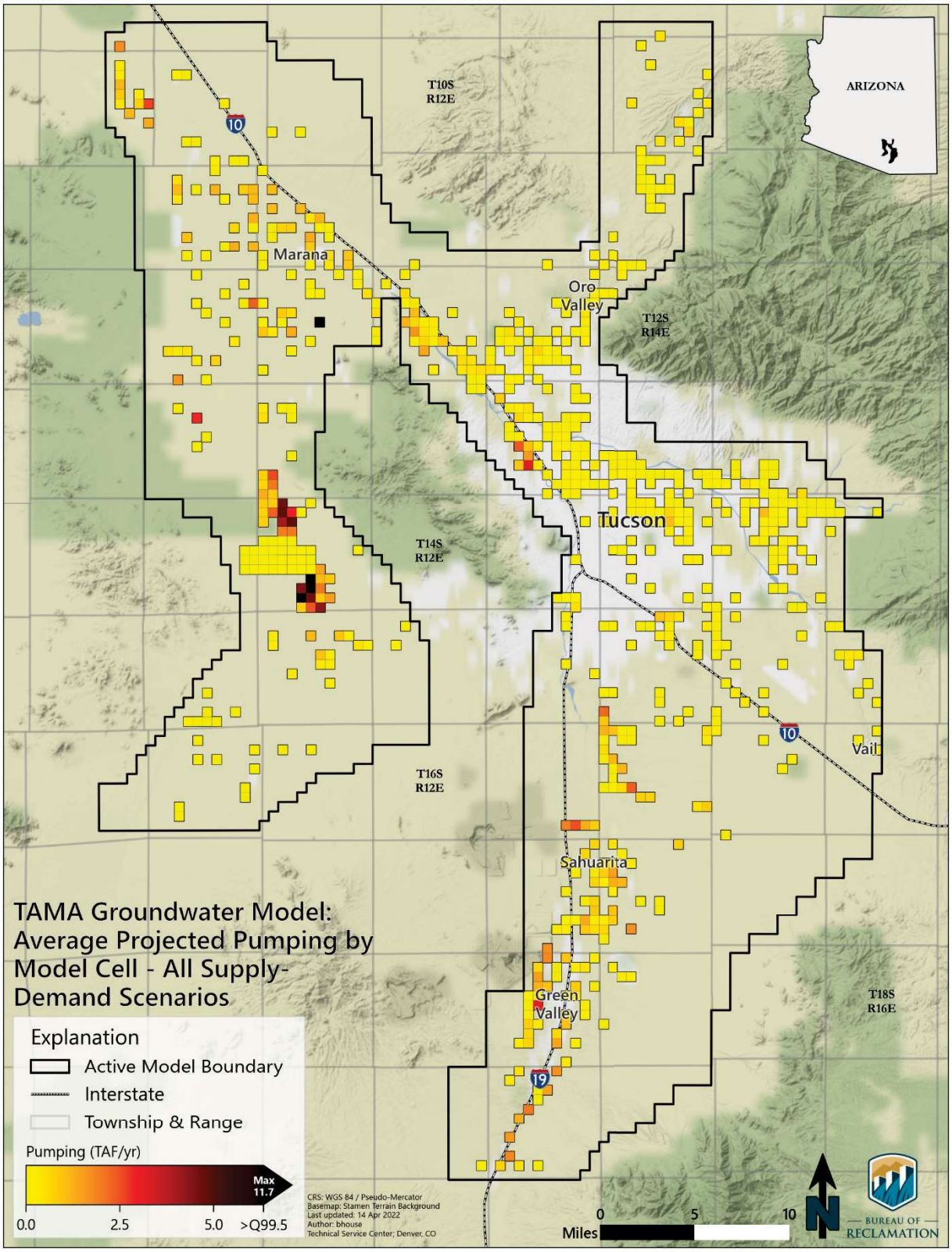


Figure 24. Average groundwater pumping by model cell over the projection period. Simulated pumping has been summed over the model layers. For clarity, the maximum value on the color bar was set to the 99.5th quantile.

Comparison of pumping projections between scenarios B and F provides insight into the range of risk to water resources covered by this Study. Scenario B combines the best-case climate with slow/compact demand growth and represents an S-D scenario with a lower risk to water resources; scenario F combines the worse-case climate with rapid/outward demand growth and represents an S-D scenario with a higher risk to water resources. Pumping projections by sector for these two S-D scenarios are shown in Figures 25 and 26. Shaded areas in Figures 25 and 26 represent the annual volume of groundwater pumping by each sector. Scenario B (Figure 25) maintains an almost constant pumping rate over the projection period, both overall and in within a given sector. Scenario F shows a significant, approximately 50%, increase in pumping. Most of this increase in projected pumping under scenario F is from the municipal sector (green area in Figure 26).

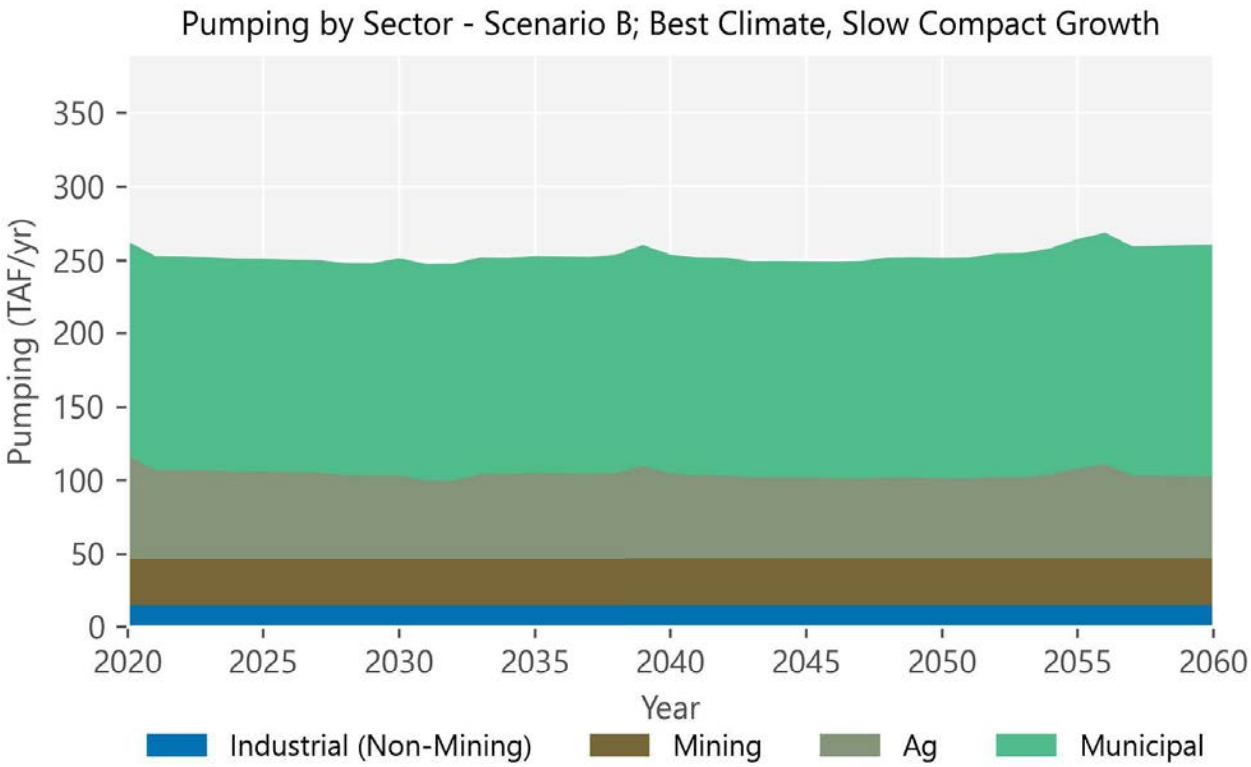


Figure 25. Pumping projections by water use sector for the lower risk S-D scenario (B).

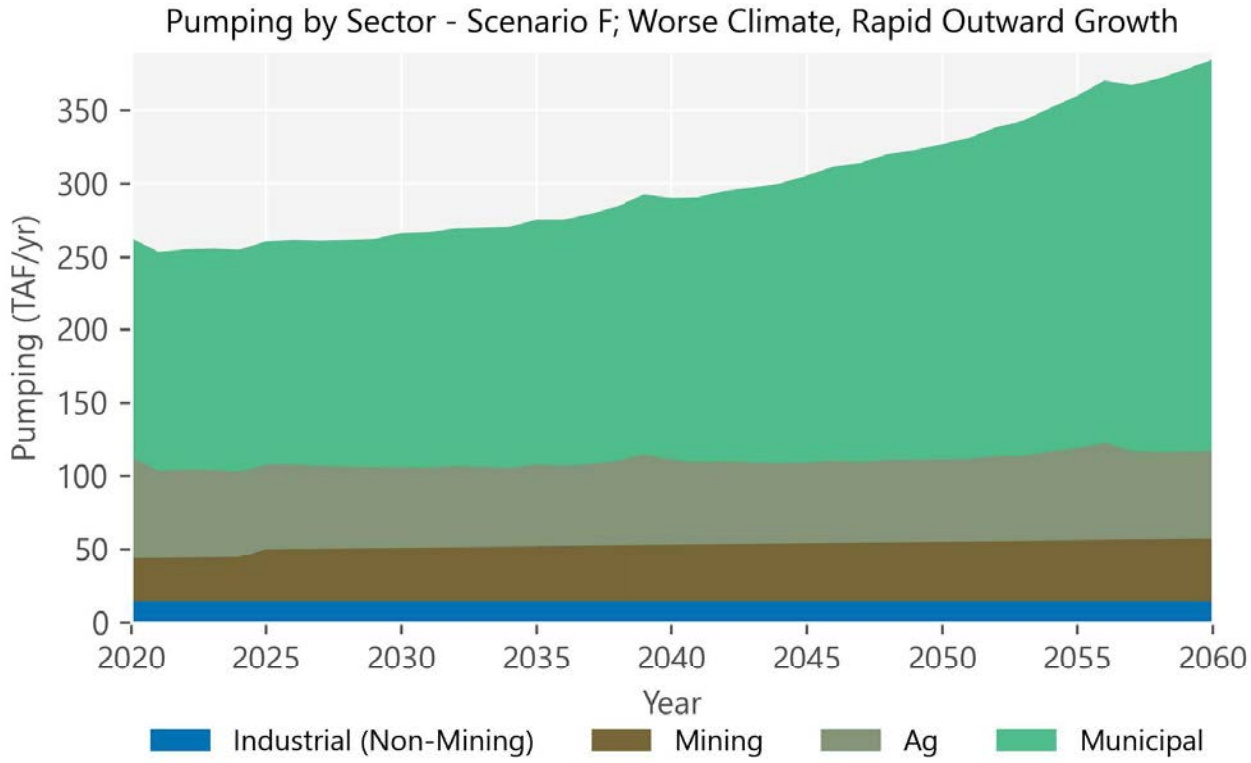


Figure 26. Pumping projections by water use sector for the higher risk S-D scenario (F).

After executing the groundwater model with the pumping projections described above, results indicated that there was insufficient groundwater to meet the applied pumping demands in some model cells. MODFLOW-NWT will automatically reduce groundwater abstraction to prevent model cells from going dry (Niswanger et. al., 2011). Mason & Hipke (2013) reported similar results during the historical modeled period. After discussion with Study Partners, it was decided that a likely course of action if a well were to go dry would be to construct a new, deeper well within a short distance of the existing well. To accomplish this, an iterative process was developed to shift a portion of the unmet pumping demand to a deeper layer and rerun the model.

This process was repeated until a minimum threshold of 10 TAF of total pumping reductions over the model period (1940-2060) was met. Even under the higher risk to water resources demand growth scenario (i.e., scenario F), the total pumping shift to lower layers was approximately 1% of the total applied pumping in a given year. Though the cause of unmet pumping demands may be due to overextraction, it is also possible (especially given the relatively small proportion of total demand) that this was due to limitations in the TAMA Model construction. This is supported by the fact that some unmet pumping also occurs in the historical period when actual pumping rates are applied.

2.3.2. Underflow to Pinal AMA

Underflow from the TAMA Model to PAMA is represented as a constant groundwater head boundary implemented using the Time-Varying Specified-Head (CHD) Package (Figure 18). The CHD Package allows flow across the boundaries to vary depending on the groundwater gradient between active model cells and constant-head cells. Mason & Hipke (2013) assigned varying values of head based on recent head contours of the area. The varying heads in the CHD allow for representing changes in groundwater heads in PAMA, near the TAMA-PAMA boundary.

A CHD with an extended period was not available from ADWR. This Study is focused within the TAMA and does not consider projections of groundwater conditions for adjoining basins. The most recent head values (2010) were held constant for the duration of the interim (2010-2019) and projection periods. This assumes that groundwater heads in PAMA near the TAMA-PAMA boundary remain consistent over the interim and projection periods. Underflow to PAMA accounts for an average of 20 TAF/yr out of the TAMA Model over the projection period.

2.3.3. Evapotranspiration

Evapotranspiration was included in Mason & Hipke (2013) along stream reaches where riparian vegetation is present. It is represented in the TAMA Model using the MODFLOW Evapotranspiration package (EVT). The input parameters are spatially and temporally constant over the historical simulation period. The locations and input parameters for the interim (2010-2019) and projection periods were unaltered from Mason & Hipke (2013) and held constant. In generally, evapotranspiration represents a minor portion of the overall groundwater budget and accounts for an average 4 TAF/yr over the projection period and all S-D scenarios.

2.3.4. Summary of Simulated Outflows

Outflows from the TAMA Model over the projection period are summarized in Table 6. Table 6 includes the range of outflows from the various sources across all S-D scenarios and the MODFLOW package that is used to simulate each outflow. The rate columns provide insight

into the relative impact that changes to a given source of outflow have on the groundwater model results. Pumping across all sectors accounts for an average of 92% of total outflows simulated from the TAMA Model over the projection period and across all S-D scenarios.

Table 6. Summary of groundwater model outflows over the projection period and across all S-D scenarios. Development of each is described in the *Simulated Outflows* section of this Technical Memorandum.

Description	Rate (TAF/yr)			MODFLOW Package	Data Source(s)
	Min	Mean	Max		
Evapotranspiration	0.4	4	16	EVT	Mason & Hipke (2013)
Underflow	17	20	26	CHD	Mason & Hipke (2013)
Pumping – Municipal	145	166	268	WEL	Mason & Hipke (2013), CAP (2021), Study Partners
Pumping – Ag	47	57	70	WEL	Mason & Hipke (2013), CAP (2021)
Pumping – Mining	29	34	46	WEL	Mason & Hipke (2013), Study Partners
Pumping – Industrial (Non-Mining)*	-	13	-	WEL	Mason & Hipke (2013)

*Outflow is constant over the projection period and across all S-D scenarios

3. Supply-Demand Scenario Results

Predictive groundwater model runs were performed for each S-D scenario over the projection period using the TAMA Model (2020-2060; Table 1). Each S-D scenario was simulated by modifying model inputs to reflect projected changes in groundwater inflows and outflows as detailed above in the *Groundwater Model Updates* section of this Technical Memorandum (Section 2). Model results were evaluated to assess projected changes in groundwater heads and groundwater storage. Projected changes in groundwater heads and storage under future S-D scenarios are discussed below in Section 3.1. Results are then compared between S-D scenarios to analyze risk to water resources (Section 3.2), impacts of climate (Section 3.3), and impacts of demand growth (Section 3.4). Impacts of climate and demand growth are then compared in Section 3.5.

3.1. All Supply-Demand Scenarios

The LSCR Basin (TAMA) was in a state of overdraft throughout most of the historical period due to rising groundwater pumping and little augmentation from artificial recharge. Overdraft led to significant declines in groundwater heads and storage resulting in a cumulative groundwater storage deficit over 7 million acre-feet (MAF) by 2004 within the LSCR Basin. Implementation of artificial recharge projects and reductions in groundwater pumping allowed groundwater heads and storage to begin rebounding by the mid-2000s. By the end of the interim period (2019), groundwater storage had rebounded by more than 0.7 MAF, leaving about a 6.3 MAF deficit in storage since pre-development (Figure 27).

Simulated changes in groundwater storage over the projection period under each S-D scenario are shown in the right portion of Figure 27. Projected changes in groundwater storage exhibit a general grouping by climate scenario. Groundwater storage increases for all S-D scenarios through the end of 2030s. By 2060 scenarios A, B, and C (current and best-case climates) result in a notably greater increase in groundwater storage than scenarios D, E, and F (worse-case climate). Differences in demand growth are projected to have a larger impact during the later portion of the projection period. This is apparent from the separation between scenarios D, E, and F beginning around 2040 (Figure 27).

Under the higher risk to water resources S-D scenario (i.e., scenario F), approximately 0.9 MAF of groundwater storage replenishment occurs by the end of the projection period. While this higher risk S-D scenario is generally in overdraft for the final 10-years of the projection period, all other S-D scenarios are generally in surplus (Figure 27). This result suggests that under the range of water supply and demand growth considered in the S-D scenarios, the LSCR Basin as a whole has increasing groundwater storage throughout the projection period. However, this result does not mean that groundwater storage increases in all areas of the LSCR Basin; some areas exhibit declines in groundwater heads and storage while others experience increases.

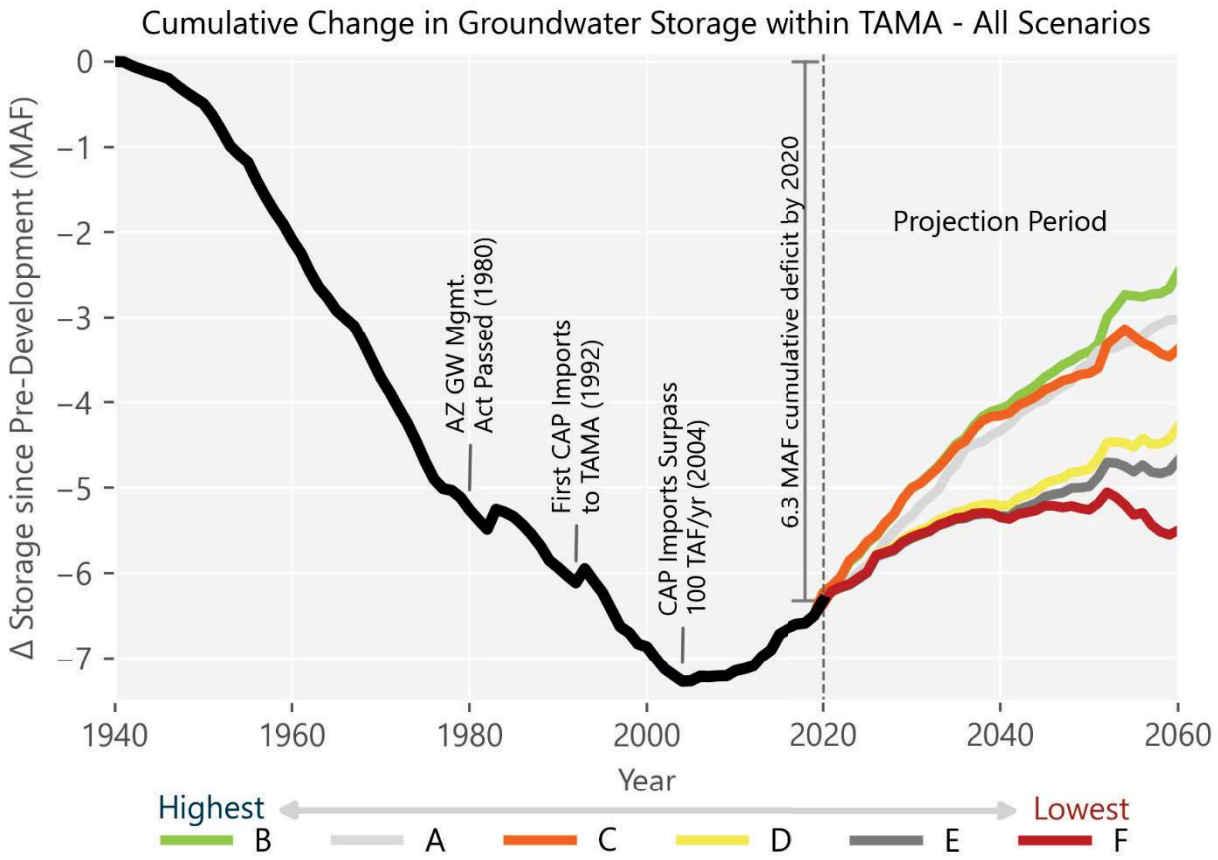


Figure 27. Simulated cumulative change in groundwater storage within the TAMA Model since pre-development (1940). Historical period is in black with results from S-D scenarios branching out at the start of the projection period (2020).

Maps of the simulated change in the groundwater table over the projection period—i.e., the difference in water table elevation between 2060 and 2020—provide insight into the spatial distribution of projected changes in groundwater heads and storage. Total hydraulic head of groundwater is a combination of both pressure from the weight of the water and the elevation of the water. For this Study, groundwater head can generally be considered to be the elevation of the water table. The spatial distribution of projected changes in groundwater heads under each S-D scenario is presented in Figure 28. The color scale is the same across all panels in Figure 28, with blue areas indicating an increase in groundwater levels and red areas indicating a decrease. Detailed, full-page maps of simulated change in groundwater head over the projection period for each S-D scenario are also included in Appendix B.

All panels of Figure 28 show blue shading near and along the Santa Cruz River (SCR) northwest of the Tucson metropolitan area, indicating rising groundwater levels in this portion of the LSCR Basin under all S-D scenarios. This is a result of increased infiltration of reclaimed water. Darker blue under scenarios B and C, compared to scenarios D, E, and F, represents the projected increases in streamflow in the Tanque Verde and Rillito Creek area under the best-case climate (Reclamation, 2021). Figure 28 also shows continued propagation of the mounds created by the recharge of CAP water at the CAVSARP and SAVSARP facilities in Avra Valley under all S-D scenarios. Consistent areas of rising groundwater levels under all S-D scenarios related to new recharge facilities are also depicted. Three new facilities (two of which have now begun

operation) are included in the projections with: SHARP to the east, Project RENEWS in the Green Valley area, and the Santa Cruz Heritage Project in southwest Tucson (locations of these facilities are noted in Figure 7). Recharge of reclaimed water from the Green Valley WRF also contributes to the rise in the Green Valley area across all scenarios.

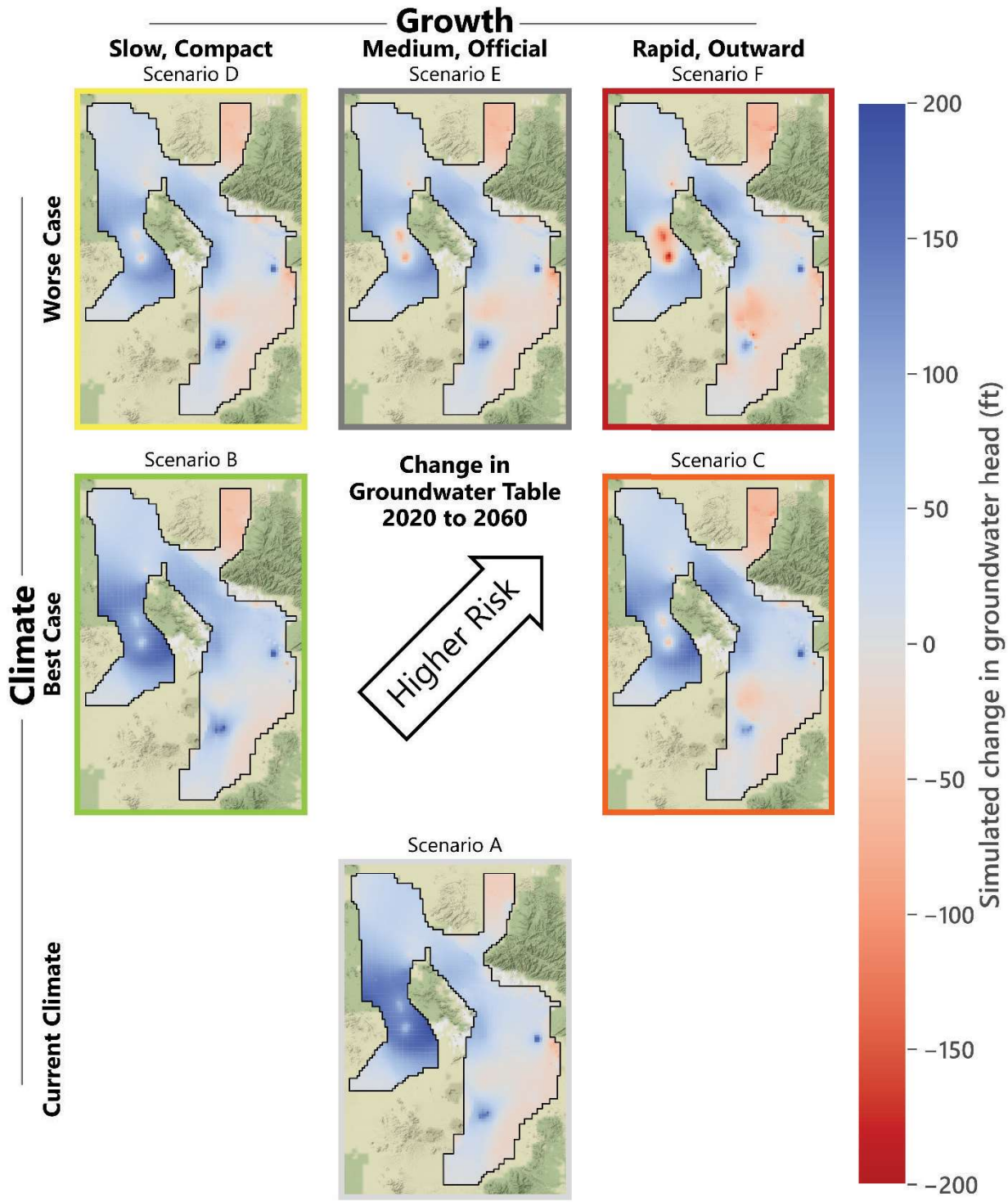


Figure 28. Change in simulated groundwater head by model cell over the projection period for each S-D scenario. Maps are positioned in the layout of Table 1. Color scale is shared between all maps.

3.2. Range of Risk to Water Resources

Of the S-D scenarios included in the Study, B has a lower risk to water resources and F has a higher risk. Comparison of these S-D scenarios provides insight into the range of future conditions considered in this Study. Figure 29 shows the simplified groundwater budgets and the annual change in groundwater storage for scenarios B and F. For simplicity, only major sources of recharge (all except underflow) and pumping (as on average it represents 92% of the total outflow from the model) are included in these figures. The yellow lines in the first and third panels of Figure 29 show annual recharge (inflow) to the TAMA Model and the blue lines show annual groundwater pumping (outflow) from the TAMA Model. When inflows exceed outflows, there is a surplus and water is added to groundwater storage (blue shaded area in second and fourth panels). When outflows exceed inflows, there is an overdraft and water is removed from groundwater storage (red shaded area of second and fourth panels).

For scenario B, pumping (blue line) is consistently less than recharge (yellow line) over the projection period, resulting in a consistent surplus (Figure 29). Under this scenario, overdraft only occurs during two years (2055-2056) when both streamflow infiltration and artificial recharge decline simultaneously, due to concurrent low streamflows and deeper CAP water shortages (Figure 21). Under scenario F, the steady increase in demand over the projection period results in pumping exceeding recharge by the last third of the projection period (Figure 29). Pumping in excess of recharge results in multiple years of overdraft, particularly towards the end of the projection period. However, during high streamflow years under the worse-case climate (2056, 2060), natural recharge exceeds these increased demands and results in surplus.

These results highlight the uncertainty in the range of plausible futures resulting from the Study, as well as the success of the historic water supply planning measures undertaken within the LSCR Basin. Even under the higher risk S-D scenario of this Study, projected annual overdraft is consistently less than historic overdraft, except for a few years during the last portion of the projection period.

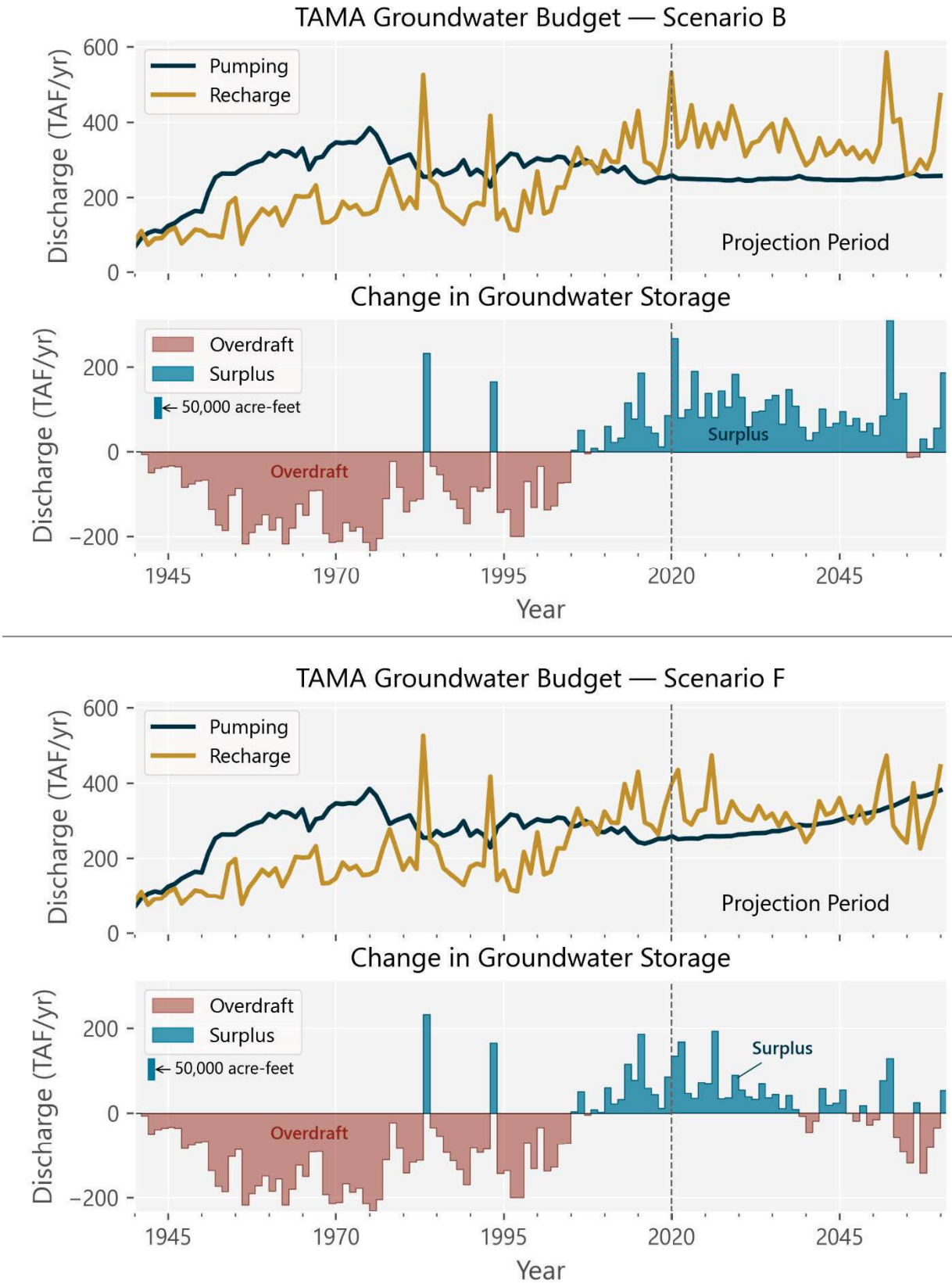


Figure 29. Simplified groundwater budget and change in storage for scenarios B (lower risk) and F (higher risk). Shaded areas (blue and red) are proportional to the volume of groundwater storage change (the area for 50,000 acre-feet is noted by the legend in blue).

In order to understand risk to water resources and identify effective adaptation strategies, it is important to consider the spatial distribution of changes in groundwater heads and storage. Figure 30 shows a map of the projected change in groundwater head over the projection period (2020-2060) under scenario F. Scenario F represents the S-D scenario with a higher risk to water resources considered in this Study and is expected to require the most adaptation. Areas of notable declines are labelled 1 to 5 in Figure 30. Each area is discussed below.

Area 1 in Figure 30 shows substantial declines in the groundwater table in the Cañada del Oro/Saddlebrook area, northeast of Oro Valley. Substantial declines result from the projected increase in pumping demand of about 50% by the end of the projection period combined with limited and intermittent recharge in this area.

The groundwater table in the Sabino Canyon and Tanque Verde area (Area 2) is also projected to decline slightly due to projected reductions in natural streamflow and corresponding streamflow infiltration. While small in magnitude, this decline is important because this location contains many of the LSCR Basin's remaining riparian areas. Riparian areas support habitat for a wide variety of plants and animals and provide recreational and aesthetic values.

Area 3 in Figure 30 shows groundwater table declines in southeast Tucson. Declines in this area are largely driven by projected reductions in natural streamflow and increases in pumping demand for municipal supply. While the SHARP artificial recharge facility is projected to provide some additional recharge (facility location is shown in Figure 7), simulated recharge from SHARP does not propagate much to the southeast to offset the impacts of increased pumping and declining recharge.

Area 4 shows groundwater table declines in the Green Valley/Sahuarita area south of Tucson. Under scenario F, mining pumping is projected to increase in this area and recharge at the Pima Mine Road USF is projected to decrease due to reductions in available CAP supplies (facility location is shown in Figure 7). Natural streamflow in this area is also projected to decline during the initial 30 years of the projection period, followed by some recovery during the last 10 years. These factors combine to result in broad declines throughout the Green Valley/Sahuarita area.

Finally, Area 5 in Figure 30 shows substantial groundwater table declines in Avra Valley near the CAVSARP and SAVSARP facilities (facility locations are shown in Figure 7). These declines are a result of recovery of previously stored water from the CAVSARP and SAVSARP facilities. This area does not require adaptation as it is a result the facilities functioning as intended—water stored in the ground for later recovery. It does, however, indicate a projected decline in the stored groundwater available for future recovery.

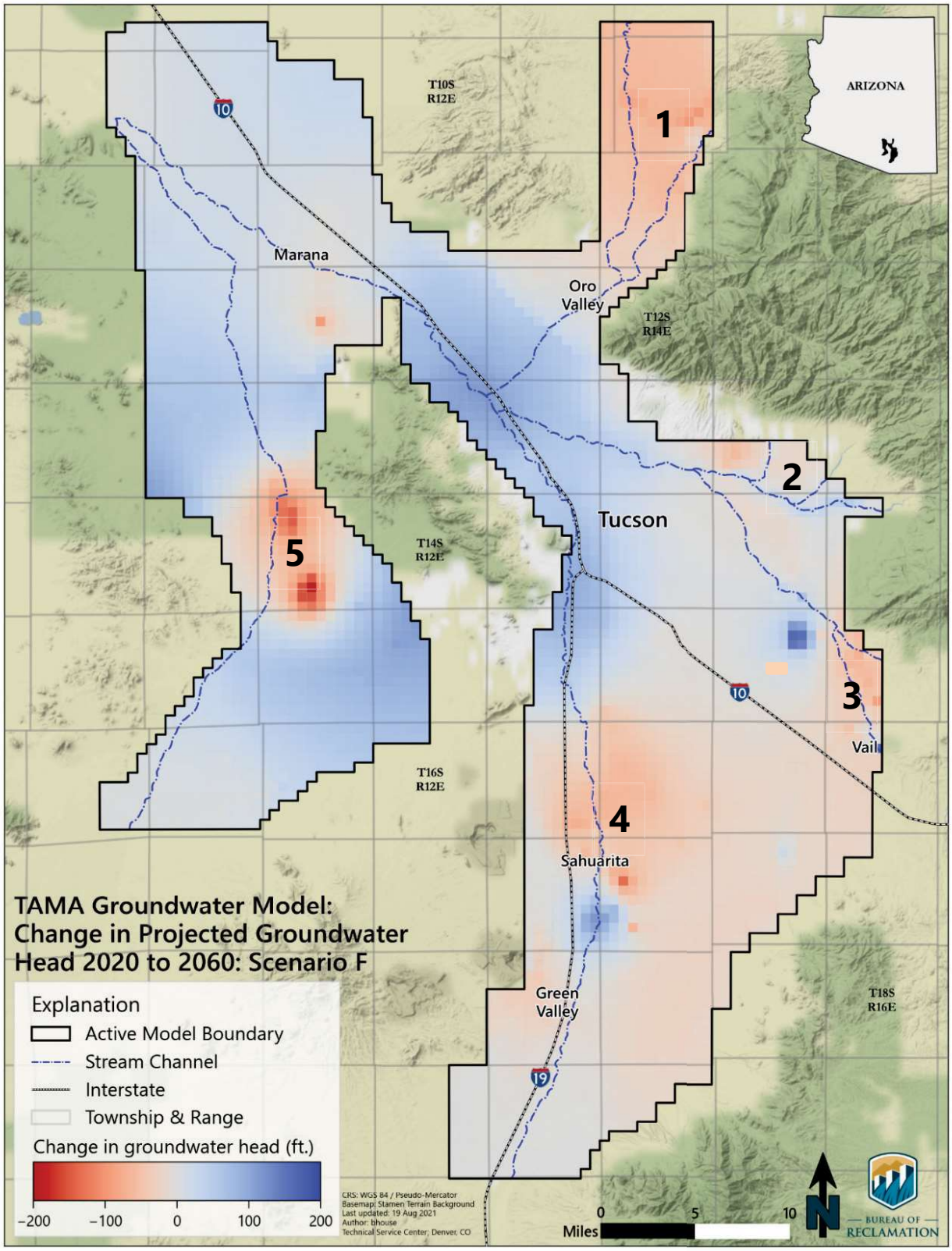


Figure 30. Change in groundwater head by model cell over the Study projection period (2020-2060) for scenario F (higher risk). Areas of general decline are labelled 1 to 5 and are discussed in the text.

3.3. Climate Impact

The contribution of future climate to the projected changes in groundwater heads and storage can be evaluated by comparing results for scenarios C and F. Both S-D scenarios reflect rapid/outward demand growth, with scenario C incorporating the best-case climate and scenario F incorporating the worse-case climate. Differences in the projected groundwater heads and storage between these S-D scenarios reflect the influence of climate assumptions on projected groundwater conditions. Comparison of scenarios B and D also isolates the influence of climate. This comparison yielded similar differences in projected groundwater heads and storage.

Figure 31 shows the difference in projected groundwater heads for the last year of the projection period (2060) between scenarios C and F. Blue shading in Figure 31 indicates areas where the projected groundwater table under scenario C (best-case climate) is higher than under the scenario F (worse-case climate). Red shading indicates areas where the projected groundwater table is higher under scenario F. Climate impacts both local streamflow and availability of Colorado River water for importation via the CAP. The difference in simulated groundwater head between scenarios C and F reflects both of these impacts.

The blue-shaded areas in Avra Valley near the CAVSARP and SAVSARP facilities are simulated to receive identical recharge from natural streamflow in Brawley Wash (see the *Streamflow Infiltration* section of this technical memorandum for further explanation). Differences in groundwater levels in the Avra Valley are therefore due to climate-driven differences over the entire Colorado River Basin, which results in different levels of CAP deliveries under the best-case and worse-case climates.

CAP deliveries under each of the climate scenarios analyzed here are based on projections of supply for the overall Colorado River Basin (CAP, 2021). The volume of CAP water available for recharge at the CAVSARP and SAVARP facilities is approximately 0.5 MAF greater over the projection period under the best-case climate than under the worse-case climate. More CAP water is also available to meet demands under the best-case climate, which reduces the need for recovery of stored groundwater. Thus, the impacts of climate over the entire Colorado River Basin water supply is the predominate driver of the higher groundwater heads in the Avra Valley under scenario B.

In contrast to the Avra Valley, blue-shaded areas in the vicinities of Green Valley/Sahuarita, Vail, and Tanque Verde in Figure 31 are predominately driven by greater recharge from natural streamflow under the best-case climate (scenario B) compared to the worse-case climate (scenario F). The best-case climate exhibits greater runoff in this portion of the LSCR Basin, which results in greater groundwater recharge from natural streamflow. This additional streamflow recharge under the best-case climate offsets increased pumping to meet rising municipal and mining demands in these areas.

The best-case climate reflects lower future greenhouse gas (GHG) concentrations (RCP 4.5) whereas the worse-case climate reflects higher future GHG concentrations (RCP 8.5). The difference in the streamflow and water availability between these climate scenarios impacts projected groundwater heads and storage over large swaths of the Study area (Figure 31). Notably, impacts within the Study area reflect the effects of climate conditions on local streamflow within the LSCR Basin as well as streamflow and water availability within the broader Colorado River Basin (in the form of CAP supplies). These results suggest that the future of groundwater supplies within the LSCR Basin depends not only on climate changes

within the Study area, but also on changes for the Colorado River Basin as a whole. In other words, the water supply future of the LSCR Basin is linked to that of the Colorado River Basin as a whole through the importation of Colorado River water via the CAP.

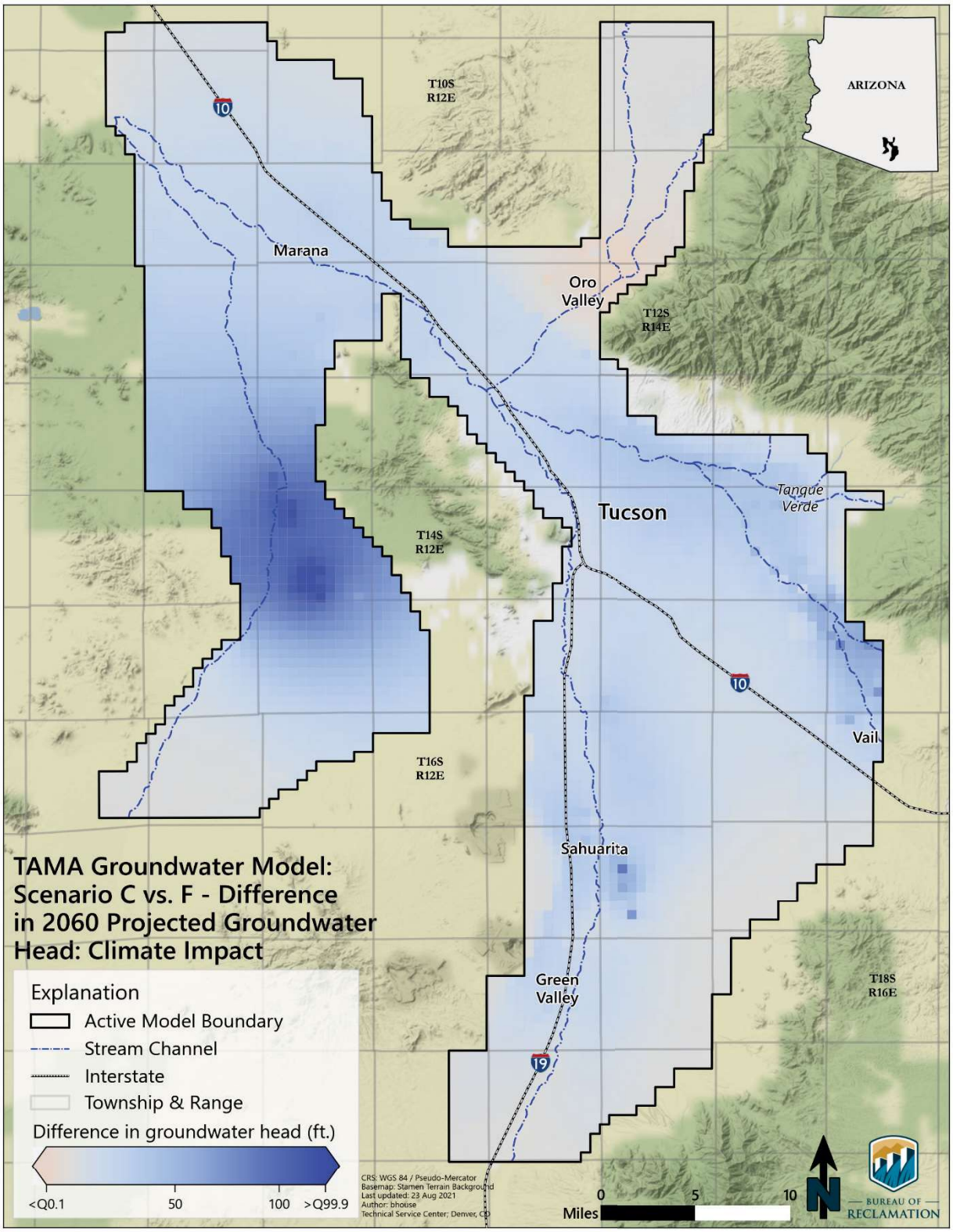


Figure 31. Difference in simulated head between scenarios C and F at the end of the projection period (2060). Map shows the spatial impact of the different climate scenarios (best-case vs. worse-case climates). Blue shading are areas where scenario C heads are higher than F—vice-versa for red. For clarity, the minimum and maximum values on the color scale were set to the 0.1 and 99.9th quantile, respectively.

3.4. Demand Growth Impact

The impact of demand growth assumptions on the projected changes in groundwater heads and storage can be evaluated by comparing results for scenarios D and F. Both S-D scenarios reflect the worse-case climate, with scenario D representing slow/compact demand growth case and scenario F representing the rapid/outward demand growth case. Differences in projected groundwater heads and storage reflects the influence of assumptions regarding future demand and growth patterns on projected groundwater conditions. Comparison of scenarios B and C also isolates the influence of demand growth. This comparison yielded similar differences in projected groundwater heads and storage.

Figure 32 shows the difference in projected groundwater heads for the last year of the projection period (2060) between scenarios D and F. Blue shading indicates areas where the projected groundwater table is higher under scenario D; red shading indicates areas where projected groundwater table is higher under scenario F.

Groundwater heads along the SCR northwest of Tucson are greater under scenario F (rapid/outward demand growth) compared to scenario D (slow/compact demand growth; red-shaded areas in Figure 32). This is due to increased population and municipal water use under the rapid/outward demand growth case, which results in increased discharge of reclaimed water to the SCR. The increase in WRF discharges to the SCR is illustrated in **Error! Reference source not found.** for the SCR reach above the Cortaro gage. Increased discharge of reclaimed water results in increased groundwater recharge. This increase in recharge along the SCR northwest of Tucson results in higher groundwater heads in this area. Additional groundwater is largely recovered from Avra Valley to meet the greater municipal demand under scenario F. These locations are hydrogeologically disconnected. The additional groundwater recovery does not impact this area.

Figure 32 shows higher groundwater levels under scenario D compared to scenario F (blue-shaded areas) in the Avra Valley near the CAVSARP and SAVSARP recharge facilities. These facilities receive nearly identical volumes of recharge over the projection period under scenarios D and F. However, higher water demands under scenario F (rapid/outward demand growth) result in greater recovery of stored groundwater from these facilities to meet those demands. By the end of the projection period, the amount of groundwater recovered from the CAVSARP and SAVSARP facilities under scenario F is approximately double the amount recovered under scenario D. This difference in recovery between scenarios D and F demonstrates that these facilities are functioning as intended—artificially recharged water is being recovered to meet demands within the LSCR Basin when other water supplies are not available.

The Green Valley/Sahuarita area is also projected to have higher groundwater heads under scenario D (slow/compact demand growth) compared to scenario F (rapid/outward demand growth). Two active mines are located in this area. Under scenario F, pumping to meet mining demands is projected to increase 30% above current rates by the end of the projection period. Scenario F also includes groundwater pumping to meet demands for a new mine. Under scenario D, pumping to meet mining demands is projected to remain constant for the duration of the projection period. Scenario D incorporates lower projections of population growth than in scenario F.

Scenario D also incorporates lower projections of population growth than in scenario F. Pumping to meet municipal demands for the Green Valley/Sahuarita area are projected to more than

double by the end of the projection period under scenario F (CAP, 2021). Higher groundwater heads in the Green Valley/Sahuarita area under scenario D are therefore due to lower pumping rates for the mining and municipal sectors. It should be noted that the TAMA groundwater model is known to not perform as well in this area and is undergoing some structural changes for the next update by ADWR (Nelson & Clark, 2020). The spatial distribution of differences in the groundwater heads in this area is therefore better interpreted as a general difference over the area then as cell-specific changes.

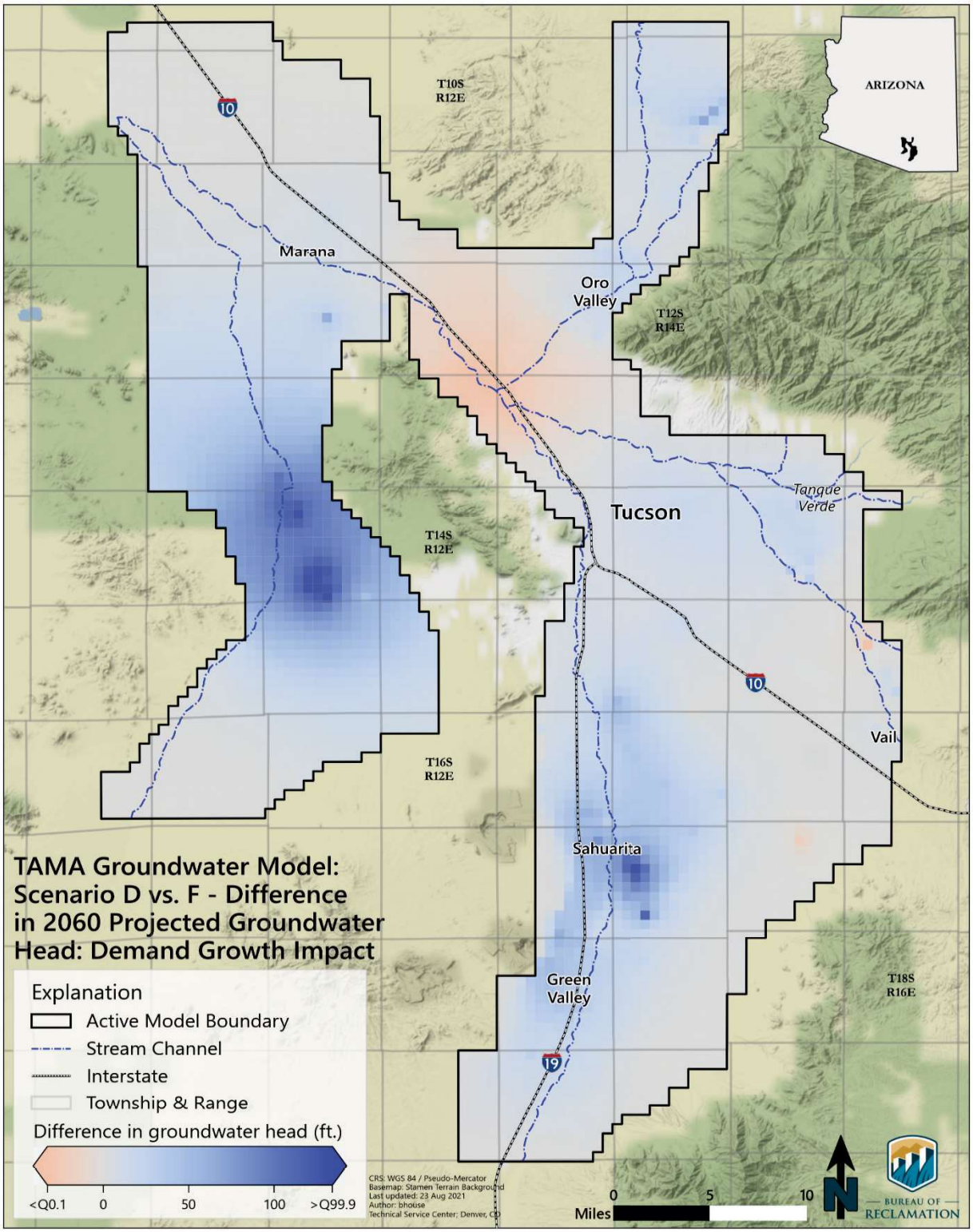


Figure 32. Difference in simulated head between scenarios D and F at the end of the projection period (2060). Map shows the spatial impact of the different demand growth cases (slow/compact vs. rapid/outward). Blue shading are areas where scenario D heads are higher than F—vice-versa for red. For clarity, the minimum and maximum values on the color scale were set to the 0.1 and 99.9th quantile, respectively.

3.5. Climate vs. Demand Growth Impact

The relative impacts of climate and demand growth on projected groundwater storage can be evaluated by comparing results from scenarios B, D, and F. Scenarios B and D share the same demand growth scenario (slow/compact) but different climate scenarios (best-case for scenario B, worse-case for scenario D). Scenarios D and F share the same climate scenario (worse-case) but different demand growth scenarios (slow/compact for scenario D, rapid/outward for scenario F).

Cumulative changes in groundwater storage under scenarios B, D, and F are illustrated in Figure 33. Results indicate that future climate conditions have a greater impact on projected groundwater storage than future demand growth (Figure 33). The difference between scenarios B and D (green area) increases more rapidly than the difference between scenarios D and F (yellow area), suggesting that differences in climate would have an impact sooner than differences in demand growth. By the end of the projection period, about 60% of the range of projected change in groundwater storage is due to the influence of the climate scenario. This result reflects impacts of climate on both local runoff and on water availability within the broader Colorado River Basin. The remaining 40% of the range is due to the difference in demand growth scenario.

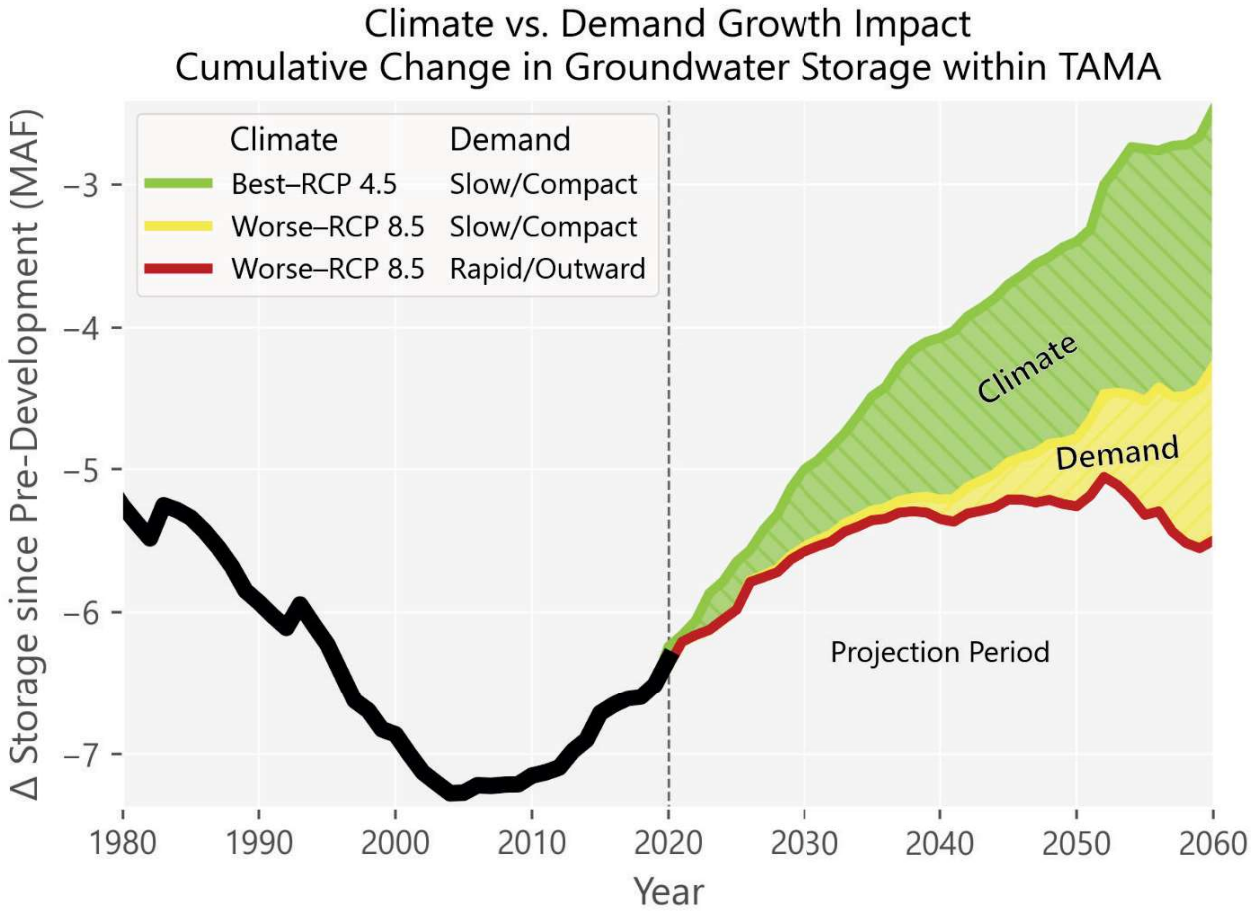


Figure 33. Simulated cumulative change in groundwater storage within the TAMA Model since pre-development (1940) for scenarios B, D, and F. Historical period is in black starting at 1980 (40 years post commencement of the simulation). The difference between scenarios B and D represents the impact of climate, while the difference between scenarios D and F represents the impact of demand growth.

4. Adaptation Strategies

As discussed above in Section 3, groundwater storage and heads are projected to decline in several portions of the LSCR Basin. Areas where adaptation strategies may be necessary to mitigate projected declines were identified based on the S-D scenario with the higher risk to water resources (i.e., scenario F) and Study Partner direction. Projected changes in the groundwater table under this S-D scenario are illustrated in Figure 30. Areas identified as potentially requiring adaptation strategies include: the Cañada del Oro/Saddlebrooke area northeast of Oro Valley; the Sabino Canyon and Tanque Verde area east of Tucson; southeast Tucson; and the Green Valley/Sahuarita area south of Tucson.

Study Partners developed fifteen adaptation strategies to mitigate the impacts of future climate and demand growth on water supplies in the Study area (Reclamation, 2022). Eleven of these strategies targeted a specific area of supply/demand imbalance listed above. Some of these adaptive strategies assume additional supplies of CAP water being delivered to the LSCR Basin. The origin of these additional supplies is not defined in this Study. Five of these adaptation strategies were appropriate for simulation in the TAMA Model and are summarized in Table 7. These adaptation strategies focused on the Cañada del Oro/Saddlebrooke and Green Valley/Sahuarita areas.

Table 7. Adaptation strategies evaluated in the TAMA Model (LSCR Basin Study Partners, 2021).

Strategy ID	Rate (TAF/yr)	Strategy Name	Brief Description
CDO-1	5	CAP Supplies to CDO In-stream Recharge	Pipeline and pump stations to convey additional water from the CAP Red Rock Pumping Plant to Cañada del Oro (CDO) Wash area for in-stream recharge.
CDO-2	10	SCR Reclaimed to CDO In-Stream Recharge	Pipeline to convey reclaimed water flowing out of the LSCR Basin from the Santa Cruz River (SCR) to the CDO Wash area for in-stream recharge. Includes treatment for PFAS and 1,4 dioxane.
CDO-3	1.12	Saddlebrooke Sub-regional WRF with In-stream Recharge	Saddlebrooke sub-regional WRF and pipeline for in-stream recharge to CDO. WRF would have 1 million gallon per day (MGD) capacity.
GV-1	10	CAP Supplies to FICO Continental Farms (pecan orchards)	Extend Farmers Investment Company (FICO) Groundwater Savings Facility (GSF) pipeline to convey CAP water to additional pecan orchards in lieu of irrigation with groundwater.
GV-2	2	CAP Supplies to Canoa Ranch Recharge via FICO Pipeline Extension	Extend FICO GSF pipeline to Canoa Ranch for in-stream or basin recharge in the winter months (when not needed for irrigation).

Adaptation strategies CDO-1, CDO-2, CDO-3, and GV-2 include discharge into a stream channel at a strategic location. GV-1 involves the use of CAP water in lieu of groundwater pumping for irrigation at the FICO pecan orchards over and above what has already been planned. GV-2 would extend the pipeline bringing CAP water to the FICO orchards southward to Canoa Ranch. CAP water would be recharged in this area seasonally, when the pipeline was not being used for agricultural irrigation.

Each of these strategies was simulated individually with the TAMA Model by modifying the model input files to include a new inflow (recharge) or to reflect reduced groundwater pumping. Additional recharge was represented as a constant inflow over the projection period (2020-2060). Reduced groundwater pumping was represented as a reduction in annual pumping rates. All strategies were simulated under scenario F, which reflects the worse-case climate and rapid/outward demand growth scenario.

For CDO-1 and 2, water would be conveyed for discharge into Big Wash (location noted in Figure 8) and would contribute to streamflow infiltration along this reach. CDO-3 involves the construction of a new WRF in the area to serve future development, with the discharge of reclaimed water at the same location as in CDO-1 and CDO-2. Equation 1 was used to distribute the added streamflow infiltration along the channel (Burkham, 1970).

For GV-1, approximately 10 TAF/yr of additional CAP supplies would be made available beginning in 2027 for irrigation on the FICO Sahuarita Farm in lieu of pumping. The existing FICO CAP Line, LLC (FCAP) pipeline would be extended to convey CAP water to portions of the farm currently irrigated with groundwater. Groundwater pumping rates would be reduced accordingly. The CAP supplies would be a combination of water already being imported into the LSCR Basin and new supplies imported by FICO storage partners. Reduced pumping rates for GV-1 were provided by Study Partners.

Under GV-2, the existing pipeline conveying CAP water to the FICO Sahuarita Farm would be extended southward approximately 10 miles to provide 2 TAF/yr for infiltration into the SCR at the Canoa Ranch south of Green Valley. This additional water would be conveyed during the irrigation off-season.

The potential benefit of each adaptation strategy on the LSCR Basin water supply was evaluated based on the difference in the groundwater table between simulations of scenario F with and without the adaptation strategy. Figures 34 to 38 illustrate the extent of the LSCR Basin where each strategy would result in an increase in groundwater table of one foot or greater for the final year of the projection period (2060). Note: Results shown in Figures 34 to 38 represent the projected benefit of each adaptation strategy if the strategy was implemented for the duration of the projection period (e.g., under CDO-1, 5 TAF/yr being discharged into Big Wash for 40 years).

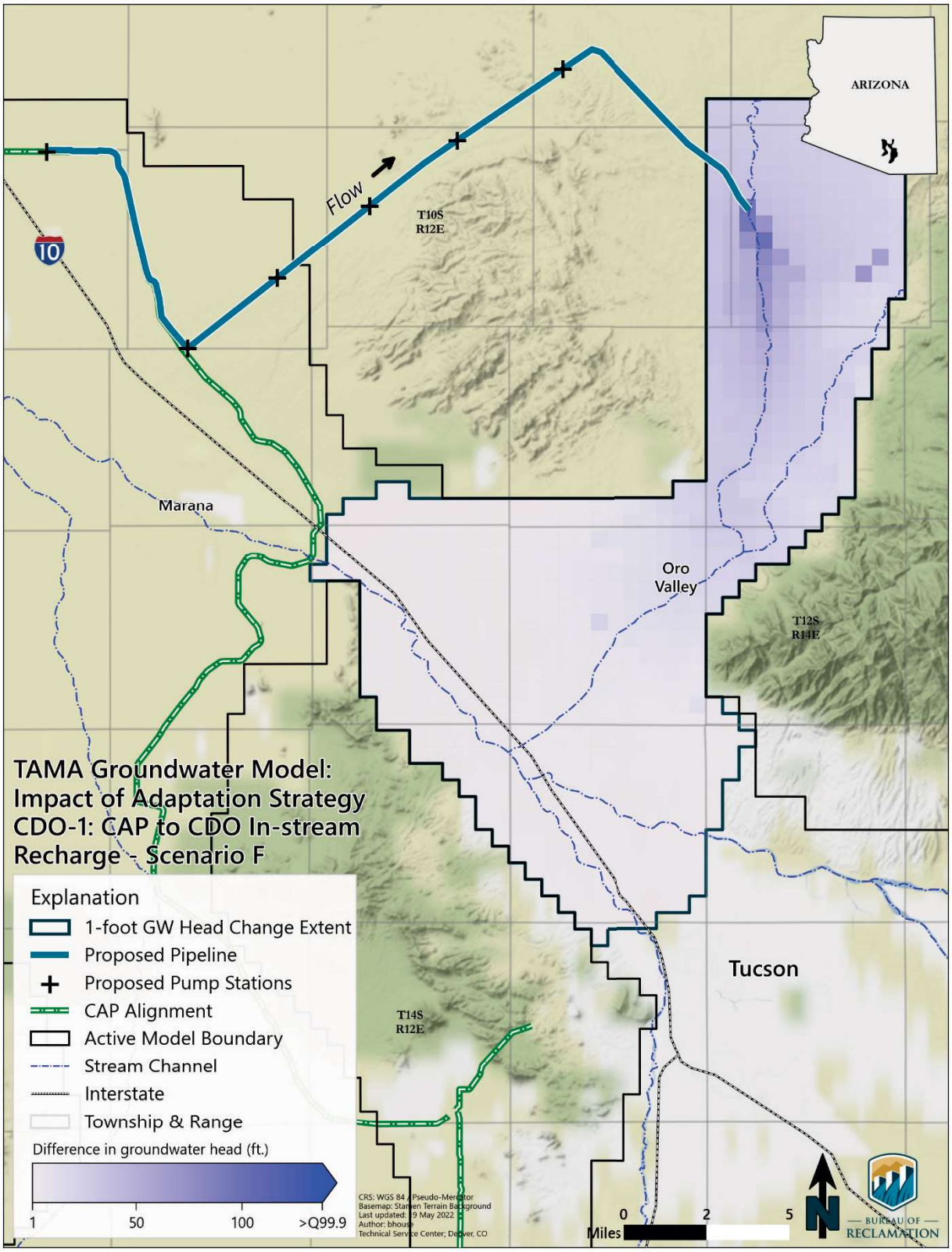


Figure 34. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy CDO-1. CDO-1 includes 5 TAF/yr of CAP water being recharged near the top of Big Wash in the CDO watershed over the projection period. Figures 34 to 38 share a color scale.

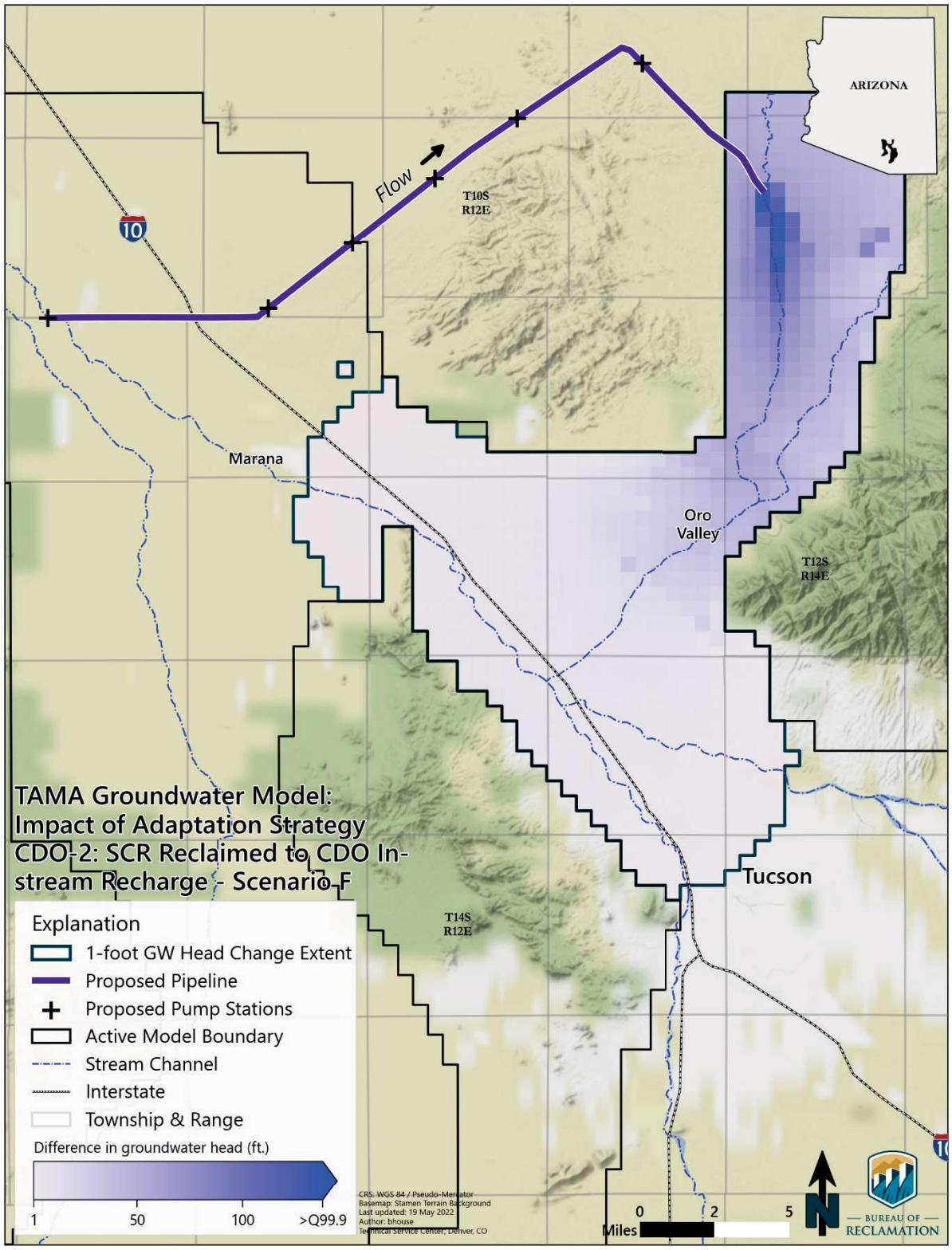


Figure 35. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy CDO-2. CDO-2 includes 10 TAF/yr of reclaimed water diverted from the SCR being recharged near the top of Big Wash in the CDO watershed over the projection period. Figures 34 to 38 share a color scale.

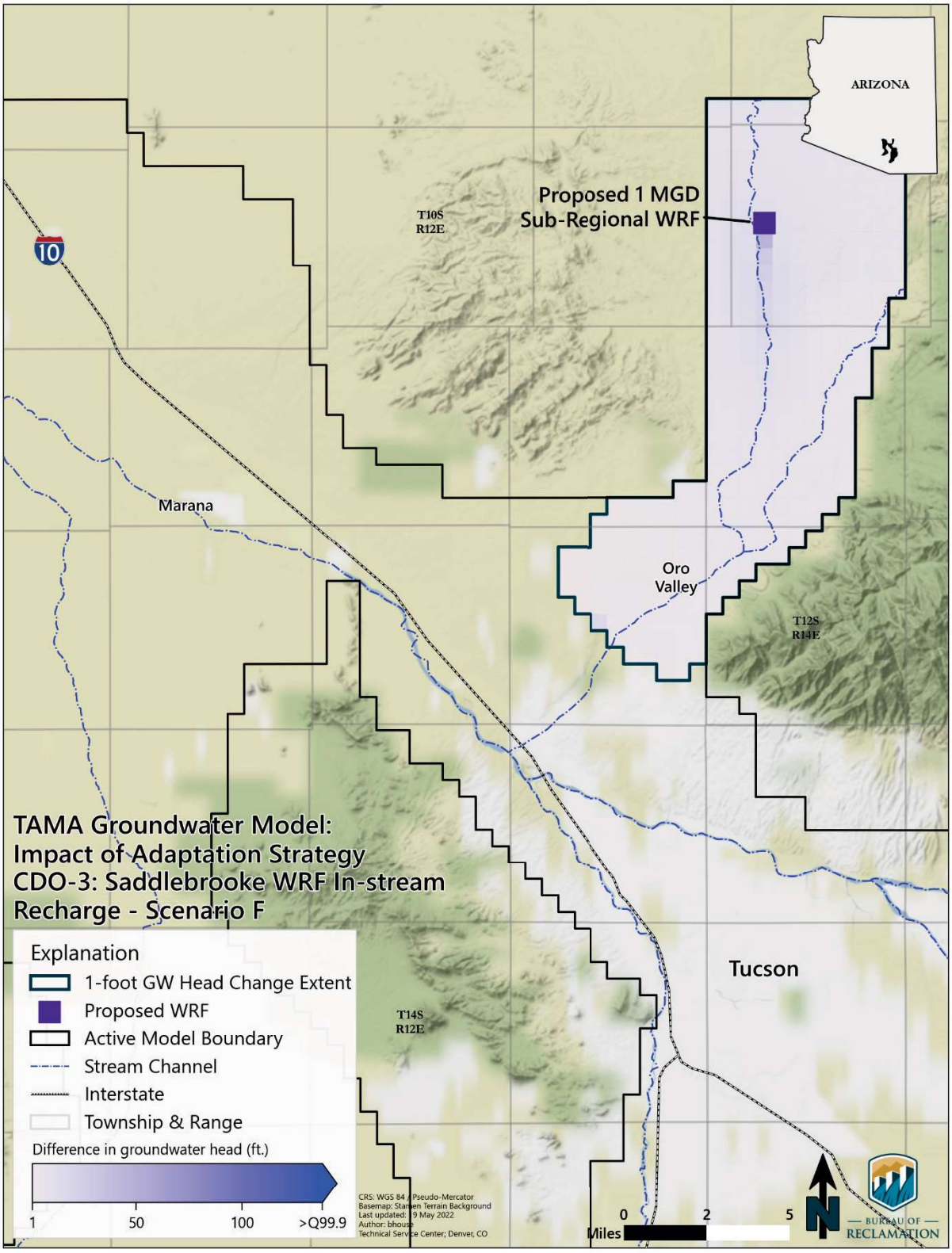


Figure 36. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy CDO-3. CDO-3 includes 1.12 TAF/yr (1 MGD) of reclaimed water recharged near the top of Big Wash in the CDO watershed from a potential WRF over the projection period. Figures 34 to 38 share a color scale.

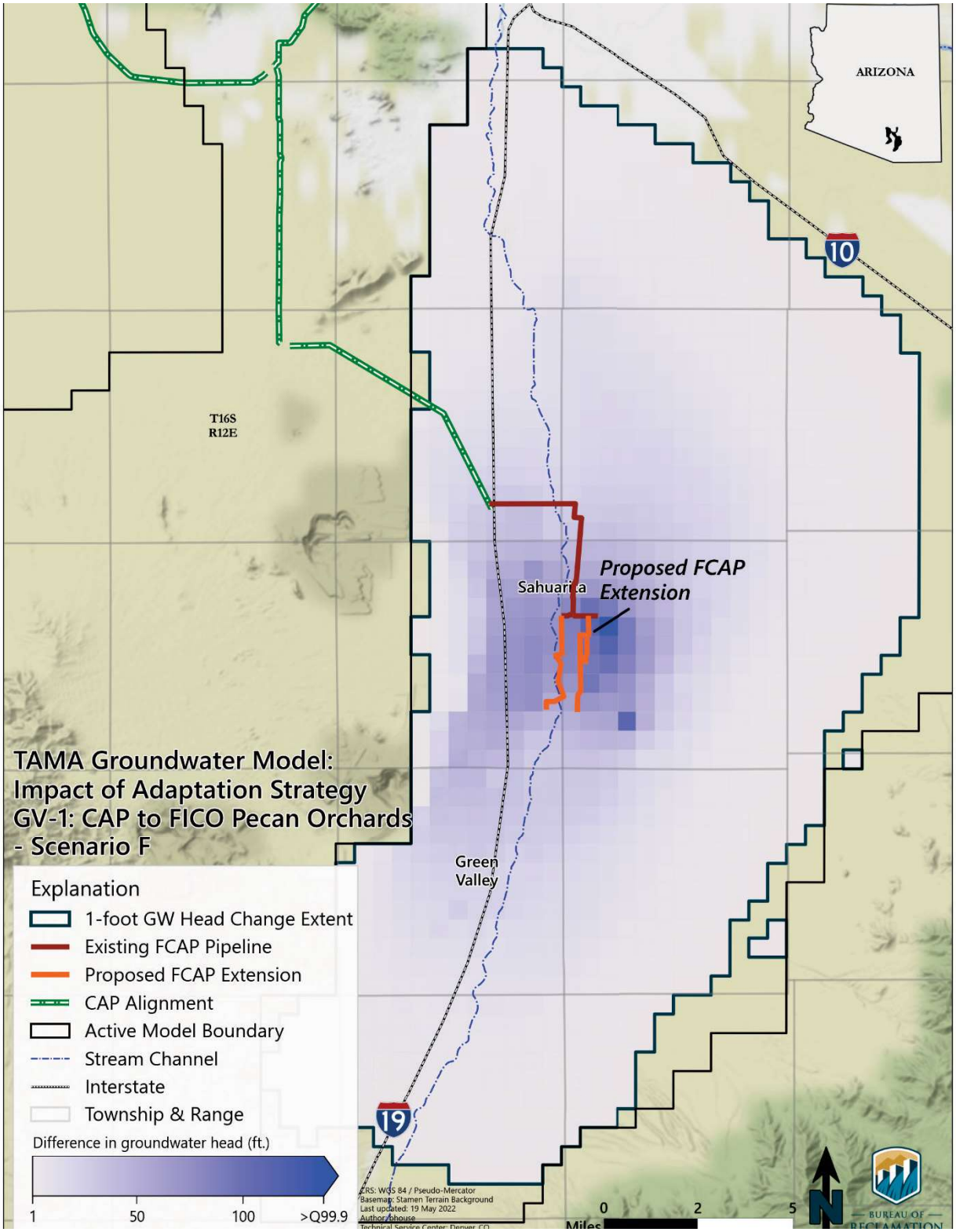


Figure 37. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy GV-1. GV-1 includes providing CAP surface water supplies in lieu of pumping groundwater to meet irrigation demands for FICO through the extension of the FCAP pipeline. This offsets about 10 TAF/yr of pumping starting in 2027 until the end of the projection period. Figures 34 to 38 share a color scale.

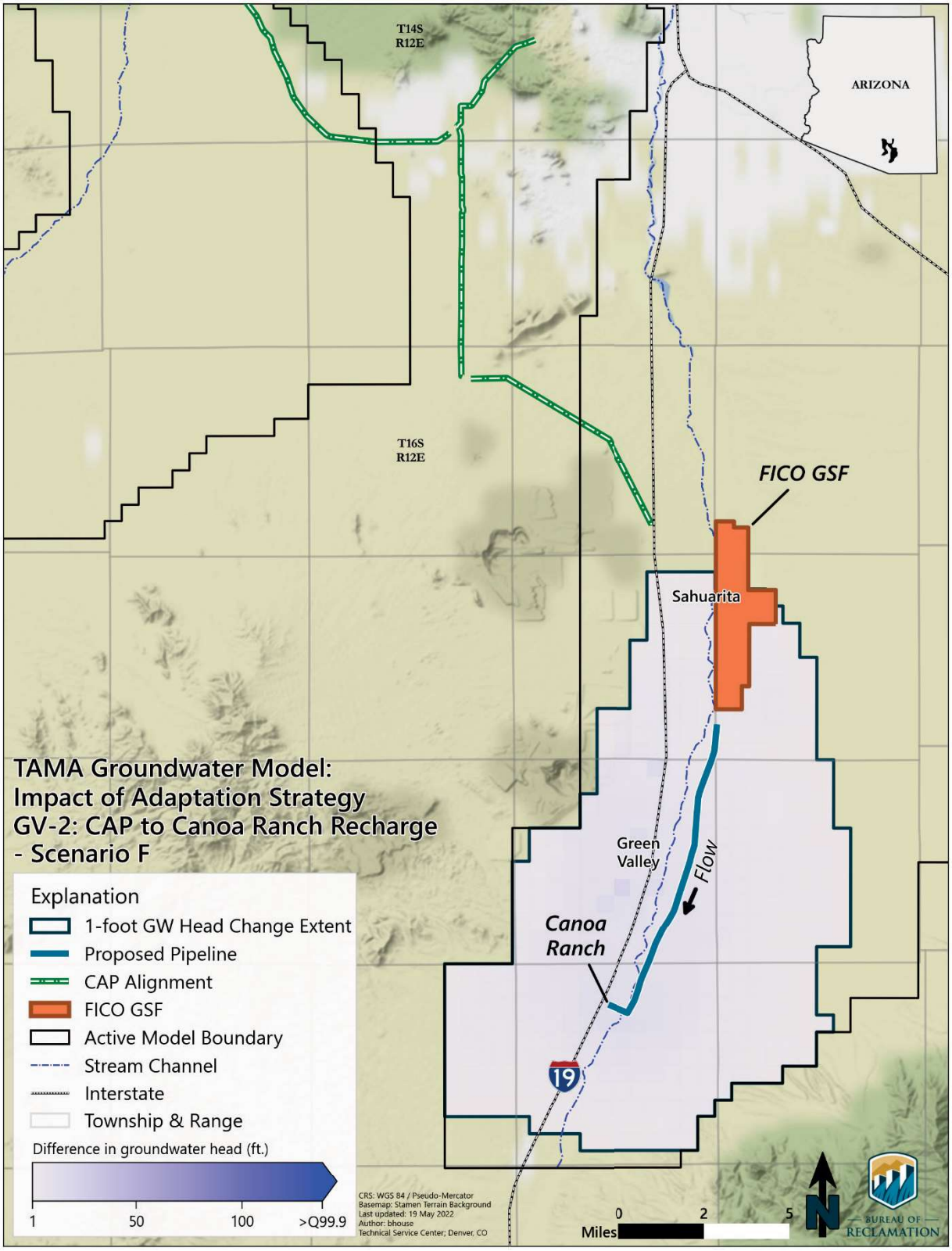


Figure 38. Difference in the simulated groundwater table for scenario F with inclusion of adaptation strategy GV-2. GV-2 includes extension of a pipeline to the Canoa Ranch. Here, 2 TAF/yr of CAP water would be recharged when capacity in the pipeline was available (i.e., not during the growing season) over the projection period. Figures 34 to 38 share a color scale.

This analysis demonstrates that the five strategies identified by the Study Partners and simulated using the TAMA Model all result in a projected increase in the groundwater table by at least a foot over large portions of the TAMA Model domain. The impact of a given strategy is proportional to the rate of additional recharge or pumping offset. As the rate of discharge to a stream channel increases, the model simulation shows that water will travel farther down the channel before infiltrating.

The hydrogeologic properties of the area where adaptation occurs also impact the results. For example, results from GV-2 (Figure 38) indicate minimal groundwater mounding near the recharge site and a 1-foot impact extent propagated farther in the north-south direction. These results are due to the relatively high horizontal hydraulic conductivity (causing the recharge to spread faster and not mound), and higher hydraulic conductivity along the SCR (allowing recharge to propagate faster along the SCR in the north-south direction; hydraulic conductivity distribution is shown in Figure 4). An economic analysis of these adaptation strategies was also conducted as part of the Basin Study. Results of the economic analysis are presented in a separate Technical Memorandum.

5. Summary and Conclusions

Infiltration of both natural and reclaimed water streamflow along stream channels and recharge at artificial recharge facilities are the major sources of inflows to the LSCR Basin groundwater system over the projection period (Table 5; Figures 21 and 22). Recharge is strongly influenced by future climate, with large differences in projected recharge across the best-case and worse-case climates (Figure 20). Cumulative inflows (recharge) under the current and best-case climates are about 1.6 MAF greater over the projection period than under the worse-case climate. Differences between the best-case and the worse-case climates result in a divergence in annual average recharge of about 40 TAF/yr over the projection period.

Recharge at artificial recharge facilities generally trends downward over the projection period due to projected reductions in CAP supplies. However, the interannual variability of natural stream channel recharge tends to drive the variability in recharge over the projection period (Figures 21 and 22).

Groundwater pumping is the predominant outflow from the LSCR Basin groundwater system over the projection period—with pumping to meet municipal demands being the greatest among the sectors (Table 6; Figures 25 and 26). Pumping is projected to either maintain a relatively constant rate (scenarios B and D, slow/compact demand growth case) or to increase to levels similar to the historical maximum pumping rate of the 1970s (scenarios C and F, rapid/outward demand growth case; Figure 23). Increases in pumping under the rapid/outward demand growth case are primarily driven by rising demands in the municipal sector (Figure 26).

Results from the TAMA Model projections suggest that under all S-D scenarios included in this Study, LSCR Basin-wide groundwater storage will increase over the projection period (Figure 27). While the S-D scenario with higher risk to water resources (F) is generally in overdraft for the final 10-years of the projection period, all other S-D scenarios are generally in surplus (Figure 27). However, while total groundwater storage within the LSCR Basin is projected to increase from current levels, model results indicate substantial declines in groundwater heads and storage in some areas of the LSCR Basin (Figure 28).

Both climate and demand growth impact groundwater supply. While the impact of lower atmospheric GHG concentrations (best-case climate [RCP 4.5]) shows some localized and broad increases in the simulated groundwater table (Figure 31), the impact of reduced demand growth (slow/compact) is often more localized (Figure 32). Impacts to groundwater resources within the Study area reflect the effects of climate conditions on both local streamflow within the LSCR Basin as well as CAP water availability within the broader Colorado River Basin. This highlights that the future of groundwater resources within the LSCR Basin depend not only on climate changes within the Study area, but also on changes for the Colorado River Basin as a whole. The water supply future of the LSCR Basin is linked to that of the Colorado River Basin through the import of Colorado River water via the CAP. By the end of the projection period, about 60% of the range of projected change in groundwater storage is due to the climate (Figure 33). The remaining 40% is due to the differences in demand growth.

Five adaptation strategies were simulated with the TAMA Model to evaluate the impact each would have on the groundwater table at the end of the projection period. Simulations were conducted as if a given adaptation strategy was implemented for the duration of the projection period (40 years). All simulations were conducted under scenario F, which reflects the S-D

scenario with the higher risk to water resources for this Study. Results suggest that all five strategies are effective at increasing the simulated groundwater table by at least a foot over large portions of the Study area. In general, the greater the rate of recharge or pumping offset, the greater the benefit to groundwater table.

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Appendix A—Streamflow Bias-Correction Method

A.1 Background

Projections of streamflow at 17 streamgages within the Study area were developed by Reclamation (2021) using the Sac-SMA rainfall-runoff model. These streamflow projections were subsequently used to develop streamflow infiltration inputs to the TAMA Model for the best-case and worse-case future climate scenarios as described in the *Streamflow Infiltration* section of this Technical Memorandum. Prior to developing streamflow infiltration inputs, streamflow projections were bias-corrected to correct for systematic errors (biases) between simulated historical streamflows and the observed record. This appendix summarizes the bias-correction methodology applied to streamflow projections. A variety of bias-correction methods have been applied in previous Reclamation Basin Studies. The method described here was recommended by senior technical staff at Reclamation's Technical Service Center. There are many similarities between this method and other statistically-based bias-correction methods (e.g., see Hamlet et. al. [2010] on statistical bias-correction).

A.2 Description of Methodology

The bias-correction method applied to projected streamflows for this Study is based on the relationships between simulated streamflows from the Sac-SMA model when forced with historical or future climate conditions and the observed streamflow record. The approach uses the cumulative probability distribution functions (CDF) of mean monthly streamflow (by month) from: the observed streamgage record (blue line in Figure A-1), the Sac-SMA historic simulation (green dashed line in Figure A-1), and the Sac-SMA projection simulation (red dashed line in Figure A-1) to produce a transformed version of the observed record (black line in Figure A-1). The resulting transformed version of the observational record reflects the projected change in CDF of monthly streamflows between the Sac-SMA historical and projection simulations.

Differences between the CDFs of mean monthly observed streamflow and Sac-SMA historic simulated streamflow (blue line and green dashed line in Figure A.1) reflect biases in the Sac-SMA model, as well as biases in each downscaled GCM. (For more information on how model bias was addressed during development of the streamflow projections see section *2.2.2.1. Bias Correction* in Reclamation [2021]). Differences between the CDFs of mean monthly Sac-SMA historic and projection simulations (green and red dashed lines) reflect the impacts of changes in climate on streamflow in the Study area. The bias-correction method applied here relies on both sources of information to develop a CDF of bias-corrected future streamflows for use in this Study. The method is applied on a streamgage-by-streamgage basis.

The relationship between the simulated historic and projected CDFs (the difference between the green and red dashed lines in Figure A-1) is imposed on the observed record through exceedance probability (quantile) mapping. This approach preserves the observed streamflow values but transforms the probability of a particular flow occurring during the projection period. This transformation represents the simulated change in streamflows between the historic and projected conditions. The sequencing of flows from the Sac-SMA projections is preserved through the projection period. The sequencing in the Sac-SMA projections is a product of the stochastic weather generator (Reclamation, 2021).

This method assumes that the CDF of monthly streamflow from the Sac-SMA historic simulation should be similar to that from the observed record. Due to systematic errors in both the Sac-SMA model configuration and the GCMs used force it, residuals between the observed and simulated streamflows are present. For example, in Figure A.1 the Sac-SMA historical CDF (green dashed line) is below the observed CDF (blue line) for streamflows less than approximately 10^1 cfs and above it for streamflows greater than 10^1 cfs. This would suggest that, for this particular month and streamgage, the bias in the GCMs and Sac-SMA result in overestimating streamflow at lower flow rates ($<10^1$ cfs) and underestimating streamflow at higher flow rates ($>10^1$ cfs).

A.3 Implementation of Methodology

Bias-correction of mean monthly streamflow projections is implemented using a Python script. The script applied the bias-correction method independently for each month of the year (i.e., Jan, Feb, …, Nov, Dec), Sac-SMA streamgage, and weather generator realization. Linear interpolation between discrete values within a given CDF is applied during the bias-correction process. After constructing CDFs for the three input datasets, execution of the script follows the steps below (and is depicted in Figure A.1):

1. Obtain a mean monthly streamflow from the Sac-SMA projection simulation (e.g., 15 cfs in January 2055).
2. Calculate the exceedance probability of the projected flow occurring in the Sac-SMA historic simulation period (e.g., 0.7).
3. Calculate the streamflow with equal exceedance probability from the observed streamgage record CDF (e.g., 35 cfs).

The mean monthly streamflow from the Sac-SMA projection simulation is then replaced with the bias-corrected value for the given month (e.g., for January 2055, 15 cfs is replaced with 35 cfs). For this example, the CDF of the bias-corrected flows (i.e., transformed version of the observed record) is shown as the black line in Figure A.1. The resulting difference between the observed record and bias-corrected CDFs (blue and black lines in Figure A.1) reflect the differences between the Sac-SMA historic and projection simulation CDFs (green and red dashed lines in Figure A.1). In this example, these differences include an increased probability of no and lower streamflows. This is expected since the bias-correction method imposes the simulated change in projected streamflow upon the observed record.

This bias-correction process does not alter the temporal sequencing of low and high flows from the Sac-SMA projection simulation. The sequencing of flows is predominantly a result of precipitation from the weather generator employed by Reclamation (2021). The weather generator ingests information on temporal sequencing of precipitation from downscaled GCMs. The resulting total annual TAMA Model-wide groundwater recharge from the bias-corrected streamflows for the two future climate scenarios are shown in Figures 11 and 12. Comparison of the projections of groundwater recharge from infiltration of bias-corrected streamflows to historic simulated rates from ADWR (2020b) indicates reasonable agreement in both sequencing and magnitude of annual totals.

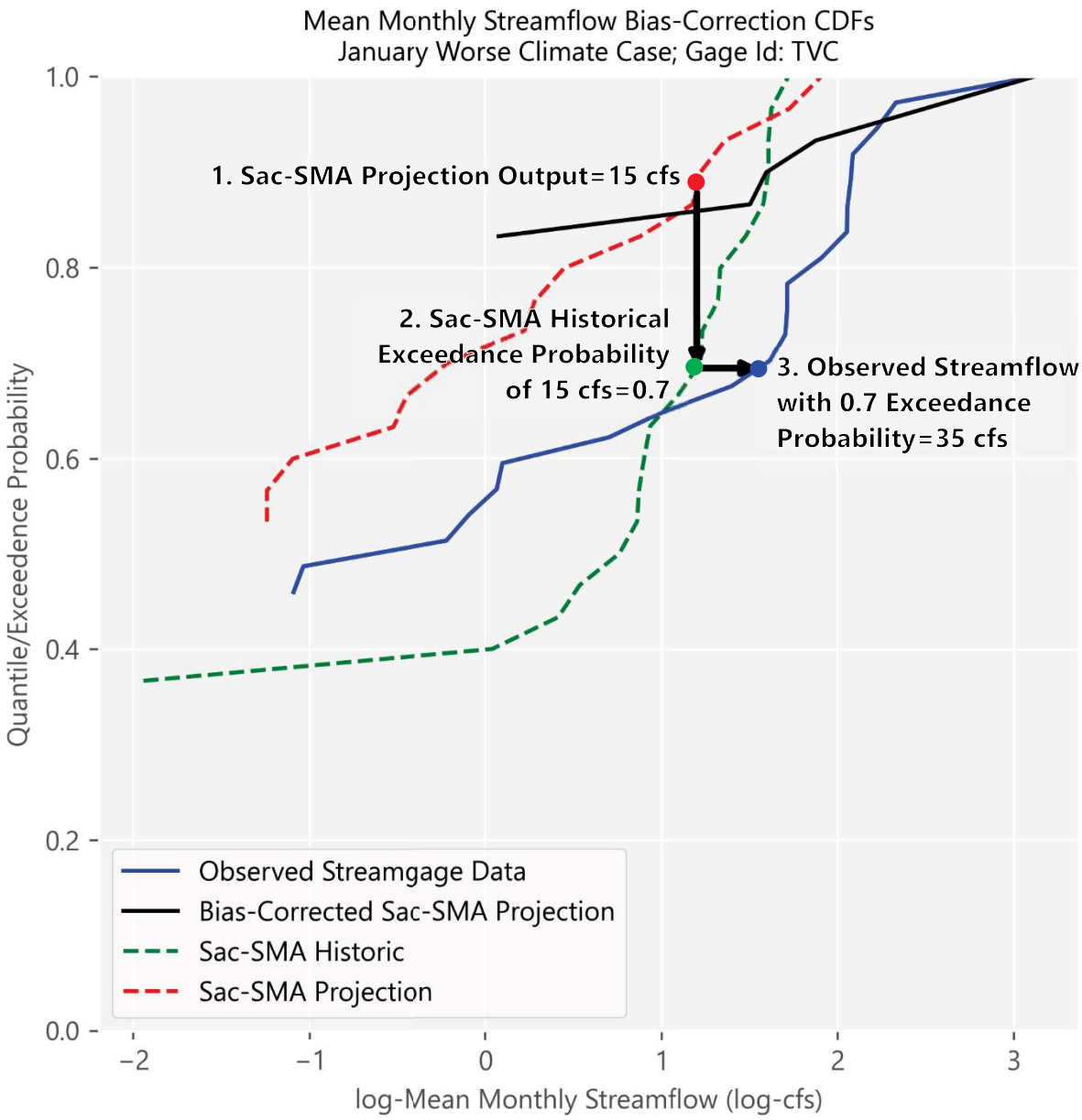

Figure A-1. Illustrative CDFs for mean monthly streamflow bias-correction process. Data are from January of the worse-case climate scenario for Sac-SMA gage TVC. An example of the bias-correction process is depicted for a projected mean monthly streamflow of 15 cfs ($10^{1.18}$ log-cfs).

A.4 Assumptions and Limitations

An assumption of this bias-correction method is that the maximum mean monthly flow during the projection period does not exceed maximum mean monthly flow in the observed record. This assumption eliminates the potential for unrealistically large future streamflows from being simulated. However, this assumption could have the potential to mute projections of greater than historic streamflows. The impact of this is partially mitigated as streamflows are aggregated to mean monthly rates—and ultimately to a total annual groundwater recharge rate.

The method also assumes that the impact of historical model biases is transferable to the future period. Information on the downscaled GCM and Sac-SMA model biases is contained within the difference between the CDFs of mean monthly observed streamflow and Sac-SMA historic simulated streamflow. This method assumes that the impacts of this bias are also applicable to the projection period. The impact of this assumption is likely to be greater if the projected model forcings deviate significantly from historic forcings.

This method is also sensitive to the breadth of data contained in the observed record. The method inherently assumes that any discrepancy between the observed and Sac-SMA historic simulation is due to model bias. It is possible that the streamgage record could have a limited number of observations that do not represent the actual range of possible streamflows. This sensitivity was mitigated in this Study through expansion of the observed record at select streamgages based on historic simulated groundwater recharge from ADWR (2020b).

This bias-correction method should undergo additional evaluation if it were to be applied to data with a shorter timestep (e.g., daily). For this Study, estimates of total annual streamflow infiltration were required. Figures 11 and 12 indicate that reasonable recharge sequencing and magnitudes were achieved. Figure 14 also shows that the projected changes in streamflow (and therefore infiltration) under each future climate scenario concluded by Reclamation (2021) are represented in these results. However, working with data on a shorter timestep is likely to present additional challenges that would require further evaluation.

Appendix B—Groundwater Model Results: Simulated Change in Head Maps

Detailed, full-page maps of the simulated change in groundwater head by model cell over the projection period (2020-2060) for each Basin Study S-D scenario (A-F) are included here for ease of review. These results are identical to those presented in Figure 28 of the main body of this Technical Memorandum.

Figure B-1. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario A (current climate, medium/official demand growth).

Figure B-2. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario B (best-case climate, slow/compact demand growth).

Figure B-3. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario C (best-case climate, rapid/outward demand growth).

Figure B-4. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario D (worse-case climate, slow/compact demand growth).

Figure B-5. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario E (worse-case climate, medium / official demand growth).

Figure B-6. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario F (worse-case climate, rapid/outward demand growth).

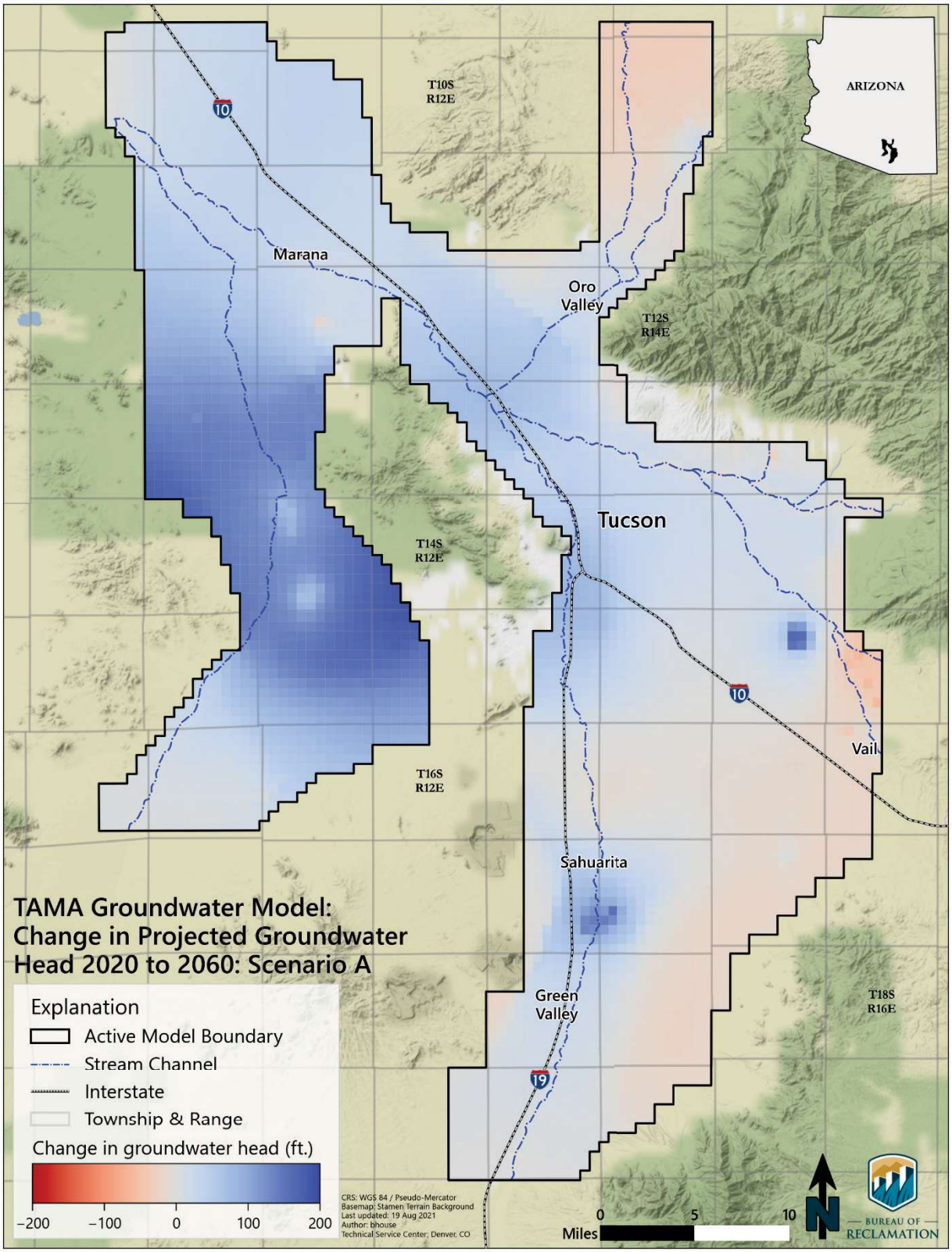

Figure B-1. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario A (current climate, medium/official demand growth).

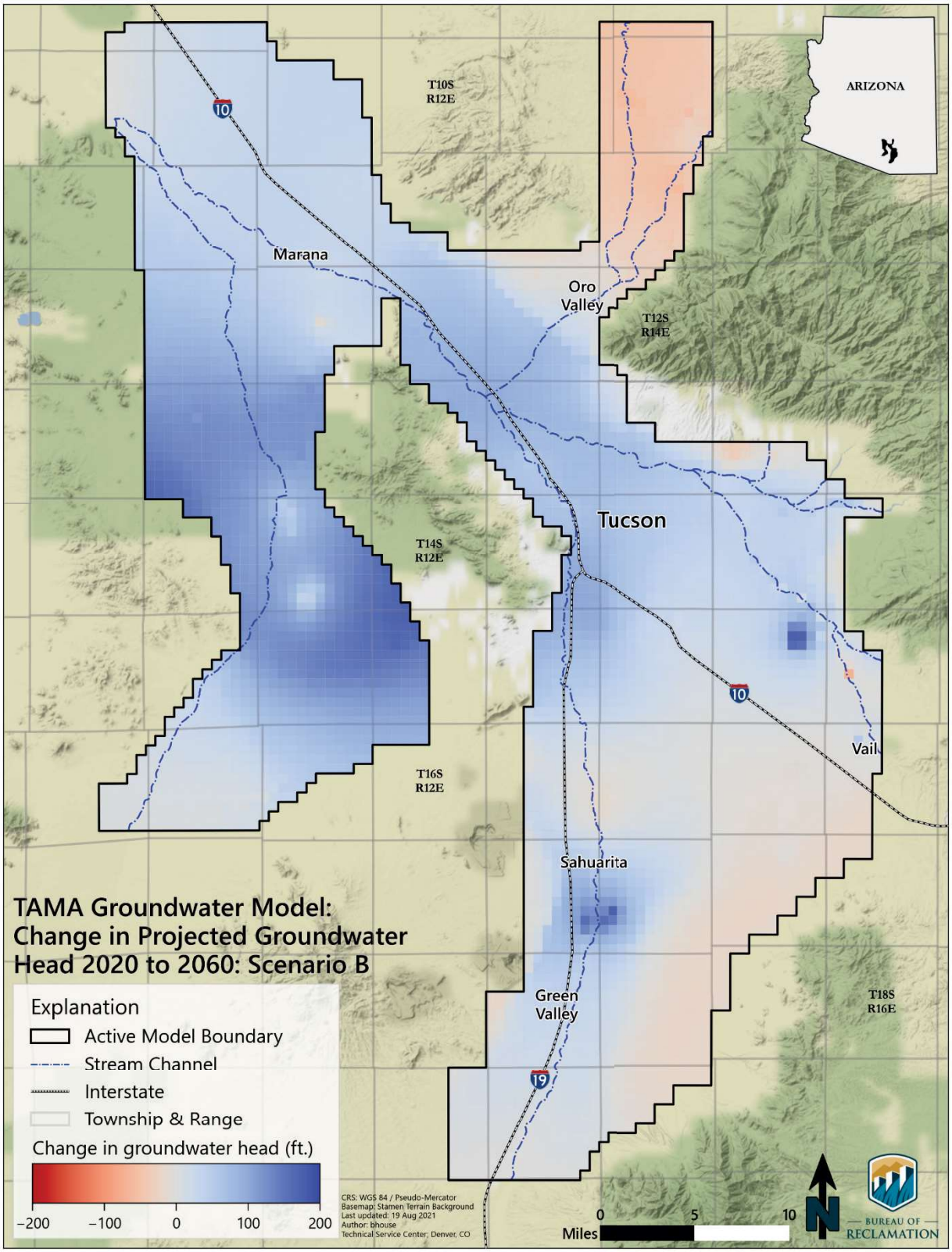

Figure B-2. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario B (best-case climate, slow/compact demand growth).

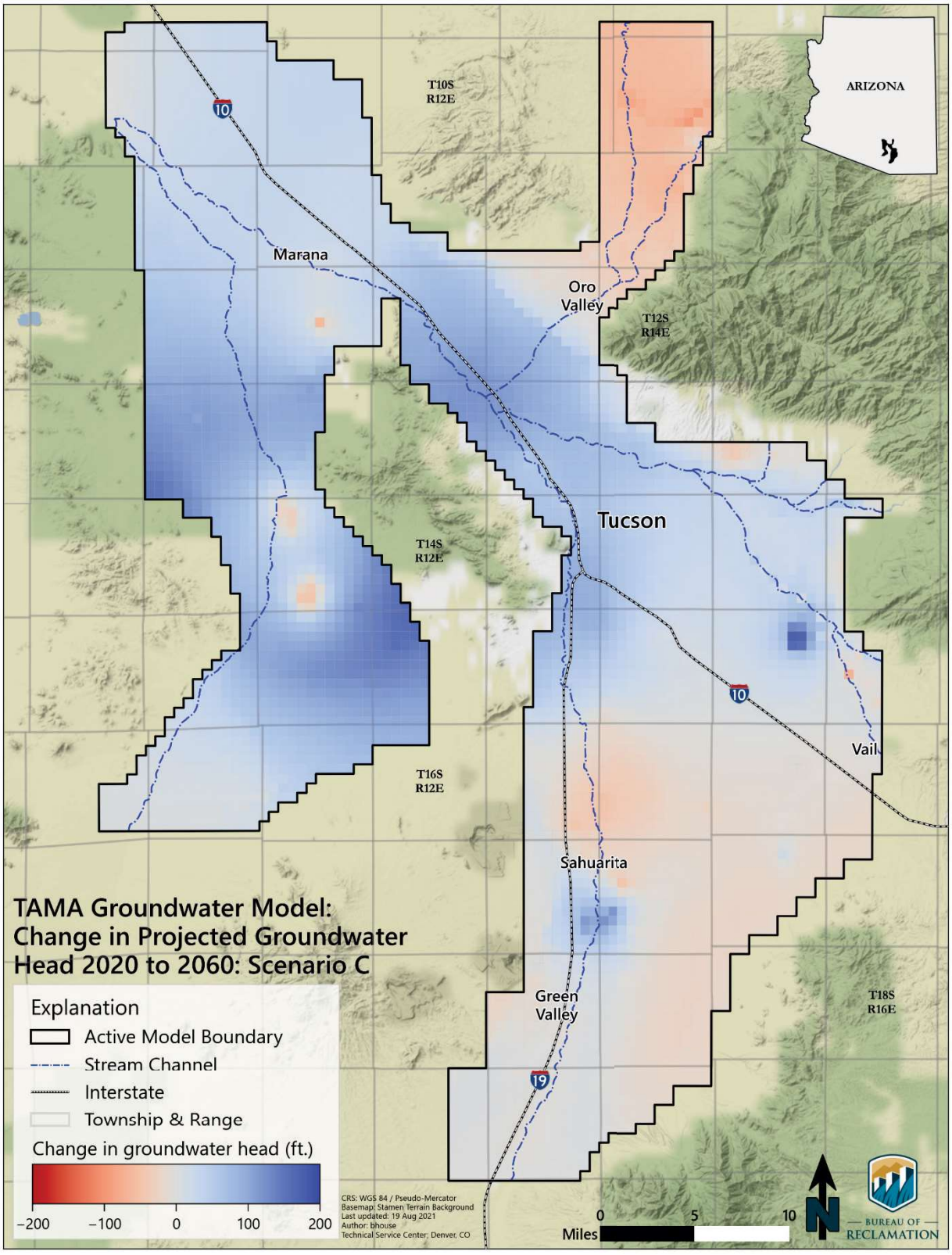

Figure B-3. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario C (best-case climate, rapid/outward demand growth).

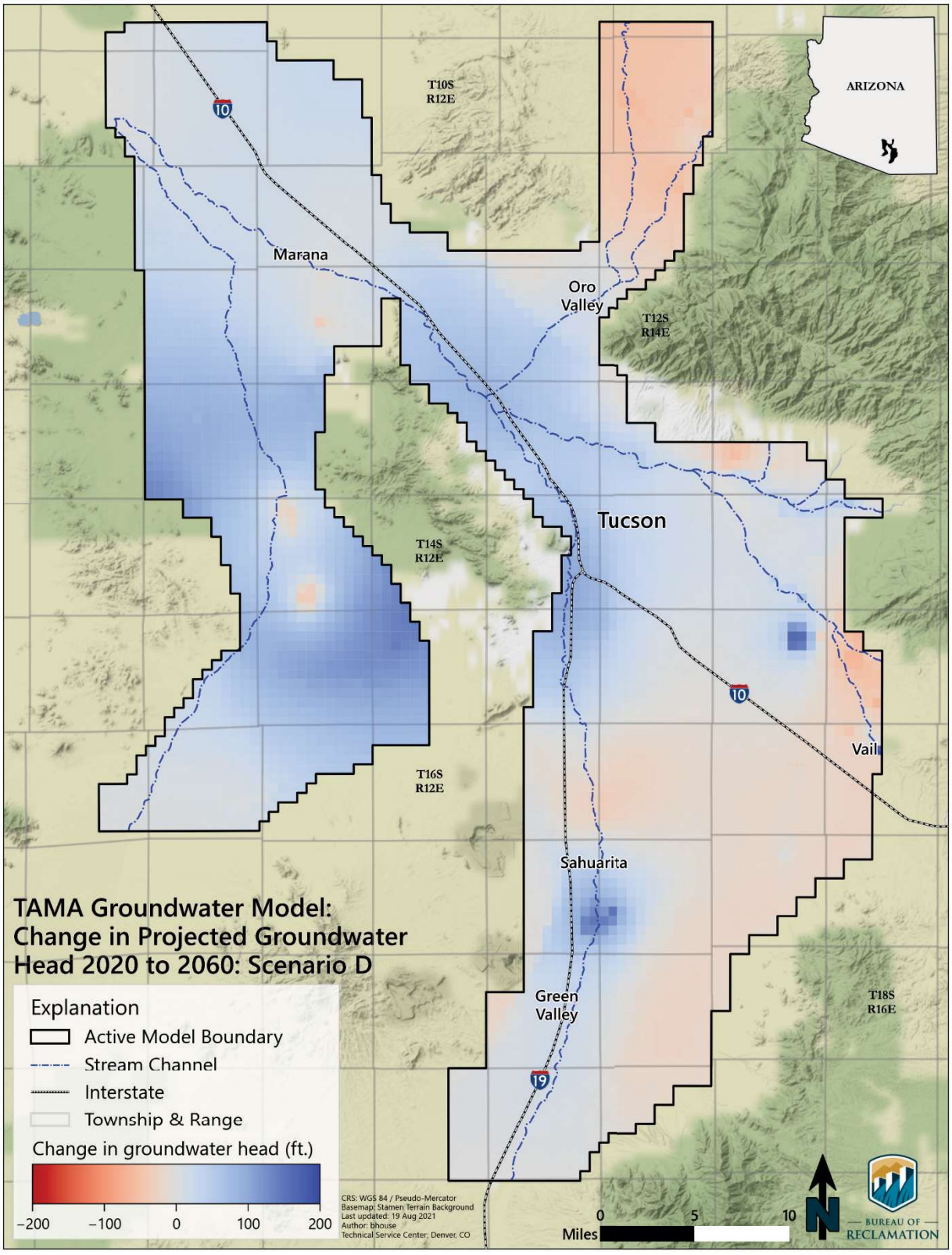

Figure B-4. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario D (worse-case climate, slow/compact demand growth).

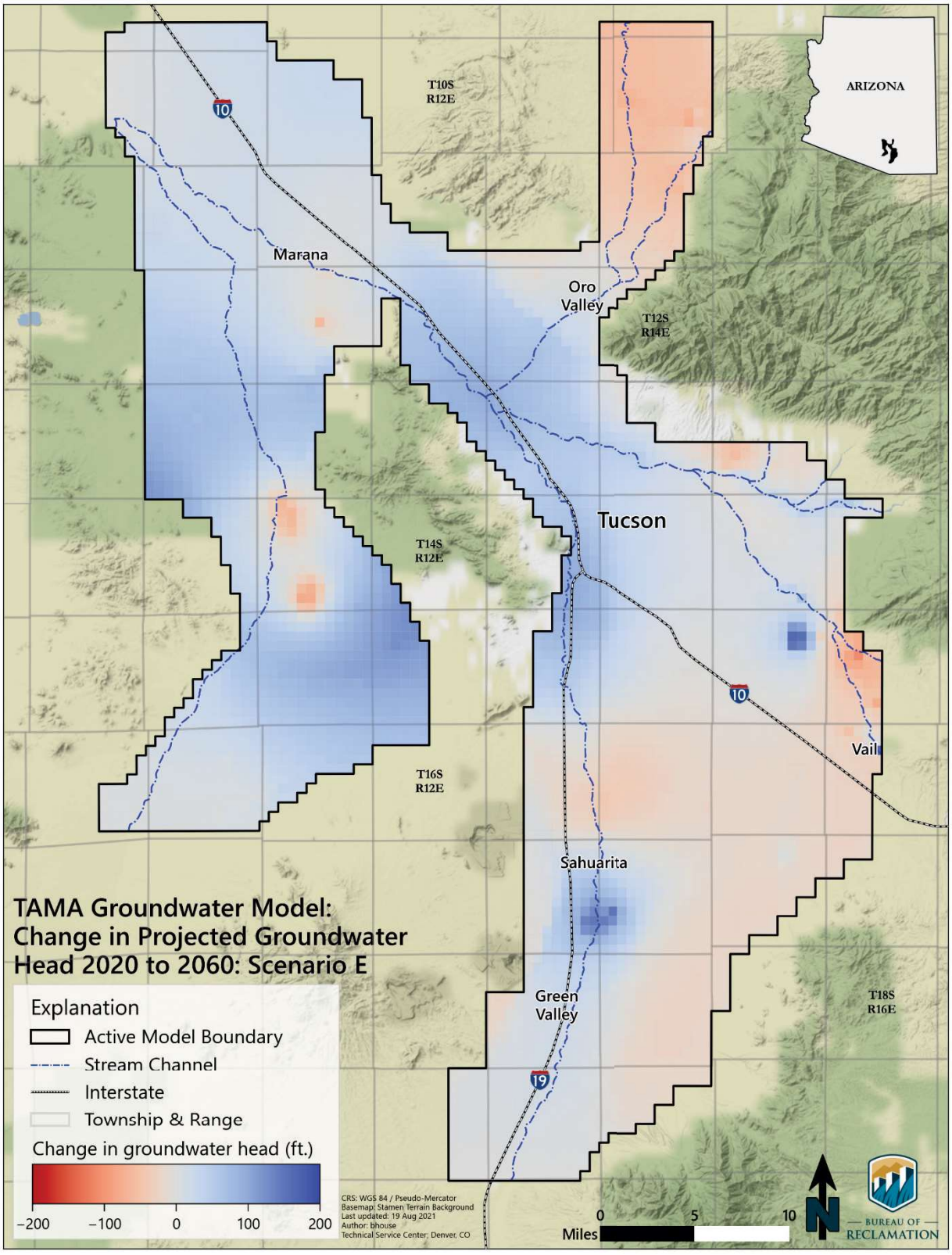

Figure B-5. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario E (worse-case climate, medium/official demand growth).

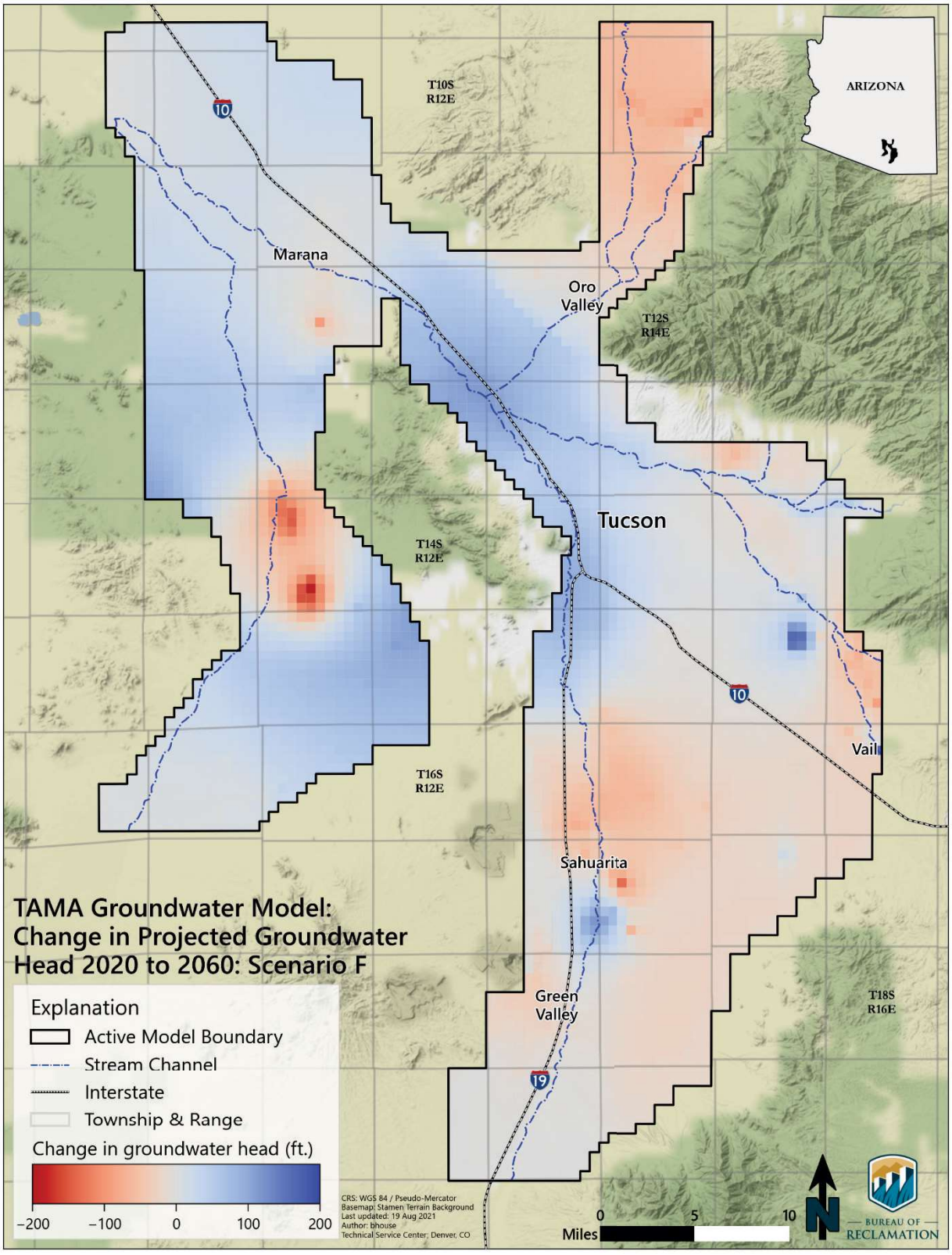

Figure B-6. Change in groundwater table by groundwater model cell over the Study projection period (2020-2060) for scenario F (worse-case climate, rapid/outward demand growth).

Appendix E – Adaptation Strategy Workshop I & II Summaries

I. Overview of Adaptation Strategy Development Process

The development of adaptation strategies for the Lower Santa Cruz River Basin Study was a multi-step process that actively engaged staff from the Cost-share Partners, as well as a wide range of local interests and individuals with subject matter expertise. Ideas for adaptation strategies and evaluation criteria were solicited at two workshops. The first was held in person on November 21, 2019, and the second was held remotely over two days: February 22-23, 2022.

Adaptation Strategy Workshop One, November 21, 2019

The purpose of Workshop One was to brainstorm a wide variety of adaptation strategies using existing knowledge, obtain stakeholder feedback on screening criteria and prepare to apply strategies to forthcoming groundwater model results. Strategies were based on areas known to be vulnerable to declining groundwater levels. The first workshop was held in person and utilized professional facilitators to moderate discussions and record participant responses.

28 participants were divided into four groups representing a range of organizational types (e.g., water provider, wastewater provider, non-profit, other government agency). Each group brainstormed strategies for the areas they considered vulnerable to groundwater declines, as well as regional strategies. Ideas were recorded in writing as well as locations on maps of the Study Area.

Strategies brainstormed in the workshop fell into the following categories:

- Central Arizona Project Water Strategies
- Shallow Groundwater and Environmental Projects
- Wastewater and Reclaimed Water Strategies
- Agriculture and Landscape Irrigation Strategies
- Infrastructure
- Policy Strategies
- Mountainous Region Strategies
- Low Impact Development Strategies

Notable suggestions included:

- Maximizing efficient use of Central Arizona Project within the Tucson Active Management Area, including direct use, stream channel recharge, basin recharge and wheeling
- Maximizing the use of wastewater in the Tucson Active Management Area, including decentralized treatment, extending Tucson Water's reclaimed water system, ensuring the presence of reclaimed water in the Santa Cruz River at critical times of year for supporting habitat and developing additional environmental projects using reclaimed water
- Retrofitting low impact development and green infrastructure in existing and new neighborhoods, prioritizing low income and high flood risk areas.
- Rainwater harvesting with cisterns to capture post-development runoff at the household level
- Large scale stormwater capture projects similar to the Kino Environmental Restoration Project

Adaptation Strategy Workshop Two, March 2021

The purpose of Workshop Two was to present the groundwater modeling to the stakeholders and to refine the adaptation strategies consistent with these results. Due to the Covid-19 pandemic, the second workshop was held on-line, using Zoom, for approximately six hours over a two-day period. 48 individuals participated in the workshop. Break-out groups were held in which specific adaptation techniques were applied to the four areas of concern identified through the groundwater modeling.

The workshop also featured a discussion of suggested evaluation criteria for the adaptation strategies. Suggested criteria fell into three categories: Water for Society, Environmental Concerns and Broader Considerations. Examples of criteria for each category are listed below:

Water for Society
- Minimizes impacts of pumping to parts of the aquifer vulnerable to aquifer storage depletion
- Minimizes impacts of over-pumping in aquifer regions connected to riparian areas
- Minimizes costs of new infrastructure
- Minimizes costs of operations and maintenance
- Promotes water supply reliability
- Has a significant impact on the projected supply/demand imbalance

Environmental Concerns:
- Enhances or protects high value habitat
- Promotes landscape connectivity
- Protects water quality
- Promotes accessible recreational opportunities
- Enhances or protects Cultural /Heritage values
- Reduces flood risk

Broader Considerations:
- Provides benefits to a large population
- Addresses multiple adaptation objectives/sectors (multiple co-benefits)
- Addresses a priority risk
- Builds on existing resources and projects/leverages existing investments
- Low cost relative to benefits
- Low opportunity cost

Zoom polling indicated that the workshop participants were comfortable with these criteria. This listed provided a basis for the final development of criteria in partnership with Reclamation's Technical Service Center staff economist.

Final Adaptation Strategies

The final list of adaptation strategies is below, sorted by area of concern. Strategies with an asterisk were carried forward from the Adaptation Workshops to the Trade-off Analysis.

Canada del Oro / Saddlebrooke area
- Convey Central Arizona Project water to the Cañada del Oro Wash area for in-stream recharge*
- Convey reclaimed water in the Santa Cruz River past Trico Road to the Cañada del Oro Wash area for in-stream recharge. (Includes treatment for PFAS and 1,4 dioxane.)

- Construct a new sub-regional wastewater reclamation facility in the Saddlebrooke area with a pipeline for in-stream recharge

Tanque Verde / Sabino Canyon area

- Extend Tucson Water Reclaimed Water System to replace outdoor potable uses and enhance riparian habitat*
- Construct interconnect to the Metropolitan Water District's Hub Service Area to enable wheeling of renewable supplies through Tucson Water infrastructure and cessation of local groundwater pumping*

Southeast Tucson area:

- Construct interconnections between the Tucson Water central potable system and Southeast Tucson water providers to allow wheeling of renewable supplies, thereby reducing local groundwater pumping.*
- Development of a regional water reclamation facility to treat and recharge wastewater from new development in the area.*

Green Valley / Sahuarita area

- Extend Farmers Investment Company pipeline to convey CAP water to additional pecan orchards in lieu of irrigation with groundwater.*
- Extend Farmers Investment Company irrigation distribution system to reach the Canoa Ranch site for riparian enhancement and in-stream recharge during non-irrigation season.*
- Construction of new regional water reclamation facility to treat and recharge wastewater from new development in the area.

In addition, the following strategies were suggested for all areas of concern and could be applied in many areas throughout in the Study Area and are referred to as Regional Strategies.

Regional Strategies

- Retrofit existing properties and incorporate Low Impact Development features into new developments to harvest and use renewable stormwater at the residential scale. (Build-out takes place from 2020 -2060.)*
- Construct large multi-benefit retention and detention basins to collect and slow stormwater from impervious areas for flood mitigation, storage and/or habitat restoration.*
- Perform upland restoration using small, distributed features such as gabions and check dams*
- Construct a desalination facility in Mexico and convey desalinated water to the Tucson region via pipeline

Final Evaluation Criteria

Reclamation TSC Economist Dr. Matthew Elmer reviewed the list of suggested evaluation criteria and helped the Project Team narrow the criteria down to the final ten. His considerations in narrowing the criteria included the following considerations:

- Evaluation criteria should capture all expected effects of the strategies
- Do the criteria help to distinguish between strategies?
- Is there overlap among the criteria?
- Are the criteria of equal importance?
- Are the criteria quantitative or qualitative?

The final criteria are summarized below. Three criteria were able to be monetized, the remaining seven relied on quantitative evaluation by the trade-off analysis participants. Depending on whether criteria could be considered a cost, a benefit, or both, qualitative criteria scored on a scale of either 0 – 3 (benefit); -3 to 0 (cost) or -3 to 3 (cost-benefit). It should be noted that the "Water Availability and Reliability Benefit" specifically refers to economic benefits that would be realized by municipal and industrial users. Benefits to the environment are captured in other criteria such as aquifer benefit, quality of life benefit, riparian impact, water quality and flood risk impact.

Table 1- List of Final Evaluation Criteria for Trade-off Analysis

Criterion	Description	Measurement	Directionality
(1) Water Availability and Reliability Benefit	Benefit (to M&I) from reducing future shortages anticipated for the region (in CAP:SAM).	Monetary	Benefit
(2) Capital Cost	Cost of construction or implementation (upfront cost).	Monetary	Cost
(3) O&M Cost	Cost of operation and maintenance (ongoing cost).	Monetary	Cost
(4) Aquifer Benefit	Improvements in groundwater levels to reduce pumping costs, prevent subsidence, or improve general aquifer condition.	0 to 3	Benefit
(5) Quality of Life Benefit	Improvements in recreation, aesthetics, health, safety, heat island effect, or cultural resources.	0 to 3	Benefit
(6) Leverage Existing Resources	Utilizes or enhances existing investments or infrastructure.	0 to 3	Benefit
(7) Barriers to Implementation	Obstacles from public perception, regulations, administrative complexity, or physical limitations.	-3 to 0	Cost
(8) Riparian Impact	Changes to riparian habitat and conditions.	-3 to 3	Cost/Benefit
(9) Water Quality Impact	Changes in the chemical, physical, or biological characteristic of water resources.	-3 to 3	Cost/Benefit
(10) Flood Risk Impact	Changes in flood risk (probability or consequences).	-3 to 3	Cost/Benefit

II. Workshop One Summary

Lower Santa Cruz River Basin Study
Adaptation Workshop One
November 21, 2019 | Pima Association of Governments, Tucson AZ

Workshop Summary

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Study Description

The goal of the Lower Santa Cruz River Basin Study is to identify where physical water resources are needed to mitigate supply-demand imbalances due to climate change and other factors and develop strategies to improve water reliability for municipal, industrial, agricultural, cultural and environment sectors in the Lower Santa Cruz River Basin.

Water supply-demand projections were developed for six scenarios using three growth scenarios and two climate scenarios. The study plan calls for running the Arizona Department of Water Resources' groundwater model to evaluate the effects of these scenarios on groundwater levels, the development of reliability metrics to address infrastructure vulnerabilities and the formulation of adaptation strategies to address water supply vulnerabilities and preserve groundwater dependent ecosystems.

The purpose of Workshop One was to begin brainstorming a wide variety of adaptation strategies using existing knowledge, obtain stakeholder feedback on screening criteria and prepare to apply strategies to forthcoming groundwater model results. Strategies were based on areas known to be vulnerable to declining groundwater levels. An additional workshop will be held to refine these strategies consistent with results of the groundwater evaluation. Selected strategies will undergo a trade-off analysis to provide an objective and transparent evaluation and comparison. The resulting analysis will be a range of strategies that can be considered to adapt to future conditions.

Participants invited to the workshop were representatives of the Basin Study local cost share partners, subject experts who contributed to technical sub-teams and stakeholder advisors who expressed interest in study participation.

Setting the Stage: Mini-Presentations

Overview of the Lower Santa Cruz River Basin Study, - *Eve Halper*, Reclamation
See presentation here: Lower Santa Cruz River Basin Study Website

- While the Tucson Active Management (TAMA) has an overall abundance of renewable water supplies, there are supply-demand imbalances within the TAMA
- The improvement in the Tucson area's groundwater levels is apparent by comparing two maps developed by Tucson Water. The first shows the groundwater declines between 1940 and 1998, while the second shows how water levels have improved with the recharge of Central Arizona Project water.
- The Lower Santa Cruz River Basin Study is a partnership between the Bureau of Reclamation and state and local partners to identify where physical water resources are needed to mitigate supply-demand imbalances and to develop strategies to improve water reliability for the municipal, industrial and environmental sectors
- This workshop addresses the third element of the Basin Study, the development of adaptation strategies. Although we are not completely finished with the projection of future supply and demand imbalances, we want to identify strategies ahead of time using existing knowledge.
- The study is using a "risk-management framework". Climate change is one of many risks to a reliable water supply in the Tucson area. This study has developed state-of-the-art information on the range of climate impacts to the basin. What can be done to address these anticipated risks?
- Our first objective today is to start the brainstorming process using available information and prepare to look more closely at these strategies when the groundwater results are available.
- The workshop will examine water use in the Tucson area from geographic and sectoral perspectives
- Adaptation strategies can be large or small, address single or multiple risks, structural or non-structural, etc.
- A second objective is to identify criteria for screening which strategies will be examined in more depth. The number of strategies to be investigated depends on the type and number selected.

History of Aquifer Change (video) - *Beth Scully, Tucson Water*
See video here: Lower Santa Cruz River Basin Study Website
This Tucson Water video shows the history of decline in certain areas, and subsequent recovery of the aquifer following the introduction of Colorado River water from the Central Arizona Project (CAP).

Overview of risk-based framing and metrics – *Kathy Jacobs, University of Arizona*
See presentation here: Lower Santa Cruz River Basin Study Website

- Adaptation is iterative risk management; we need to be prepared for things to change over time and evaluate our goals and capacity to meet them on an ongoing basis.
- The process starts with defining what you are trying to achieve, how the climate is changing, and actions that will get you closer to your goal or mitigate adverse impacts. Then you can evaluate to see if you're making progress towards your goal.
- Surprises will happen since climate change affects multiple systems simultaneously.
    - Electric grid, ecosystem, transportation, etc., potential for cascading effects
    - Small, subtle changes and their intersections can add up to something important
- As managers of risk, we need to be prepared for the "worst or worse case conditions" that can be dramatic and/or problematic.
- Need to think about range of futures via scenarios, in our case we are using the highest and the next to lowest greenhouse gas emission scenario from the Intergovernmental Panel on Climate Change (IPCC).
    - There is no intrinsic reason a "mid-range" scenario is more likely than a higher/lower one. A risk-based approach does not involve using a median approach
    - Lower scenario establishes a "minimum requirement" for adaptation
- Adapting to climate change involves acting to reduce vulnerability, enhance preparedness, and overall responsible risk management and common-sense planning to protect health/safety/prosperity.
- There are still issues that need to be addressed: unmet infrastructure needs, environmental resources are still at risk, capacity to solve problems is different in different parts of the basin.
    - There is no guarantee that we will have existing riparian habitat/biodiversity into the future given climate impacts
- Simplified climate impacts: we know things will be hotter, streamflow is likely to be reduced, it will be drier on average, evapotranspiration will generally increase, imported CAP supply is at risk, and there will be serious implications for ecosystems/human health/historically disadvantaged populations.
- Can link objectives/desired conditions to climate impacts and climate metrics to evaluate risks to objectives/desired conditions.

Climate and Surface Water Analyses Summary – *Lindsay Bearup, Bureau of Reclamation*
See presentation here: Lower Santa Cruz River Basin Study Website

- Overview of emission scenarios Representative Concentration Pathway (RCP) RCP4.5 (best case) and RCP8.5 (worse case)
- We are essentially already within the "2030s" projected future; also preparing a set of projections for "2060s" time frame
- We see an increase in precipitation variability and temperature across scenarios
    - Magnitude of change varies across scenario (best = minimal change, worse = drier, hotter)
- The worse-case scenario is consistently hotter and drier than the best-case scenario
- Increase in "no flow" days with regards to streamflow – more per month in worse-case scenario
- Soil moisture decreases across the board in months before monsoon season (April) but evapotranspiration (ET) also decreases due to soil moisture limitation (if there is not enough moisture in the soil then higher temperatures do not increase ET as much)

Questions and comments:

- Are the projections used by CAP consistent with predictions made by Udall and Overpeck in their 2017 paper? How do these projections stack up against the Udall/Overpeck predictions for the Colorado Basin?
    - This work was done on the Santa Cruz, rather than the entire Colorado River Basin – we used the best available data and downscaling method that we could, and it is consistent with Reclamation's Colorado River Basin Study
    - CAP is using Reclamation's modelling of the Colorado River warming impacts, and their CAP-SAM model takes those inflows and projects deliveries to its customers.

Overview of Historic Areas of Concern – *Wally Wilson, Metro Water*

- The two Tucson Water maps from the introductory presentation were displayed again Tucson area groundwater level changes from: 1940-1998 and from 2000-2016, emphasizing the point that long-term planning was necessary to achieve the level of sustainability the Tucson area enjoys today.
- The hydrogeologic setting can make the locations of groundwater declines hard to predict. This is also true for responses to recharge.
- Green Valley's challenge is not limited aquifer capacity but a combination of industrial, municipal, and agricultural water use
    - Hydrogeologically, that aquifer can take and give water easily.
- When Tucson Water did its second long-range plan in 2004, they had the goal of stabilizing water levels in existing well fields using Avra Valley as "the bank" in which to store water.
- Multiple model runs with changing pumping in well fields zeroed in on a couple of conclusions:
    - The southeast Tucson area:
        - does not have groundwater underflow like the west part of the valley
        - does not have significant mountain front recharge
        - does not respond well to any level of groundwater pumping – we will see water level declines if there is additional pumping in area
        - is "just storage" – old groundwater that is not receiving mountain front recharge
    - The Canyon Del Oro (CDO) "lobe":
        - is dependent on mountain front recharge/snowpack/runoff out of the Catalinas
        - comprises a set of hydrogeological pockets that need to get filled
        - changes from year to year based on high/low winter precipitation
    - The entire Avra Valley area is essentially rising
        - large amounts of CAP recharge
        - the narrowest part of the aquifer is backing water up to the south
- Potential future areas of concern:
    - Northwest, Northeast (Oro Valley) and Green Valley areas
    - There is not much planned for the southeast area yet; this could be a good place for adaptive strategy work group
    - In the future there will be two recharge/replenishment projects close to Marana airport (Marana is working with Metro Water on one closer to Oro Valley)

Questions and comments

- Is the rise in groundwater in central Tucson due to natural replenishment because wells were turned off?
    - Yes, from natural recharge and underflow from the southern part of aquifer (B zone)
- For the southeast sector with the South Houghton Area Recharge Project (located just west of Houghton and Drexel, owned by Tucson Water) and Vail wheeling through intergovernmental agreements (IGA), how will that impact groundwater with new development coming online?
    - Won't see as much decline, but recharge will be smaller than other areas
- What are some the areas you're watching and/or important projects coming online?
    - Marana – The northwest replenishment area.
    - Water may be pumped from storage areas someday due to Colorado River shortages, but that is a question of pipes and pumps available by that time
- We who live in Central Tucson basin have a distinct local focus, but the AMA Is bigger than this picture. We have the potential for significant declines in the Saddlebrooke area and Arivaca – make sure that as we go forward that we don't forget to consider these areas.
- What about northeast side stresses, particularly Pinal County in the Tucson AMA?
    - That area is predominantly undeveloped desert. Water use includes an approximately 4 square mile area of farming near Picacho Peak, and a smaller area of farming to the east of Red Rock. They are not getting much mountain front recharge in that area.

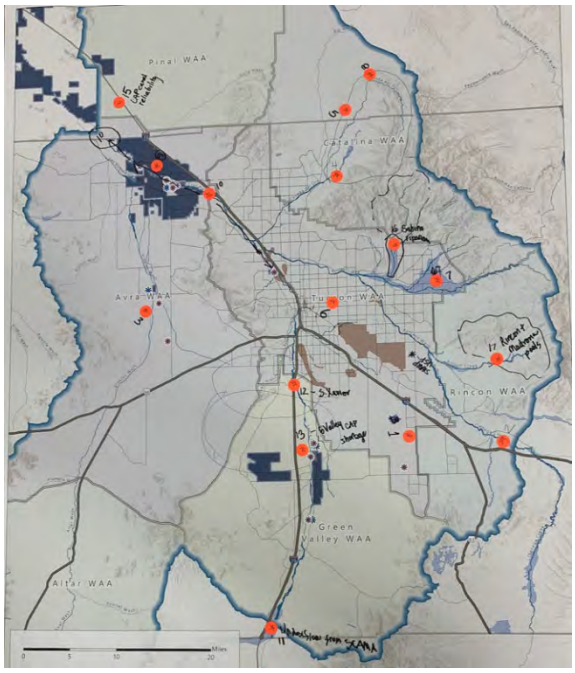
Geographic Areas of Concern (Small group work)

In small groups, participants worked to identify specific areas of concern for water availability into the future. Participants indicated areas of concern with small orange sticky dots on maps of the study area. Photos of all maps are in Appendix B.

Following is first a synthesis of all areas mentioned. Notes from each group discussion are included with more context about why *areas were identified.*

Synthesized list (combined from all groups)

*Those with * were mentioned by more than one group*



Geographic areas of concern for all groups
(Maps for individual groups are in Appendix B.)

- South Houghton corridor*
- Saddlebrooke area*
- Rincon Creek/Madrona pools*
- Lower Santa Cruz River*
- Tanque Verde/Agua Caliente Park/Sabino Canyon*
- Cienega Creek /Davidson Canyon*
- Vail
- Tucson (mid-town, southwest and southeast)
- Oro Valley
- Town of Oracle
- CAP Canal
- Canada Del Oro Wash (CDO)
- San Xavier District
- Tortolita Mountains
- Ajo Way Corridor
- Green Valley/Pima Mine Road
- Arivaca
- Marana area
- I-19 Bridge at the Santa Cruz River

Blue Group – Facilitated by Tahnee Robertson

Numbers correspond to Blue group map (orange dots) which can be found in Appendix B.

1. South Houghton corridor
2. Cienega Creek and Davidson Canyon – desiccation of a riparian area. Exempt wells, Vail wells, Rosemont Mine surface water diversions and groundwater draw toward open pit.
3. Avra Valley – eventual recovery of restored water, potential contamination of supply with proposed Interstate 11
4. Canada Del Oro/Sutherland Wash – potential effects of natural recharge by changing conditions and forest fires, expanded groundwater pumping, aquifer stress
5. Saddlebrooke Ranch – residential demand. Concern that much of the area to the south contributes to Pima County Regional Wastewater Reclamation Department-not locally recharged.
6. Tucson center – potential future reduction of Colorado River could result in additional groundwater pumping
7. Tanque Verde/Agua Caliente – riparian areas
8. Town of Oracle – physically outside of the AMA, but pumping from inside the AMA in an area with little recharge
9. Marana area – future reduction of CAP deliveries could cause problems with supply - demand balance
10. Lower Santa Cruz River (from Roger Road past Trico Road) – effluent dependent riparian/wetland area would lose water if effluent used elsewhere.
11. Green Valley – dependent on underflow, possible impacts from Santa Cruz County effluent flows
12. I-19 Bridge at Santa Cruz River – groundwater levels support surface flow
13. Green Valley/Pima Mine Road – potential future CAP shortages. Cone of depression.
14. Arivaca Valley – riparian issues
15. CAP Canal – limits to canal capacity; potential future reliability issues due to single siphons
16. Sabino Canyon - desiccation of a riparian area. No nearby recharge.
17. Rincon Creek/Madrona pools – risks to natural riparian area. Is SHARP (South Houghton Area Recharge Project) recharge close enough or large enough?

Green Group – Facilitated by Colleen Whitaker

- Cienega Creek/Davidson Canyon
- Santa Cruz River, west of I-10 - effluent dependent flows, increased water demand
- Green Valley
- Arivaca
- Sabino/Tanque Verde Creeks
- Saddlebrooke - anticipated growth area
- Oro Valley
- Santa Cruz River effluent flows
- Flowing Wells – perhaps increased demand
- Southeast Tucson (south of airport) – targeted industrial growth area
- Rincon Creek – loss of surface water; conservation opportunity in Rincon
- Flowing Wells Irrigation District – heat island demand

Yellow Group – Facilitated by Julia Sittig

- Urban corridor - urban flooding and Marana flooding

- Saddlebrooke and Catalina
- Green Valley – cone of depression on the border of the Tucson and Santa Cruz Active Management areas; as well as the pecan orchards owned by FICO pushing/pulling in and out of this cone due to seasonal irrigation
- Rincon East, Cienega Creek/Rillito Creek
- Canada Del Oro and areas that rely on mountain front recharge
- Southeast area - large number of private wells
- San Xavier - CAP may be threatened
- Tortolita Mountains – potential for wells to go dry
- Rising water levels downtown (near river) - proximity to landfills; contaminants may be mobilized if levels get too high
- If CAP supplies decrease in areas with strong ag presence, there could be a strong reliance on groundwater
- Riparian areas - particularly the intersection of pumping, declining recharge from precipitation, and proximity to shallow groundwater
- Reduced flood-carrying capacity in main channel from Martinez Hill to Marana, as its been highly channelized – at risk for flash flood
- CAP water – Tucson area should be using/storing its allocated amount (CAP water belonging to the Tohono O'odham Nation is recharged in the Phoenix and Pinal AMAs).
- Large capacity for recharge on the Tohono O'odham Nation is not being utilized

Red Group – Facilitated by Jessica Olson

- Saddlebrooke
- Vail (served by CAP)
- Green Valley, south (lots of housing and limited infrastructure)
- Southwest Tucson
- Ajo Way Corridor and South Houghton (limited infrastructure)

Climate Change Impacts by Sector: Mini Presentations

Municipal Water Supplies - *Wally Wilson, Metropolitan Water District*

- Climate change impacts on the Colorado River will have the greatest impact to water use in this region because the majority of our water use is dependent on Central Arizona Project (CAP) water.
    - Vulnerability of the entire Colorado River Basin, and negotiations of the 2007 guidelines, adds some risk.
    - We have the lowest priority on the Colorado River System; will likely just have water for municipal and tribal from CAP now. If the agricultural allocations are cut, agriculture can choose to pump groundwater.
    - If we retreat to using more groundwater, there will be more impacts to mountain front streams and riparian areas;
    - Fires that increase runoff rates/sedimentation could also have an effect
- Average use per household will depend on landscaping

    - We could see an impact from increased water use, but the cost of the water is going to go way up, especially with shortages on CAP. The cost per acre foot will go up and could significantly affect demand.
    - In some cases, we will see no outdoor water use. New developments are moving toward "hardscaping"
    - New houses will be more efficient
- We are now in surplus but that may not last.

Local Environmental Conditions/Riparian Areas - *Julia Fonseca, Pima County*
See presentation here: Lower Santa Cruz River Basin Study Website

- Value of riparian areas - wildlife, recreation, quality of life, housing prices.
- For the Sonoran Desert Protection Plan (SDCP) they looked at the historic losses - 3,000 acres lost, 32% now in protected status.
- 2004 bonds have been used to preserve bosques
    - 200 acres of the 1000-acre restoration goal have been restored
    - 3373 acres of bosque have been acquired since 2001.
- Threats - water table changes, soil moisture changes, erosion and deposition (has had the least attention so far, but this study won't address this).
- The SDCP proposed infrastructure solutions that could reduce stress on aquifers – advocated extensions of the reclaimed system to 49ers, Rocking K and Del Lago
    - Tanque Verde Creek now flows more frequently due to extension of the reclaimed system to the Forty-niners area.
- Tucson Water's "last on, first off policy" has been successful – the method allows for avoiding pumping in areas where natural recharge restores the aquifer; need to do the restoration in places where there is underground perching if possible.
- San Xavier District recharge - limits on groundwater pumping around San Xavier have resulted in enhancement of riparian
- Can also increase soil moisture by lowering the floodplain – harvesting water off the Oro Valley Marketplace has resulted in enhanced restoration
- Wild card is erosion and deposition – it affects riparian areas and infrastructure. Where will the sediment wind up? Will we have more riparian areas or more incision?
- There will be a continued need for floodplain management – more options are needed.
- We also need to look at the forest watersheds (Saguaro National Park partnerships).
- Our basin has around 50,000 AF of natural recharge – is there a bigger role for uplands?

Agriculture - *Brian Wong, BKW Farms*

- Pinal County farmers are reliant on Central Arizona Project Non-Indian Agricultural pool water; this will be a problem as the supply decreases into the future.
- Agriculture in Pima County is lucky to have ability to be on renewable supply and avoid groundwater pumping through partnerships with municipal entities.
- BKW farm has stopped all groundwater pumping since the late 1990s. In combination with use of renewable water, the aquifer has risen about 100 feet.
- All agriculture in the area is dependent on irrigation.

Questions/comments

- What about switching to lower water use crops?

    - The question with this is always - is there a market? There is a current demand for cotton and alfalfa. BKW has tried to switch over to niche markets of organic crops and heritage varieties that are more suited to the desert.
- How many heritage crops is BKW cultivating?
    - In total BKW farms has 4,500 acres of irrigated agricultural land. Approximately 100-150 acres of this is heritage crops.
- Do you have ideas of switching to something that could use drip irrigation?
    - All land is on furrow/flood irrigation now. There are other, more advanced forms (sprinklers and drip). The biggest problem is that the majority is of the land is leased from the Arizona State Land Department. These technologies have long pay-back horizons. It's hard to justify investing in water conservation infrastructure when the land could be auctioned at any time.
- If there was a community effort to support getting a longer lease on the land, would BKW consider that type of irrigation infrastructure?
    - Yes. But even if the local community is supportive, the biggest question is whether the State of Arizona will support it. At this point the leases are only 5 years.
- What percentage of your water is reclaimed, as part of the M&I (Municipal and Industrial) partnerships?
    - The majority is raw CAP water. No reclaimed water is used.
    - Treated wastewater from the prison does go to fields, but it's an extremely small percentage of overall use
- How does climate change affect your energy sources? Are there issues related to reliability or cost?
    - The majority of our pumps are on natural gas – it's more efficient than electricity.

Livability - *Mead Mier, Pima Association of Governments*

The Pima Association of Governments is run by the Regional Council, leadership from each jurisdiction in Pima County. Will highlight here what local governments are responsible for regarding water – public health, safety, welfare, healthy economy and quality of life.

- Economy – industrial demand for water; need to consider additional demand of new sectors.
- Safety – we've discussed flooding; some neighborhoods have no emergency access during a rainstorm – this is a future concern as flooding may increase.
- Water quality – in today's Workshop maps we've included the groundwater contamination areas.
- Subsidence – Caused by groundwater depletion, can affect the integrity of all infrastructure in our communities. Is recharge occurring in key areas to help with this? Does development need to avoid areas of future risk?
- Social - Need to consider disadvantaged populations – increased heat in the models we're using, less access to cooler green space in impoverished areas. Consider this when looking at distribution of projects for water in the environment and public landscape efforts that may be impacted by drought ordinance adaptations. Also consider cultural and heritage values of maintaining historic flows.
- Small private wells on the urban edge may not have access to renewable supply. Although they use a small amount, there are thousands of households that rely on these small wells (may need to be drilled deeper or bring in new renewable supplies). Also need to think about proximity of wells to shallow groundwater dependent ecosystems as we consider risks and adaptation strategies.

Other perspectives – open comments from participants

- At UA we hear about agro-voltaics. As we think about energy distribution, what does the water use look like for that?
- The Altar Valley Conservation Alliance is working on a watershed-wide plan. The overarching goal is to increase infiltration, which will have effects on other downstream areas. Anyone can participant in the Watershed Working Group (contact Julia Sittig).

Adaptation Strategies (Small Group Work)

Participants worked in small groups to brainstorm potential adaptation strategies for future areas of concern identified in an earlier session. In this session, the four groups were consolidated into three.

Note: Due to the early departure of some attendees, the remainder of participants were re-distributed into three groups: Blue, Red and Yellow.

Green Group - Facilitated by Colleen Whitaker

Note: This group developed strategies based on geographic area. Small numbers in parentheses refer to yellow sticky dots on blue group map (see Appendix B).

1. **Oro Valley area** (includes Saddlebrooke)
   - Issue: This area has groundwater level declines because that is the only source of water. Plans to try and get CAP water in that area to combat declines, but not sure if that will happen. Could Oro Valley wheel some water to Saddlebrooke?
     - **Strategies:**
       - Develop ordinances for new development [38]
       - Wastewater recharge and reuse facility (Saddlebrooke) [37] (*Note: Saddlebrooke Ranch already uses the reclaimed water from its treatment plant for golf course irrigation*)
         - There could be recharge but that would just be a portion.
         - Could capture and treat rainwater and stormwater.
         - Forest Service as a whole could do more to enhance infiltration.
   - Issue: Fire risk issue and increased flood risk
     - **Strategy:** Prescribed fire and thinning in Coronado National Forest [36]
2. **Summerhaven**
   - Issue: Wastewater is drained to San Pedro watershed. Need renewable supply.
     - **Strategy:** More storage (tanks); reclaimed; surface water runoff; wastewater treatment; rainwater collection [35]

- **Strategy:** change through Arizona Department of Environmental Quality Triennial Review to allow treated wastewater to flow down Sabino Creek, unless redefinition of WOTUS (Waters of the U.S.) passes [39]

3. Sabino/Tanque Verde

- Issue: Reliability of water supply: seasonal stress; fire risk; shallow ground water supplies
  - **Strategy:** Have a designated augmentation; partner sharing of water providers; expand definition of emergency to include environmental factors [34]
  - Potential issue: water quality
  - Potential benefit: "water security fund" (surcharge); could wheel water to different areas
- Issue: streamflow, dry days
  - **Strategy:** Doing in-channel recharge of reclaimed water during cool season (using existing infrastructure) [33]
  - Potential concern: Would be a managed recharge and earn 50% credit for the amount of reclaimed water infiltrated under current state law.
  - Potential benefit: recharge in higher portion of the watershed; supporting riparian systems
- Issue: Energy use/ consumption, dewatering of certain areas.
  - **Strategy:** Decentralized wastewater treatment and recharge [32]

4. Agua Caliente

- Issue: Spring dry; pumping water and lining ponds – tremendous economic cost
  - **Strategy:** Water harvesting (low-tech above spring), or use reclaimed water [28]

5. Vail

- Issue: Cienega Creek is diverted to a Del Lago golf course ponds creating invasive bullfrog habitat, impacting the environment and reducing natural recharge. There are risks to the golf course if Cienega Creek dries up.
  - **Strategy:** Supply Del Lago golf course with water from new wastewater reclamation plant (distributed decentralized wastewater recharge) to recover effluent, reuse and recharge here; or extended reclaimed infrastructure to match the standard used across the region [40]. Let Cienega Creek flow in river channel for riparian use and recharge of Vail wellfield.

6. Cienega Creek Preserve

- Issue: Increased water use in drought by wells plus surface water diversion; impacting groundwater dependent ecosystems, including perennial and intermittent surface water and wells nearby. Could become exacerbated because although currently Vail Water is getting CAP water wheeled, the group was concerned about times of CAP shortage. In addition, the Rosemont Mine would impact contributing runoff and groundwater levels.
  - **Strategy:** Manage underflow storage: Instead of diverting Cienega Creek to the Del Lago golf courses in Vail, remove the flumes that divert water and let flows stay in the channel. Del Lago golf course can then recover naturally recharged water through a well closer to Vail. To maintain the wetland, managers may want to maintain the dam which is holding sediment detaining shallow groundwater;[41]
  - Potential benefit: improves local recharge, allows water to flow through Cienega Creek Preserve; riparian benefits: The extended creek flows will have higher habitat value for

endangered species and higher (free) access for recreators than the golf ponds which house invasive species (bullfrogs). The extended creek flows will also infiltrate to replenish the aquifer.

- **Strategy**: Land acquisition along Davidson Canyon to reduce future pumping, work with Rosemont Mine owners to supply water (CAP, water harvesting, earthworks for natural stormwater recharge, effluent reclamation efforts) within the Cienega basin since open pit would divert groundwater and surface flow to Cienega/Davidson Canyon.

7. **Sopori Wash**
   - Issue: Historically an area of groundwater pumping; no longer farming there but perhaps in future; area had riparian vegetation at one time, but has been ephemeral for quite some time
     - **Strategy:** Land acquisition (SDLP) [43]
     - **Strategy:** Lowering flood plain for restoration [44]
     - **Strategy:** Beavers in Las Cienegas Preserve [45]

8. **Agricultural areas**
   - Issue: Weather concerns - higher temperatures, more storms
   - Issue: State land tenure – lack of security
     - **Strategy:** Address state land tenure; support more long-term Groundwater Savings Facilities (GSF) partnerships [46]
     - Amount of GSF water could be reduced in CAP shortages; unmaintained wells, no plan B
     - **Strategy:** Well maintenance [47]
     - **Strategy:** Fallow land, perhaps in south (must be rotational, or will result in potential dust storms)

9. **Central Arizona Groundwater Replenishment District**
   - Issue: Disconnect between wet water and paper rights; costly, water quality, supply
     - **Strategy:** Replenish credits in area of withdrawal/use; could accomplish this through policy at state level; more wheeling agreements could be a solution [26]

10. **General (non-location specific)**
    - Issue: Enhancing infiltration to improve riparian habitats
      - **Strategy:** Water-harvesting along Catalina mountain front, and/or other mountain fronts along shallow mountain areas [27]
    - Issue: How to provide conservation incentives to those using groundwater – who would fund these incentives (or range of incentives)?
      - **Strategy:** Residential efficiencies (conservation and/or education for those users)'; Could target areas where there's a particular imbalance [48]
      - **Strategy: Meter all wells (exempt or non-exempt)**
        - Potential concern: there would be a lot of push back in rural areas regarding non-exempt wells
      - **Strategy:** Need reporting outside AMA [31]
      - **Strategy:** County could apply for Adequate Water Supply rules to be adopted
      -

Red Group – Facilitated by Jessica Olson

A full-list of strategies developed is presented here, with further detail below on strategies #1-3.

1. **CAGRD reform** (Central Arizona Groundwater Replenishment District) – allows recharge in one area of the Active Management Area to offset development in other areas. Focus on multiple areas including north Marana and outlying communities. Strategy could include policy change and new infrastructure.
2. **Infrastructure improvements for recharge** at Saddlebrooke, Ajo Way Corridor Way, southwest area. Example: wheeling water for recharge (shared distribution).
3. **Rebuild habitat on the Santa Cruz and recharge river corridors** – expand credits for effluent reallocated into Santa Cruz River and Rillito confluence.
4. **More infill development** – reduces the need for outer area water development; designated water providers. Would include development policies, zoning changes, permitting solutions. Consideration - What would happen to all the places already slated for development outside centers?
5. **Green infrastructure in neighborhoods everywhere.** Prioritize areas with low canopy, flood risk, and low income areas. Will likely only see benefit in more densely developed areas.
6. **Large-scale restoration of riparian areas and flood plains, for recharge, community amenities, and stormwater capture.** Areas include: Airport Wash, Christmas Wash, BKW Farms, southern part of Tucson. Requires larger properties and low-density development.
7. **Use the Conservation Effluent Pool -** moving effluent where it's needed. Restructure the existing program to be more useful and user-friendly. May require a hydro study. Source is Santa Cruz River. Key players - Tucson Water and Pima County.

<u>More detail on specific strategies</u>

1. **Central Arizona Groundwater Replenishment District (CAGRD) Reform**: Need policy change to limit potential for offsite uses, require direct delivery infrastructure (developer pays), restrict depletions, and allow wheeling.
    - *Where?* Existing and future CAGRD subdivisions. Only 8-10 providers who don't have this issue.
    - *Why?* Policies are currently unsustainable, groundwater is decreasing, reliability issues.
    - *When?* Attention is focused NOW, solutions can be phased, legislative timing is important to consider.
    - *Who pays?* Now the homeowners pay, but this could be shifted to developers.
    - *Who has more details?* Kyle Center at ASU – Kathy Ferris and Sarah Porter; Robert Glennon; Representative Kristin Engel; Arizona Department of Water Resources; CAP
    - *Cons?* Politics, cost

2. **Infrastructure improvements for treated and untreated water.** Improve direct delivery, upgrade existing infrastructure to allow wheeling (immediate opportunity)
    - *Where?* Saddlebrooke, Saddlebrooke Ranch, Town of Oracle, pipeline for potable water, golf courses?
    - *When?* Immediate – pipeline to Oro Valley proposed
    - *Who pays?* Saddlebrooke, Saddlebrooke Ranch
    - *Who has more details?* Arizona Water Company, Saddlebrooke developers, Tucson Water, Metro Water, Oro Valley, Marana
    - *Cons?* Enormous cost. Does this drive development? Takes water from population cores.

3. **Rebuild habitat on the Santa Cruz,** other rivers and tributaries and improve reclaimed water opportunities past Drexel Road. Ties into restoration, green infrastructure, and capture recharge.
    - *Where?* Focus on visibility, biggest benefit south of town
    - *When?* Learning from Heritage project now. Plan ahead for ESA, NEPA, and other compliance and permitting; consider timing based on water levels
    - *Who?* Sonoran Institute, Julia Fonseca
    - *Cons?* It costs water to do this, balancing environmental and human values, benefits exported out of town, one size does not fit all.
    - *Who pays?* Taxpayers, rate payer

Yellow Group - Facilitated by Julia Sittig

1. **Recharge San Xavier District Arizona Water Settlements Act CAP water in the District-** 30,000 acre-feet/year project on San Xavier Reservation
    - Currently the 30,000 acre-feet (af) is being recharged in Maricopa and Pinal counties, not in Pima County.
    - Could consider Avra Valley as an alternative recharge area

2. **Maximize use of full allocated CAP water (250,000-acre feet) in basin**
    - Purpose: Build capacity to store groundwater for later use
    - Aim for 50,000-acre feet of storage, including water allocated under the Arizona Water Settlements Act (AWSA)
    - The City of Tucson, Arizona Department of Water Resources (ADWR), and Central Arizona Water Conservation District (CAWCD) are aware of the water-related numbers in this area. Reclamation would also have more details.
    - Groups that would benefit: municipalities, agriculture, Tohono O'odham Nation (TON) - AWSA water would go to the TON.
        - One of the TON's key goals is aquifer restoration. This project would also repair riparian habitat and mesquite bosques.
    - This strategy fulfills a AWSA water right, maximizes the value of the CAP system itself, and minimizes evapotranspiration losses.
    - Challenges: lack of funding, establishing trust with TON and San Xavier District, Santa Cruz wellfield might start getting pumped again, if it happens.
    - Suggested next steps: Form a collaborative group of everyone who has entitlements (to balance various interests): Reclamation, CAWCD, City of Tucson, Tohono O'odham, San Xavier, ADWR, etc.

3. **Local food production to address unstable situation** (have 3 days of storage)
    - Would require tens of thousands of acre-feet/year to devote to it.

4. **Harvest 65 billion gallons (20,000 acre-feet) of rainwater per year**
    - Use for tree canopy cover and water storage through network of dry wells (green infrastructure)
    - Dry wells are great but not necessarily sustainable

- 65 billion gallons (20,000 af) uses runoff as well, not just green infrastructure harvesting. 4.5 billion (13,800 is what could be harvested from rooftops, according to Brad Lancaster. Rooftop harvest retains 50-80% of the water.
- City of Tucson requires runoff from the road be directed into basin before it goes into a wash
- Below-ground cisterns that are well-maintained for potable water use
- Scales of rainwater harvesting:
    - Small-scale - active harvesting
    - Neighborhood scale - passive harvesting (street trees and landscapes, green infrastructure; high-volume in-ground storage (e.g., dry wells)
    - Above-ground and below-ground are possible with all scales
- Use pre-development water for riparian and natural uses.
- Enact legislation encouraging indoor non-potable water use for new commercial buildings.
    - Examples: City of Scottsdale uses toilet to tap. *(Note: Scottsdale was issued a permit for direct potable reuse by the Arizona Department of Environmental Quality but does not use recycled water in its drinking water system.)* The City of Austin, Texas requires rainwater harvesting for toilet flushing, irrigation, etc.

5. **Build new developments with rainwater storage as an integral component of the infrastructure**
    - Build new homes in developments with rainwater storage as part of lot design and common areas with below ground storage interconnected to new home rainwater storage. Scale rainwater storage to supply non-potable and/or potable demand. Contract with a well owner to supply water that could be trucked to the development during extended drought conditions.
    - At commercial scale it might work, but residential will be more difficult. Also need non-potable water storage.
    - Who pays? Homeowners? Developers? When you do the analysis for cost at micro level, it becomes very difficult. Is it still worth it if we run out of water and are last priority? Cost is really still unknown. If it's sufficiently integrated, it might be doable.
    - Suggested actions:
        - Link to someone who has a well so the water can be delivered from cistern to well (a micro-water grid). It could be within or without a service area as long as there was a contract.
        - Develop policies and incentivize to capture rainwater for home use in new developments as a backup during drought.
        - Get more info from City of Tucson, Austin, Milagro co-housing

6. **Use technology to address in-system water** (transparent interfaces)
    - Purpose: This strategy provides incentive to save water
    - Where: Golf courses, feedback from sensors that takes evapotranspiration into account, etc.
    - Example: Conflict of interest group in Phoenix for Home Owner Associations who have little incentive to save water.
    - Utilize more reclaimed water instead of giving it back to riparian area

- Use county lines as the barrier to focus recharge?
- Next steps: Study to assess how much water is available ("post-development water")

7. **Indirect potable re-use**
    - "recycled" water with advanced treatment

8. **Use wet water**
    - Holistic water use: stop recharging where you don't pump it
    - Pair recharge with recovery
    - Requires reworking of groundwater code, specifically recharge rules

9. **Characterize cost and value of water**
    - CAP has capital cost and delivery cost
    - CAGRD cost of water is over $700 acre-feet
    - California's cost of municipal water is over $1000 acre-feet
    - Quantify long-term Operations and Maintenance cost

10. **Dealing with flooding**
    - There are more intense rainstorms predicted in the future, even if fewer events
    - SHADE Tucson is trying to double the tree canopy; with green infrastructure (like Watershed Management Group), it can relieve some of the potential flooding.
    - Installing 100,000 check dams/erosion control structures high up in watershed could attenuate flood flows effectively (rather than downstream only)
    - Important consideration: What scale event are you preparing for or could you experience?

11. **Minimize impacts of pumping in areas prone to subsidence**
    - Where: southeast area near I-10 may have subsidence; little recharge. Also southwest of Tucson and north of Ajo Way Corridor.
    - Keep water levels high
    - Phase 2 will look at which areas are most affected.

12. **Encourage a flowing river in Green Valley**
    - Green Valley has a drawdown problem.
    - Increase in-channel Santa Cruz recharge.
    - Avra Valley has room for recharge basins. But then you have to get it back to Tucson. 120,000-acre feet that Tucson Water is recharging; 30,000 for the Arizona Water Rights Settlements Act (AWSA);
    - We get 180,000-acre feet in CAP water - 30,000 of it is for AWSA, another 40,000 is available.

<u>Discussion notes on CAP water allocations</u>

Numbers reported are in acre-feet

- The Tohono O'odham Nation is entitled to 66,000 acre-feet per year from the United States as part of the Arizona Water Settlements Act. Reclamation pays for delivery. Recharge credits from 28,200 acre-feet of Tucson area effluent helping pay for the delivery costs. The recharge credits

generated by this treated effluent represents Tucson's portion of the settlement with the Tohono O'odham Nation.

- 38,800 acre-feet of this 66,000 is for the San Xavier District within the Tohono O'odham Nation
- The City of Tucson's allocation is about 144,000 acre-feet.
- The Town of Oro Valley has an allocation of 10,305 acre-feet per year and the Metropolitan Domestic Water Improvement District (Metro) has an allocation of 13,406 acre-feet per year
- Tucson is currently storing water for Phoenix. We have the capacity to store more. There are three recharge projects possible, all upgradient of where there are wells. But there may not be recharge capacity in Tucson Basin.
- State Land in the Tucson area has a separate allocation of 28,000 acre-feet.
- Reclamation is paying for the Tohono O'odham Nation's water to be recharged in Maricopa and Pinal Active Management Areas. We should be storing it here.

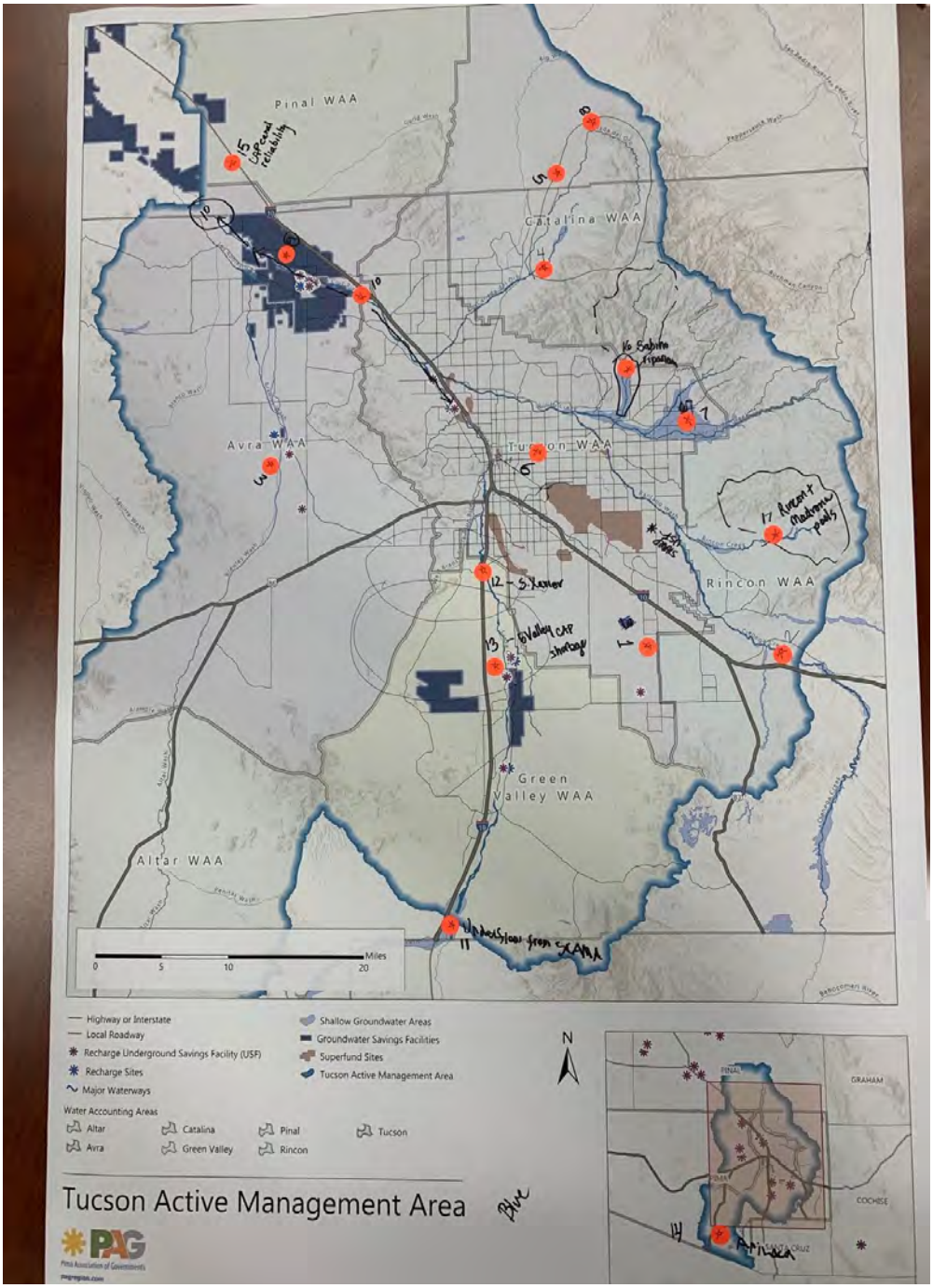
Workshop Agenda

Time	Activity
9:00 am	**Registration and coffee**
9:15	**Welcome and introductions** *Mead Mier, Pima Association of Governments & Marie Light, Pima County*
9:25	**Overview of Lower Santa Cruz River Basin Study and Purpose of Today's Meeting** *Eve Halper, Bureau of Reclamation & Kathy Chavez, Pima County*
9:45	**Setting the stage: Historic areas of concern and future projections** Mini-presentations followed by brief Q&A ● Overview of risk-based framing and climate metrics - *Kathy Jacobs, University of Arizona* (5 min) ● Review of range of climate projections, general trends and scenarios- *Lindsay Bearup, Bureau of Reclamation* (10 min) ● History of Aquifer Change - *Beth Scully, Tucson Water* (5 min) ● Overview of historic areas of concern - *Wally Wilson, Metropolitan Water District* (10 min)
10:20	**Small group discussion: Geographic areas of concern**
10:35	**Sharing back and break**
11:00	**Climate Change Impacts by Sector** Mini-presentations on the current status of: 1. Problem areas/risks/stressors 2. Objectives/ Desired Conditions (where developed) General Sector Impacts (5 min each): ● Municipal Water Supplies - *Wally Wilson, Metropolitan Water District* ● Local Environmental Conditions/Riparian Areas - *Julia Fonseca, Pima County* ● Agriculture - *Brian Wong, BKW Farms* ● Livability - *Mead Mier, Pima Association of Governments*
11:45	**General identification of problem areas** *Plenary Discussion*
12:30 pm	**Lunch** *Provided by Tucson Water*
1:15	**Small group work: Adaptation Strategies** In mixed groups participants will brainstorm potential solutions to identified geographic and sectoral problem areas
2:15	**Break**
2:30	**Sharing back from small group work and discussion**
3:15	**Criteria for selecting strategies for further evaluation** *Plenary Discussion*
3:45	**Next steps and closing** - *Eve Halper, Bureau of Reclamation & Kathy Chavez, Pima County*
4:00 pm	**Adjourn**

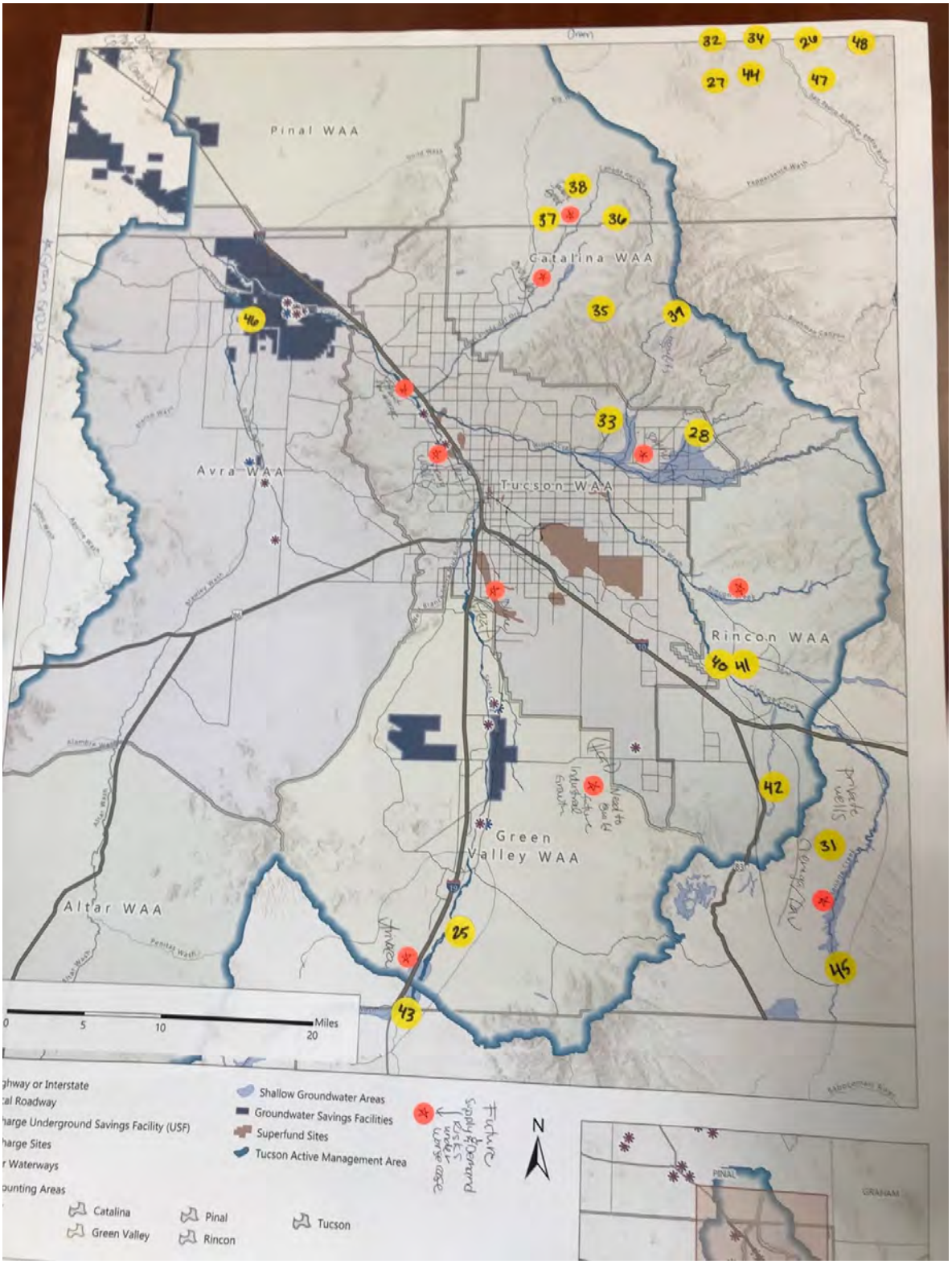
Small Group Maps – Areas of Concern & Strategies

Orange dots indicate areas of concern (from morning small group work). Yellow dots represent suggested adaptation strategies (afternoon small group work).

Blue Group



Green Group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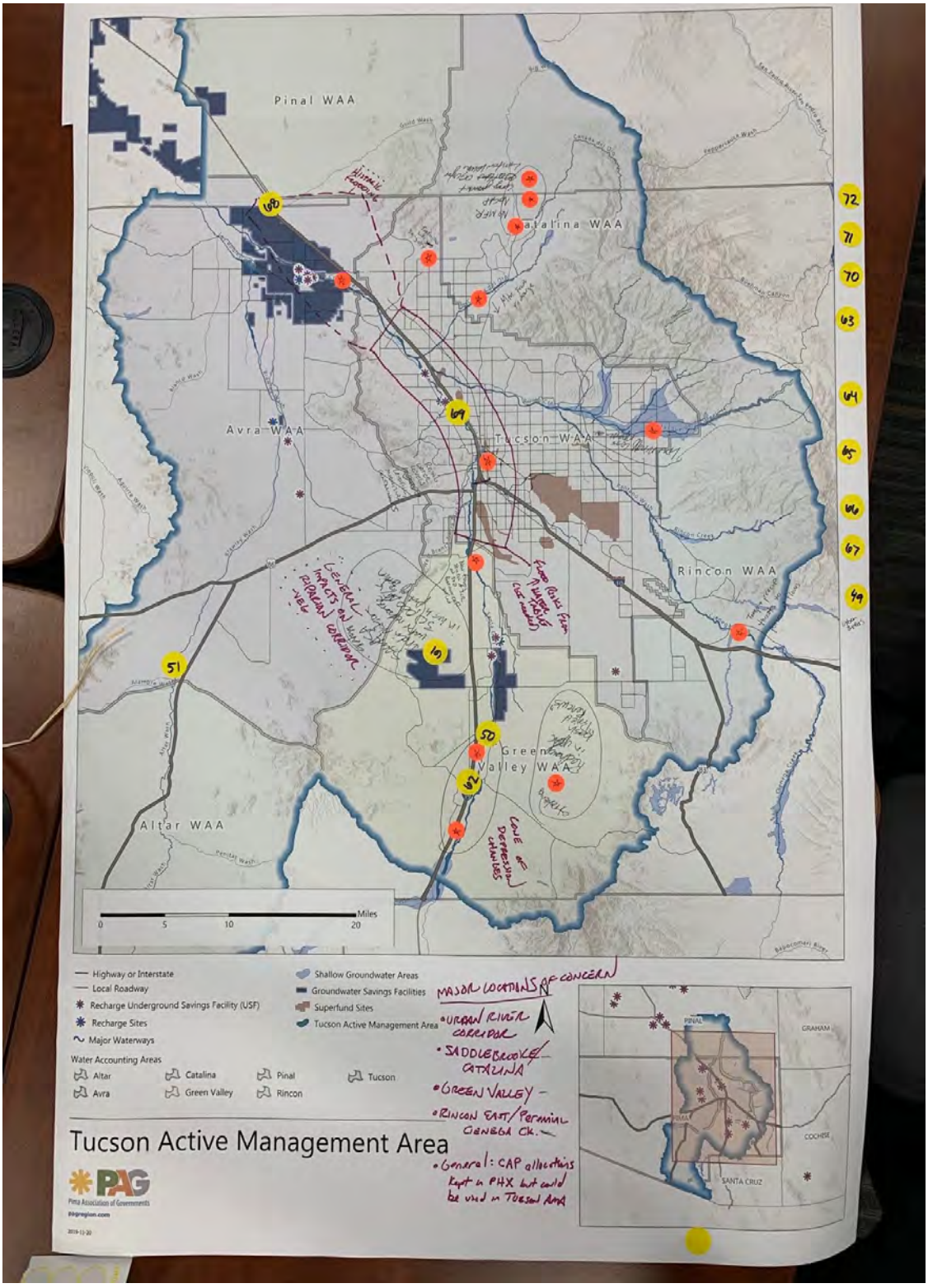
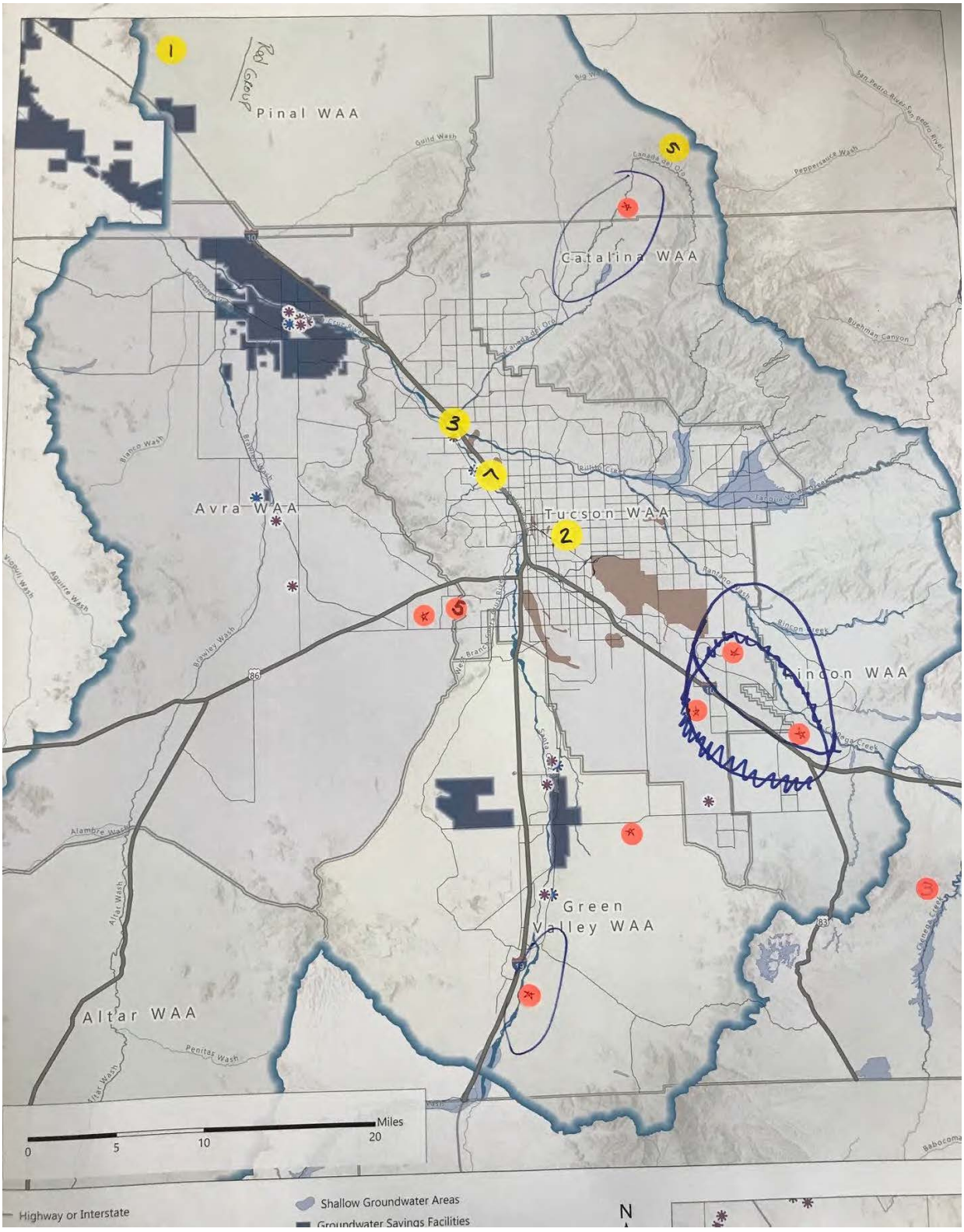
Shallow Groundwater Areas
Groundwater Savings Facilities
Superfund Sites
Tucson Active Management Area
Catalina
Green Valley
Pinal
Rincon
Tucson
N

Yellow Group



Red Group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Avra WAA
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Rincon WAA
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Altar WAA
Miles
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5
10
20
Highway or Interstate
Shallow Groundwater Areas
Groundwater Savings Facilities
N

Feedback on Initial Adaptation Strategy Screening Criteria

Criterion	**# of participants considering criterion important**
Addresses multiple adaptation objectives/sectors	12
Builds on existing resources and projects	10
Responds to urgent concern	9
Addresses vulnerable water accounting areas	9
Addresses multiple risks	9
Provides benefits to a large population	7
Addresses a priority risk	6
Promotes long-term resiliency / sustainability	3
Addresses a large geography	2
Feasibility	2
Promotes sustainable economic growth	2
Cost effective/high return on investment	2
Infrastructure availability and/or costs for improvements	1
Provides benefit to existing population	1
Deals with food stability	1
Restricts/reduces exempt wells	1
Does not support sprawl/ promotes infill and preservation of open space	1
Preserves or restores a natural system	1
Has committed, active leaders/champions	1
Address long-term impact/benefits over short-term objectives	1
Benefits long term water security and resilience across triple bottom line	1

III. Adaptation Strategy Workshop Two Summary

Lower Santa Cruz River Basin Study
Adaptation Workshop Two
February 22, 2021| Zoom Meeting

Workshop Summary

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Study Description & Meeting Purpose

The goal of the Lower Santa Cruz River Basin Study is to identify where physical water resources are needed to mitigate supply-demand imbalances due to climate change and other factors, and to develop strategies to improve water reliability for municipal, industrial, agricultural, and environmental sectors in the Lower Santa Cruz River Basin. The Study Area is identical to the Tucson Active Management Area (TAMA).

Water supply-demand projections were developed using three growth scenarios (slow/ compact, "official projections" and rapid/outward growth) and two climate scenarios (best and worse-case), for a total of six scenarios. In collaboration with Study partners, Reclamation performed a Hydroclimate Analysis to project changes in temperature, precipitation, runoff and streamflow infiltration under the two climate scenarios.

The Central Arizona Project's Service Area Model (CAP:SAM) was used to convert the climate and growth scenarios into demands by water provider and estimates of artificial recharge. The CAP:SAM projections were then used to identify locations and volumes of pumping and recharge through the period 2020 - 2060. These values were then input into Arizona Department of Water Resources' Regional Groundwater Flow Model for the TAMA to evaluate the impacts on future groundwater elevations. The next steps of the Study include an analysis of how existing water infrastructure and operations will perform under future conditions and the formulation of adaptation strategies to address water supply vulnerabilities and preserve groundwater dependent ecosystems.

Adaptation Strategy Workshop One was held on November 21, 2019, prior to the availability of groundwater modeling results. The purpose of Workshop One was to brainstorm a wide variety of adaptation strategies using existing knowledge, obtain stakeholder feedback on screening criteria and prepare to apply strategies to forthcoming groundwater model results. Strategies were based on areas known to be vulnerable to declining groundwater levels. Following Workshop One, Reclamation completed its Hydroclimate Analysis and groundwater modeling and the team synthesized the proposed adaptation strategies from Workshop One.

The purpose of Workshop Two was to present the modeling results and to refine adaptation strategies consistent with results of the groundwater evaluation. Selected strategies will undergo a high-level investigation into their costs and benefits. Finally, a trade-off analysis will be performed by the Study Partners to provide a transparent evaluation and comparison. The result of these analyses will be a range of adaptation strategies that can be proposed for future funding assistance from Reclamation.

Participants invited to the workshop were representatives of the Basin Study local cost share partners, subject experts who contributed to technical sub-teams and stakeholder advisors who expressed interest in study participation. Appendix A is the agenda for Workshop 2 and a list of participants can be found in Appendix B.

DAY ONE SUMMARY:

Lower Santa Cruz River Basin Study Project Progress - *Eve Halper, Reclamation and Kathy Chavez, Pima County*

See Presentations here:
LSCR Basin Study Catch-up Presentation:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/1.%20LSCR%20BS%20Background.pdf

LSCR Basin Study Project Progress:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/2.%20LSCR%20BS%20Project%20Progress.pdf

The Lower Santa Cruz River (LSCR) Basin Study is one of several Basin Studies currently underway in Arizona pursuant to the SECURE Water Act of 2009. It has been under way for five years (2016-2021) and is scheduled for completion in September 2021. Its goal is to identify where physical water resources are needed to mitigate supply-demand imbalances and to develop strategies to improve water reliability for municipal, industrial, agricultural, and environmental sectors. The planning horizon is through 2060 and the geographic scope is the Tucson Active Management Area.

The study entails four main steps: 1) Project future supply and demand imbalances (without adaptation measures); 2) Evaluate risks to infrastructure and other systems; 3) Develop & investigate adaptation strategies (structural and non-structural); 4) Conduct a tradeoff analysis of strategies.

Total funding is $2,065,750 and involves a 50/50 in-kind cost share between Reclamation and local cost share partners: Southern Arizona Water Users Association, Arizona Department of Water Resources, Central Arizona Water Conservation District, Pima Association of Governments, Cortaro-Marana Irrigation District-Cortaro Water Users Association and the University of Arizona.

The LSCR Basin Study uses a scenario planning approach. The scenario driving forces are grouped into climate and socioeconomic factors. The study utilizes the Central Arizona Project Service Area Model (CAP:SAM) to project future pumping and artificial recharge by water provider, and the Tucson Active Management Area (AMA) Regional Groundwater Model developed by the Arizona Department of Water Resources (ADWR) to estimate future groundwater elevation.

The development of climate scenarios began with the use of two Representative Concentration Pathways (RCPs) developed by the Intergovernmental Panel on Climate Change (IPCC). Representative Concentration Pathways are standardized time series of worldwide emissions and greenhouse gas concentrations through 2100. This study uses RCP 4.5 and RCP 8.5, but for ease of reference, we refer to RCP 4.5 as the “best case” and RCP 8.5 as the “worse case” (within the Study). Study partners reviewed the available climate projections and selected two that would best inform their information needs. More detail on the selection of climate projections is available in the Hydroclimate Analysis.

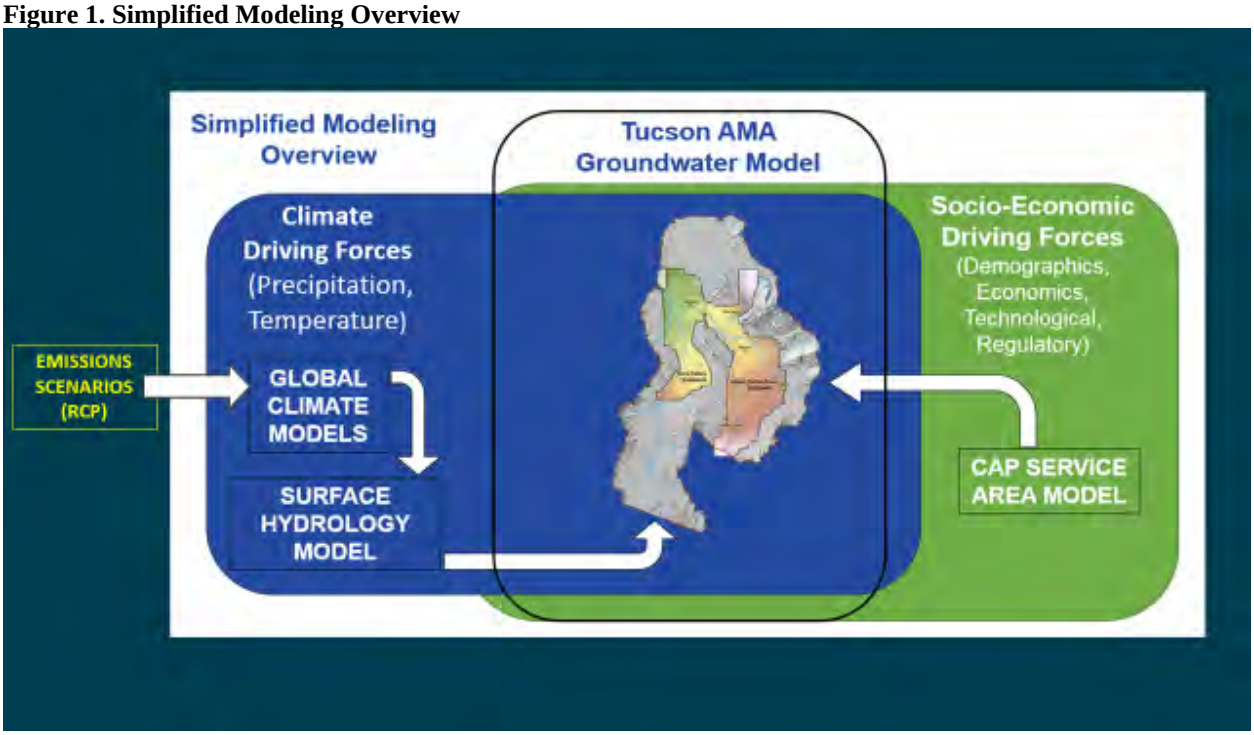
The output from global climate models includes projected changes in precipitation and temperature for the Tucson AMA; modeling has already been completed separately for Colorado River flows. The precipitation and temperature projections were input into a “weather generator”, a computer program that simulates the seasonal variability characteristic of the basin. Each projection of temperature and precipitation was input into the weather generator to produce 100 plausible temperature and precipitation time series representative of the variability in the study area. This is how the Study provides ranges of results instead of single value estimates.

The Study uses a surface water hydrology model called the Sacramento Soil Moisture Accounting Model (SAC-SMA) to convert the weather-generated time series into runoff, streamflow, soil moisture and stream infiltration, among other variables of interest. Climate projections using the "best case" and "worse-case" emission scenarios were input into SAC-SMA. The values for climate-impacted stream infiltration were used in the ADWR groundwater model to evaluate how changes in stream infiltration would affect recharge into the aquifer under a changing climate.

Socioeconomic projection were used for input into the Central Arizona Project's Service Area Model (CAP:SAM). This socio-economic modeling includes population and economic growth, housing growth characteristics, sector trends, policy changes, and behavior shifts. It also incorporates overall Colorado River Basin climate and projected changes to Central Arizona Project supplies. Three growth scenarios were selected: 1) official state projections, 2) slow compact growth, and 3) rapid outward growth. CAP:SAM was used to estimate the amount of water demand that would be available in the future for individual utilities, mines and agricultural users of Central Arizona Project (CAP).

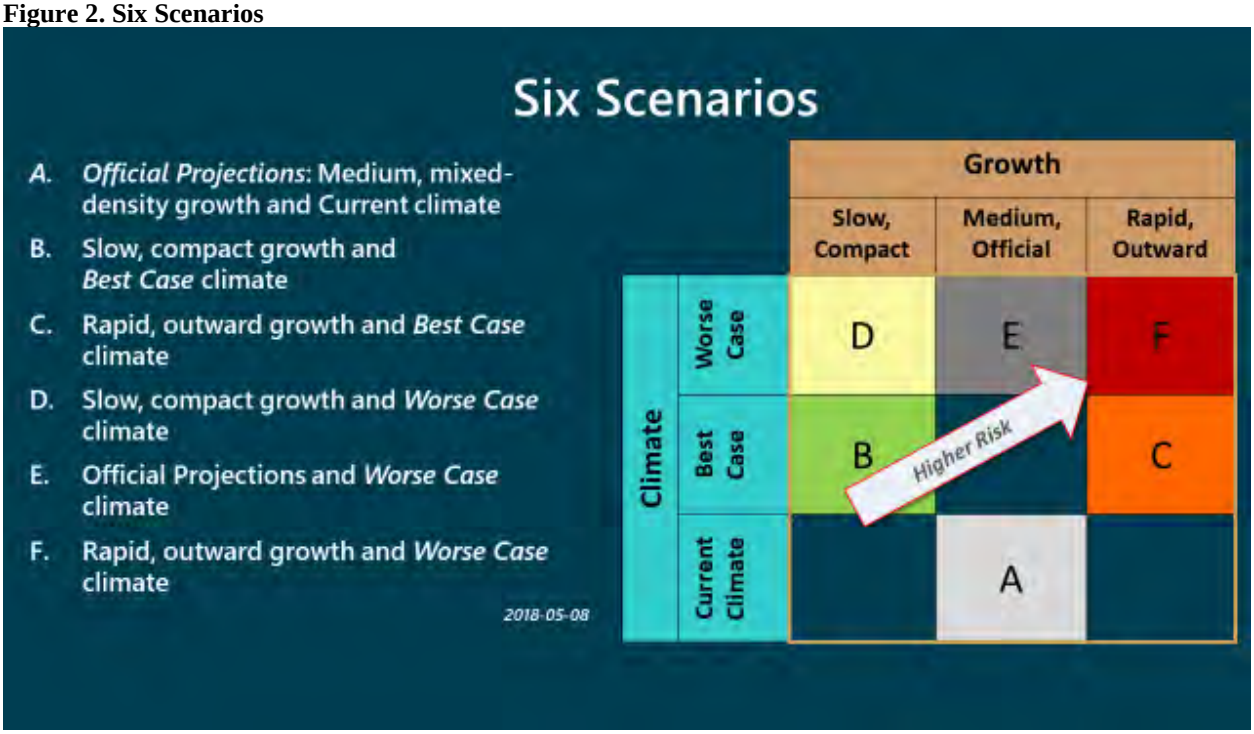
Reclamation's Groundwater Team used those calculated demands by water provider and located them as pumping within the Active Management Area. These pumping rates became inputs to the groundwater model. See Figure 1, below.

Figure 1. Simplified Modeling Overview



Six scenarios consisting of combinations of climate projections and socio-economic driving forces were selected for evaluation. See Figure 2 below:

Figure 2. Six Scenarios



Groundwater Modeling Results - *Brandon House, Reclamation*
See presentation here:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/3.%20GW%20Modeling%20Results.pdf

- Tucson Active Management Area Groundwater Model Overview:
  - Developed by the Arizona Department of Water Resources (2013) using Modflow. Annual model with no seasonal variability, 1940-2010. Three layers based on geology. Half-mile by half-mile grid cell resolution.
  - Standard Inflows: Mountain front recharge, stream infiltration, underflow from other basins to the south, artificial recharge, incidental recharge
  - Outflows: Pumping, evapotranspiration, underflow to the north out of the study area
- For results, see presentation.
- Key Takeaways:
  - Impacts of demand growth are largely driven by local decisions
  - Impacts of climate are driven by global decisions
  - Climate has a greater impact than demand growth on the overall water balance
  - Modeling informs specific four areas of concern (e.g., projected change in water level for Scenario F – worse climate, high growth scenario)
- Next Steps: Identify risks, develop and refine adaptation strategies. Participants wanting to provide feedback on adaptation options for areas in which they were not assigned were encouraged to provide feedback to bor-pxa-lscrbs@usbr.gov.

Questions & Answers, Comments:

- Why did the groundwater model data stop in 2010?
    - Historically, the groundwater model developed by ADWR was finished in 2013 so it runs through 2010. They wanted to use actual data as much as they could. Will see more detail on the visuals to understand the interim period between 2010 and 2020. 1940-2010 is the initial transient run, their major calibration period. They started in 1940 as a static period and then ran the model through 2010. From that point on they started adding years of known data and calibrating them. They're working on an update to extend the model period and other updates.

- Why was the climate calibration 1970-1999?
    - The climate analysis was not "calibrated" between 1970 and 1999. We simply present our results as the change in the thirty-year average temperature and precipitation between each of the future periods (2020 – 2049 and 2050 – 2079) and the period of 1970 – 1999.
    - 1970-1999 is the historical for calibration of surface water model. While this was a wet period in the U.S. Southwest, it has the advantage of providing a wide range of events for the model calibration.
    - For more information on this discussion, go Appendix F of this document, "Response to questions from Mark Day"

- What are the limitations of resolution of the groundwater model in developing strategies? How much better can it be and what is needed to get there? What are the limitations of resolution used in model in developing strategies?
    - Most likely the adaptation strategies won't materially differ — only the urgency. Urgency is likely to be much more political and economic rather than scientific and quantitative.

- How is Central Arizona Project (CAP) and reclaimed/wastewater discharges projected to 2060?
    - Within the CAP:SAM model there are water provider- level production factors that can be dynamically varied to project effluent volume produced through time. CAP:SAM also used information from the Effluent Generation and Utilization Reports provided by the Pima County Regional Wastewater Reclamation Department to distribute the effluent, including in storage facilities and discharge.

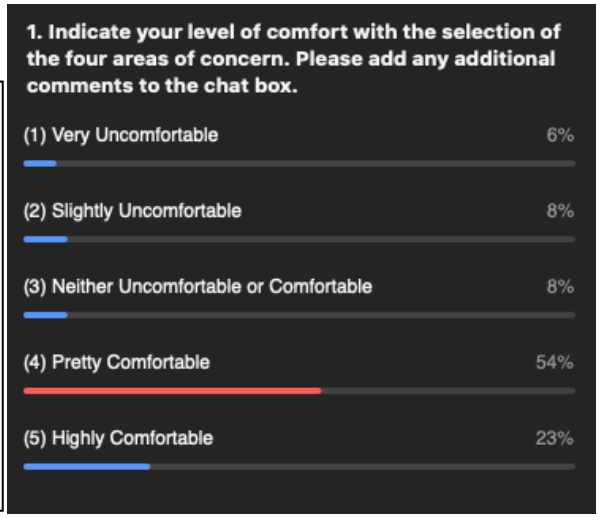
- From the Living River studies and flow extent studies we see anecdotal evidence of recharge in the three rivers, which supports this 'where will the recharge occur' plot.
- Recharge related questions: Does/can the precipitation modeling suggest anything about assuming constant Mountain Front Recharge into the future (27 TAF/yr)?
- Marana WRF underground storage facility (~1690 AF/yr) began 2018, so it is not included in ADWR model, but was included in projections, yes?
    - Yes, the Marana WRF underground storage facility is included in the projections
- Does the model include focused recharge from storm/flood water along the Rillito, CDO, Santa Cruz and other washes?
    - Yes, it does. That is the purpose of the surface water modeling. The modeling simulates recharge from effluent discharge as well as runoff in the other washes.

- Do all projections assume no Central Arizona Project cuts?
    - All of the projections assume reductions to the CAP supply. There is a significant decline assumed in CAP being stored underground over time. One of the unique aspects of this study is it evaluates the impact of climate on imported supplies (CAP) as well as local surface and groundwater changes.
- Can you share hydrographs for each red area (area of concern) similar to the one produced for the CAVSARP (Central Avra Valley Storage and Recovery Project) and SAVSARP (Southern Avra Valley Storage and Recovery Project)?
    - Yes, hydrographs can be generated for each.

Poll #1 Indicate level of comfort with the selection of the four areas of concern
See Appendix D for Map of Areas of Concern
Number of participants: 48
Poll Results:

Comments from chat box:

- Avra Valley is also a concern as it is a major storage area....
- Are we certain to omit SAVSARP area with proposed Interstate 11?
- I vote for "regional" over "local" (we need to regionalize more planning and land use decisions); and advocate for all of our decisions to try to affect climate too!



Discussion of Areas of Concern, Potential Risks and Path Forward

Risks to Municipal Water Supply - *Wally Wilson, Metro Water District*
See presentation here:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/4.%20Areas%20of%20Concern,%20Mgmt%20Obj,%20Criteria,%20Strat.pdf

- Designated providers with Central Arizona Project (CAP) allocations have been importing more water into the Tucson Active Management Area than is pumped from wells
- Imbalances in groundwater storage/use indicate growing demand without recharge/replenishment in the area of pumping (e.g. Cañada del Oro, an area of concern while their CAP water is being recharged in Marana)
- Providers with Assured Water Supply (AWS) designations have planned to serve a population within the means of their designations. Communities are reluctant to absorb areas of growth that are outside of their designation.

- Areas anticipated to support large populations without direct aquifer replenishment should expect to bear the full cost of obtaining renewable supplies, including pipeline construction and maintenance. Wheeling partnerships have been a highly successful way for providers with CAP allocations to move renewable water to meet demands without pumping localized wells.
- Exempt wells at the boundaries of the basin are typically deeper and rely on mountain front recharge which can be reduced by climate change.
- If there is less snowpack, there will be less mountain front recharge overtime.
- Continued expansion of exempt wells at basin boundaries will only exacerbate water level declines causing some older wells to go dry.

Risks to Environmental Resources - *Julia Fonseca, Pima County*
Julia Fonseca gave examples of how the Study area's environmental resources could be impacted by the projected changes in surface and groundwater.

See presentation here, beginning on Slide 4:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/4.%20Areas%20of%20Concern,%20Mgmt%20Obj,%20Criteria,%20Strat.pdf

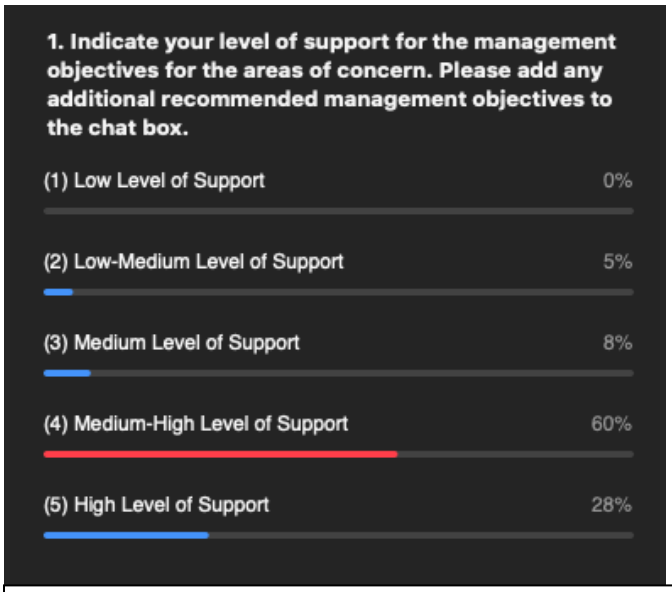
- Contaminant plumes: All scenarios have potential plume management issues. These are primarily located along Interstate 10, Interstate-19, railroad, and near landfills. With groundwater pumping there is a potential for mobilization of contaminants.
- Stream flow and vegetation growth: In all scenarios in the San Xavier District, the Lower Santa Cruz River rises, benefitting riparian areas in the root zone. This occurs in scenarios B and C in Tanque Verde Wash and Rillito River.
- Desiccation:
    - Rillito/Tanque Verde/Sabino Canyon: Scenarios E & F
    - Rincon/Las Cienegas: All scenarios
    - Sutherland/ Cañada del Oro: All scenarios
    - Ventana: All scenarios
- Potential for Subsidence:
    - Pima Mine Road: Scenarios C, E, & F; Avra Valley: E & F and possible impacts to the CAP canal

Questions & Answers, Comments:
- Decreasing groundwater level impacts on recharge pits is also a concern at Pima Mine Road area Upper Santa Cruz River.
- Are we considering possible Rosemont mine pumping impacts?
    - These are considered in Scenarios C&F

Management Objectives for Areas of Concern – *Kathy Chavez, Pima County*
See Appendix D for Map of Areas of Concern

Key Areas of Concern	**Key Issue (Historic and Future)**	**Management Objective**
Area #1 Sabino Canyon Tanque Verde Wash	Groundwater depletion, within and outside of riparian areas (shallow and deep aquifers) Reduced surface base flows. Larger events causing flood erosion/sediment issues	1. Riparian protection 2. Water level restoration 3. Reduce groundwater demand and drawdown 4. Flood attenuation
Area #2 Cañada del Oro Saddlebrooke	Groundwater depletion, within and outside of riparian areas	1. Riparian protection and water level restoration 2. Reduce drawdown
Area #3 Southeast Tucson Vail Cienega Creek	Groundwater depletion, within and outside of riparian areas (shallow and deep aquifers)	1. Riparian protection 2. Water level restoration 3. Reduce groundwater demand and drawdown
Area #4 Green Valley Sahuarita	Groundwater drawdown due to industrial, municipal, and agricultural use, resulting in cones of depression	1. Reduce drawdown and restore groundwater levels 2. Protect riparian habitat in Canoa Ranch area

Poll #2 Indicate level of support for Management Objectives for the areas of concern
Number of participants: 36
Poll Results:



Comments from chat box:

- Water levels in the Avra Valley around the CAVSARP/SAVSARP recharge areas were historically pumped down by agricultural wells far more than what projected pumping will do. Most, if not all, subsidence should have occurred prior to the start of recharge. There is the potential for land rebound. However, I don't think there would be much potential for land subsidence.
- Did the SAC-SMA model consider a change in vegetation cover on the mountain upstream of Sabino and the CDO? We think climax vegetation may change resulting in more runoff and less moisture on the mountain.
    - No, vegetation change was not part of the surface hydrology analysis
- Glad we are including riparian areas as part of what needs to be supported by our water
- The recent flooding on Sabino seems mostly related to climate and not management. Three floods since 1999 have been larger than the ones observed since the early 1930s when gaging started.
    - I believe when I last looked that the number of no flow days from Sabino, it has increased over the decades, but the total volume of streamflow has also increased indicating a flashier system
    - Perhaps it is both forest health linked to climate change and forest management
    - Or higher volume precipitation events occurring less frequently.
    - Don Falk and Jim Malusa from the University of Arizona are looking at what may be post-fire climax vegetative cover on the Catalina Mountains. We have seen warmer vegetation types populating further up the mountain in the wake of the previous fires.

Criteria for Review of Adaptation Strategies – *Neha Gupta, University of Arizona*

See presentation here, beginning on Slide 5:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/4.%20Areas%20of%20Concern,%20Mgmt%20Obj,%20Criteria,%20Strat.pdf

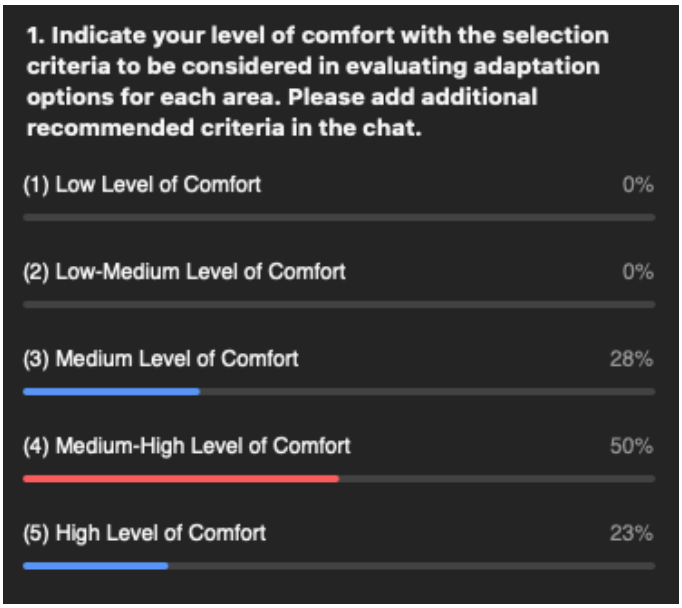
- Purpose of the criteria is to systematically review the merit of proposed adaptation strategies across multiple perspectives: water for society, environmental, and broader considerations.

- Water for Society:
    - Developed by demand sub-team consisting of municipal and industrial water users who need to comply with Assured Water Supply (AWS) rules.
    - Criteria:
        - *Minimizes impacts of pumping to parts of the aquifer vulnerable to storage depletion*
        - *Minimizes impacts of over-pumping in aquifer regions connected to riparian areas*
        - *Minimizes costs of new infrastructure*
        - *Minimizes costs of operations and maintenance*
        - *Promotes water supply reliability*
        - *Has a significant impact on the projected supply/demand imbalance*

- Environmental Concerns:
    - Protect and enhance environmental resources and maintain environmental quality of life. Environmental quality of life is broadly defined, spanning urban and ecosystems.
    - Criteria:
        - *Enhances or protects high value habitat*
        - *Promotes landscape connectivity*
        - *Protects water quality*
        - *Promotes accessible recreational opportunities*
        - *Enhances or protects Cultural /Heritage values*
        - *Reduces flood risk*

- Broader Considerations:
    - Big picture reflection and considerations in evaluation adaptation strategies.
    - Criteria:
        - *Provides benefits to a large population*
        - *Addresses multiple adaptation objectives/sectors (multiple co-benefits)*
        - *Addresses a priority risk*
        - *Builds on existing resources and projects/leverages existing investments*
        - *Low cost relative to benefits*
        - *Low opportunity cost*

<u>Poll #3 Level of comfort with the selection criteria to be considered in evaluating adaptation options for each area.</u>
Number of participants: 40
Poll Results:



Synopsis of Strategies developed in Adaptation #1 Workshop (held November 21, 2019) – *Kathy Jacobs, University of Arizona*

See presentation, starting on Slide 11:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/4.%20Areas%20of%20Concern,%20Mgmt%20Obj,%20Criteria,%20Strat.pdf,

Also see Appendix E: Strategies to Address Imbalances between Supply and Demand

See results of Workshop 1:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/20191121Adaptation_Strategy_Wkshp_Summary.pdf

Notes:

- A synopsis of adaptation strategies for each area is provided in the attached handout.
- At Workshop One, participants didn't have modeling results yet but had good guesses about where there might be areas of concern. Participants worked on adaptation options based on these assumptions. Ultimately, most anticipated areas of concern were corroborated by modeling, but others did not. Some concerns named by participants in Workshop One did not have to do with supply and demand.
    - **a.** The areas that are red (high risk/areas of concern) are actually areas of opportunity, because we will work on adaptations for these areas of need.
    - **b.** The handout provides streamlined results – from around 70 strategies brainstormed at the workshop, the leadership team has condensed to 8 categories of adaptation options:
        - **i.** Natural channel design
        - **ii.** Watershed & Riparian Protection
        - **iii.** Maximize Use of Wastewater
        - **iv.** Maximize Use of Stormwater
        - **v.** Improve Water Delivery Infrastructure
        - **vi.** Reduce Local GW Pumping
        - **vii.** Recover stored water in area of hydrologic impact and/or change recovery criteria
        - **viii.** Agricultural/mining
    - **c.** The goal is to select 3-4 key strategies for each area of concern during the breakout groups.

First Impressions of Proposed Adaptation Strategies:

- It would help to know water usage by sector to target reduction strategies. Are there some areas of the county where residential water use is higher to target conservation efforts there?
    - Graphs from Reclamation's groundwater model show water per year used by sectors and more information at ADWR.
    - The municipal sector uses the most water but also has already reduced their per capita consumption significantly. And the vast majority of what previously was groundwater use is being replaced by CAP supplies.
    - All large users of groundwater in the AMA are already subject to mandatory conservation requirements.
    - A lot of agricultural use in the AMA is municipal-level Central Arizona Project water used in Groundwater Savings Facilities

- Would also help to know where the largest impact can be realized per dollar/effort invested.

- This is what is going to be evaluated

- A few ideas from the group prior to tomorrow's discussion:
  - Establish consistent planning, zoning and building codes across the state to reduce potable water demand, encourage water harvesting and other green stormwater infrastructure, and reduce greenhouse gas emissions (including use of natural gas for heating and cooking).
  - Evaluate individual capital improvements in a circular or regional context. For example, siting a wastewater treatment facility at the lowest end of a basin because it is the least expensive disregards the cost of moving reclaimed water from its point of production back up-basin to the areas where in-channel recharge would be most effective.
  - Improve equitable and inclusive economic markets to facilitate reductions in agricultural water use where residential growth is permitted/desired.
  - Collect and maintain groundwater extraction data for all wells (may require legislation).
  - Enact AMA-type legislation state-wide.

- Agree about capital improvement location and use of septic/package plants. Sadly, planning and zoning codes are consistently malleable.

- Does mining have conservation requirements? Yes, but this sector is not required to move to the renewable supplies, as the municipal sector is.

- Designated water providers probably have more leverage than zoning requirements to control water use.

- Realizing we are looking at multiple benefits, some of these strategies may directly accrue to a water provider's portfolio (e.g. E & C). Reclamation and the Southern Arizona Water Users' Association (SAWUA) represent water owners and providers. What is the benefit of things like Natural Channel Design to water providers?
  - This is an opportunity to enhance quality of life, reduce flooding and potentially increase water recharge

- When we're done, more explanation is needed of how wet/dry periods are built into projections, and how much Central Arizona Project cuts have been assumed...
  - Austin Carey (Central Arizona Project): 3 "traces" of magnitude, frequency and duration of reductions to CAP supplies. Each of these is associated with a climate scenario.
  - Worse case years – a shortage is assumed every year and later in the projection period, reductions of one million acre-feet on CAP system
  - This is equivalent to Tier 2b or Tier 3 under the Drought Contingency Plan
  - This scenario really "stresses the system" to see if it can withstand deep reductions in CAP supplies

- How does the Utah State study that was recently published (and reported by Tony Davis in the Arizona Daily Star) affect CAP reductions?
  - This scenario planning process used a "worse" case not "worst" case; the new Utah State study is largely consistent with prior work by B. Udall and J. Overpeck, but it does project even larger reductions to Colorado River flows with more warming
  - It will be very difficult to recalculate CAP reductions and still complete this study by September. Each new report that comes out can't be reasonably accommodated by the work being done for this study. That being said, CAP believes the anticipated reductions are conservative.

    - We are seeing a more rapid climate response than we did when we started in 2015. But, this is a start to move towards a conversation about adaptation.
    - This is a very new/progressive modeling effort – groundbreaking: impacts of climate change on CAP and locally on SW and GW system; combining them with projected demand by sub-area within the AMA; and considering riparian protection as a legitimate water management objective

- Regarding the land use dimension...what is the spatial distribution of demand between scenarios? Because in some cases, land use can ameliorate climate change stresses...
    - The spatial distribution of demand is rooted in 1) the CAP:SAM projections for where growth will happen and 2) existing locations of production wells.
    - All existing non-exempt wells are in the groundwater model, pumpage is projected for each scenario
    - With regard to wells that may run out of water in the most extreme scenario, this demand was distributed within the same cell of the model, which is the likely location of any new wells.
    - Groundwater pumping outside of established service area is represented in the CAP:SAM
    - These areas won't see replenishment without an adaptive strategy
    - CAP:SAM matched official decadal population projections and distributed them spatially – on the Transportation Analysis Zone level, generated by the Maricopa and Pima Association of Governments. Used them as control totals (population #) through time. Also developed alternative spatial distribution scenarios where we matched total # with official projections but distributed them spatially differently (infill/spread).
    - In the case of outward growth, we take growth from the metropolitan area and distribute it outward, and vice versa for infill
    - If we could understand what makes a difference in our area then we might be able to find solutions
    - In general, the more compact the growth is, the more likely you are to be using renewable water supplies, meaning you are within a designated water provider's service area. It is not efficient to build pipelines to deliver renewable supplies to areas of low population density. Much more efficient to get renewable supplies to people at a higher population density, unless a residence can be a "net zero" water user
    - Effects compound as time goes on.
    - Which supports the concept of regulating new development to reduce climate impacts

- We need a scenario that includes Lake Mead at an elevation below 1025 feet. There are shortages in the scenarios that represent elevations lower than 1025 feet in Lake Mead.
- Climate change results: the table presents the differences between the future period and the period of 1970 – 1999. It gives an idea of the rate of change. The climate model runs begin in 2006, it is not possible to incorporate information on conditions that occurred last year.
- Question about inclusion of the period between 2000 and 2020 in the climate model: see Appendix F
- What looks extreme today may not appear to be extreme tomorrow. In particular, intensity of precipitation is predicted to increase.

DAY TWO SUMMARY

Information Needed by Reclamation and Overview of Process – *Mark Spears, Reclamation*

See presentation starting on slide 5:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/mdocs/5.%20Info%20Needed,%20Brkout%20Grps,%20Discuss.pdf

The recommended adaptation strategies from this workshop will be undergo a cost/benefit analysis per the Basin Study Plan. Strategies will need to have sufficient detail to develop conceptual cost estimates.

Breakout Groups Discussion - *Kathy Jacobs, University of Arizona*
Participants were assigned to one of four facilitated breakout groups where each group discussed two areas of concern. Appendix C summarizes the breakout group discussion of strategies missing, the most promising strategies and why and suggestions for implementing promising strategies. Maps of each of areas of concern were provided to the breakout groups (see Appendix D). Proposed Adaptation Strategies identified in Workshop 1 were used as a framework for discussion (see Appendix E).

- Cañada del Oro and Saddlebrooke
- Tanque Verde Wash and Sabino Canyon
- Southeast Tucson, Vail and Cienega Creek
- Green Valley and Sahuarita

Reassemble in Plenary and share findings/ Discuss path forward
Each breakout group reported on the most promising strategies discussed and why. A summary of the most promising strategies is provided below.

Recommended Strategies by Area of Concern:

Cañada del Oro Wash (CDO), Saddlebrooke	Natural channel design: enhance stormwater recharge/control erosion through gabions/check dams; augment levees and increase mountain front recharge in uplands; restore riparian vegetation and water levels.	Install Green Stormwater Infrastructure /Low impact development: rainwater and stormwater in new construction in Arroyo Grande area. Improve household water conservation.	Construct reclaimed water line to the upper watershed from the Santa Cruz River at Trico Road to the CDO Wash and recharge in CDO Wash.	Improve Central Arizona Project delivery capacity along Pinal County line for either direct delivery or in stream recharge in the CDO Wash.
Tanque Verde Creek / Sabino Canyon	Construct a water service interconnect with Tucson Water to serve CAP to Metropolitan Water District's Hub service area and other areas that rely on local wells.	Evaluate reclaimed water rate decrease to incentivize additional use of reclaimed in lieu of groundwater.	Construct check dams and other flood water retention structures to improve recharge along Tanque Verde Creek and Sabino Creek upstream of the areas of projected groundwater declines.	Construct reclaimed water extension to Agua Caliente Park and discharge to Agua Caliente Wash to recharge groundwater and enhance riparian habitat.

Southeast Tucson/ Vail/ Cienega Creek	Expand Tucson Water's wheeling of CAP water into this area; explore delivery by Tucson Water to private well areas and/or recharge CAP closer to area of hydrologic impact.	Wastewater: 1. Extend reclaimed water infrastructure to Del Lago golf course in lieu of stream diversion at Cienega Creek 2. Use reclaimed water at Rocking K development 3. Treat and use wastewater locally	Natural channel design: enhance stormwater recharge/control erosion to enhance groundwater recharge	Install Green Stormwater Infrastructure /Low impact development: rainwater and stormwater in new construction. Improve household water conservation
Green Valley Sahuarita	Natural channel design: Santa Cruz River restoration and bank stabilization at the downstream segment near San Xavier District and upstream of Continental Road. Install gabions along the downstream, northern segment of the Santa Cruz River, especially near San Xavier District to restore river function and riparian habitat	Maximize use of stormwater and rainwater harvesting. Install Green Stormwater Infrastructure and Low Impact Development in new construction; collect rainwater in Sahuarita and Lee More Wash Drainage. Improve household water conservation	Wastewater: Construct a sub-regional water reclamation plant near Sahuarita and discharge to in channel recharge in the Santa Cruz River	Extend CAP water infrastructure to upper Santa Cruz River and in stream recharge near Sopori Wash

Plenary discussion topics

- In Sabino Canyon and Tanque Verde Wash, connecting the Metro Water Hub service area to Tucson Water's infrastructure is constrained by the costs, not infrastructure availability according to Wally Wilson of the Metro Water District.
- Participants discussed the cause of groundwater level declines north of Cloud Road. The water level declines are not coincident with Hub's pumping wells south of Cloud Road. Instead, the water level declines (red area) are associated with dozens and dozens of private wells in the area just north of Cloud Road.

- The groundwater model may not be specific enough to accurately portray water level changes in that area given that it is adjacent to the model boundary. The researchers will need to verify the model projections.
- Another alternative for this area is to redirect reclaimed water upstream along Sabino Canyon Wash to supply riparian areas during times of drought. Given the high quality of reclaimed water from Agua Nueva and Tres Rios Water Reclamation Facilities, additional volumes could be released when feasible, such as during the winter months when reclaimed water demand is low to restore the shallow aquifer water levels.
- Hub's service area is nearly built-out, meaning there are just a few properties to be developed that would add water demand. Demand has declined somewhat to 800 AFY in previous years and rose to 900 AFY last year due to drought conditions. This means the upper limit of water to be supplied would be 900 AFY. This was confirmed by Wally Wilson of the Metro Water District.
- Tucson Water's Pre-Annexation Development Agreement (PADA) could be an obstacle for other communities to obtain renewable supplies.
- Structured water rates provide incentives to conserve water. This type of structure also allows recovery of costs invested in the water system.

Next Steps: Concept Level Analysis of Costs/Benefits/Considerations – *Eve Halper, Reclamation*

- We will be developing conceptual projects using the feedback that we received.
- We will send out descriptions to you and requesting feedback.
- We want to involve people who are interested in developing some of these ideas. If you are interested in working on a particular idea, please put your name in the chat.

Adjourn

Appendix A – Workshop 2 Agenda

Lower Santa Cruz River Basin Study
Adaptation Strategies Workshop #2
Day One | February 22, 2021 | 1:00-5:00 pm

Time	Topic	Leader
1:00	**Lower Santa Cruz River Basin Study Background** (Optional presentation for new participants and those who wish a detailed refresher on the study to date)	Kathy Chavez, Pima County Eve Halper, Reclamation
1:45	**Break**	
2:00	**Welcome and Introductions, Purpose of Meeting, Review Agenda for the Workshop** (& technical instructions for zoom)	Marie Light, Pima County
2:10	**Lower Santa Cruz River Basin Study Project Progress** (Presentation/short overview of key phases, including scenario development)	Eve Halper & Kathy Chavez
2:25	**Groundwater Modeling Results** • Modelling Outcomes – Brandon House (45 minutes) • Questions (10 minutes) Q&A on the modeling and results, moderated by Kathy Chavez **Poll #1 Indicate level of support for areas of concern**	Brandon House, Reclamation
3:20	**Break**	
3:30	**Discussion of Areas of Concern, Potential Risks and Path Forward** ● Water Supply ● Environmental Issues	Wally Wilson, Metro Water & Julia Fonseca, Pima County
3:45	**Management Objectives for Areas of Concern** (Handouts: maps, management objectives) • Sabino Canyon and Tanque Verde Area • Cañada del Oro and Saddlebrooke Area • Southeast Tucson, Vail and Cienega Creek Area • Green Valley and Sahuarita Area **Poll #2 Indicate level of support for Management Objectives**	Kathy Chavez
4:00	**Criteria for Review of Adaptation Strategies** **Poll #3**	Neha Gupta, University of Arizona

4:20	**Synopsis of Strategies developed in Adaptation #1 Workshop (November 19, 2019)** • Original results • Streamlined results (Handout: Synopsis of Strategies)	Kathy Jacobs, University of Arizona
4:45	**First impressions of Proposed Adaptation Strategies** (Handout: Adaptation Strategies with descriptions) • Do we have the right strategies? Are any strategies missing?	Kathy Jacobs
4:55	**Review of Goals for Day Two; Adjourn**	Eve Halper

Day Two | February 23, 2021 | 9:00 am – noon

Time	Topic	Leader
9:00	**Welcome, Review of the Day**	Marie Light
9:05	**Information needed by Reclamation to develop high-level cost and benefit estimates for Adaptation Strategies,**	Mark Spears, Reclamation
9:15	**Explanation of Breakout Groups and Maps**	Kathy Jacobs
9:20	**Breakout group discussions to refine adaptation strategies** **Each pre-assigned group will discuss strategies for one of the following areas of concern:** • Sabino Canyon and Tanque Verde Area • Cañada del Oro and Saddlebrooke Area • Southeast Tucson, Vail and Cienega Creek Area • Green Valley and Sahuarita Area Structure of discussion: What is missing? What should be removed? Details to be considered within each location and option	Facilitated by Kathy Jacobs, Eve Halper, Kathy Chavez and Neha Gupta
9:55	**Break**	
10:05	**Breakout Groups Continue - Second area of concern**	Facilitated by Kathy Jacobs, Eve Halper, Kathy Chavez and Neha Gupta

10:40	**Reassemble in plenary and share findings/discuss path forward** • Refinements/additional strategies • Refinements for specific areas Discussion of priority Adaptation Strategies to be evaluated for each area Identify 3 top priority Adaptation Strategies in each area, by consensus	Facilitated by Kathy Jacobs
11:40	**Next steps: Concept Level Analysis of Costs/Benefits/Considerations** (request for volunteers)	Eve Halper
12:00	**Adjourn**	

Appendix B – Breakout Group Discussions and Plenary Notes

1. Cañada del Oro (CDO) and Saddlebrooke

Major categories of strategy missing:

- Flood attenuation and managing flood risk – augment or install levees and increase stormwater recharge in uplands.

Most promising strategies & why:

- Natural Channel Design is important for mountain front recharge (MFR). MFR is better because wastewater and stormwater are linked to water quality issues.
- Watershed & Riparian Protection will go a long way to increasing aquifer recharge - good passive approach to getting more aquifer recharge into that area. More physical stream channel restoration projects needed.
- Improve Water Delivery Infrastructure
- Maximize Use of Stormwater by harvesting roof runoff in new housing stock as retrofitting is harder. Capture runoff from hardscapes.
- Maximize use of wastewater

Suggestions for implementing promising strategies:

- Natural Channel Design
    - Arroyo Grande is an opportunity for increasing sinuosity to keep the water there. As Arroyo Grande is built out, there will be some new problems associated with the tremendous amount of hardscape. Avoiding channelization in new development and encourage passive rainwater harvesting.
    - Low Impact Development could be used to help recharge and control erosion. Slow the flow of runoff and improve recharge through channel gabions. Not sure how much this would help water supply, but it would reduce erosion.
    - Need to think big. There are big pots of money coming forward from the Federal Emergency Management Agency for climate, so there may be funding available for flood control and other projects.

- Watershed & Riparian Protection

- Improve Water Delivery Infrastructure
    - Improve, increase, and fully maximize use of CAP water by improving infrastructure. This would have largest impact of any strategy on water levels and long-term storage. Get water into more areas, as many areas as possible, as early as possible.
    - Extend a pipeline with CAP water for 1) direct use of CAP water 2) recharge in the Cañada del Oro, 3) up to the north of Tortolitas into Pinal County
    - Pump water to areas that are having well declines or wells removed.
    - Extend a pipeline from CAP canal to Saddlebrooke area for a Central Arizona Groundwater Replenishment District (CAGRD) replenishment recharge facility

($20 to $50 million??). Use existing arroyos and channels, with addition of check-dams. There may be a nitrate flush. Is the extra distance worth it?

- Maximize Use of Stormwater
    - Need a legal decision about adding check dams to tributaries to Waters of the United States (WOTUS). Might affect downstream water rights. Implement check dams higher up in the watershed to avoid legal challenges. Look at land ownership in those upper watershed areas.
    - Stormwater treatment: improved water quality would increase water supply as there are other uses for stormwater
    - Rainwater Harvesting
        - Residential rooftop rainwater harvesting, for all residences not just new development; incentives for retrofit.
        - Need to incorporate Green Stormwater Infrastructure and Low Impact Development into all new construction (residential and commercial) as an exaction and condition of approval. It is far less costly than retrofitting to incorporate it into the design phase of construction.
        - Also covering hardscapes, such as parking lots, with solar panels that can also capture rainwater. Important to emphasize the potential for partnering elevated solar panels over asphalt parking lots that can also harvest clean rainwater, avoiding contamination by the asphalt, cars, etc.
        - Embrace and stress “One Water”
        - Policy action possibilities
            - Requiring rainwater harvesting
            - Eliminate or minimize outdoor irrigation
            - Limiting amount of water that can be used

- Reduce local groundwater pumping
    - AZ State Land Department has been trying to implement related actions, but there has been pushback. Main concern is agricultural lands.
    - Given the significant drawdown in scenario B, add conservation requirements as a policy recommendation for the upper valley.
    - Model doesn't take into account exempt wells. Locations and distribution of exempt wells will need to be taken into consideration for adaptation strategies
    - Groundwater in Saddlebrooke area very much dependent on mountain front recharge and snowpack - must be taken into account.
    - Is water supplied through private wells in Saddlebrooke area? Saddlebrooke is supplied by private (non-exempt) wells that are tied to the development. The developments are Central Arizona Groundwater Replenishment District Member Lands. The developments pay about $600/acre-foot to replenish the volume of groundwater they pump each year. The replenishment is done in Marana, not where the pumping occurs. The wells associated with Saddlebrooke are non-exempt wells that serve the neighborhood scale service area. Each house does not have a well.
- Maximize Use of Wastewater

    - Evaluate moving reclaimed water that currently flows past Trico Rd to an in-channel recharge project on CDO.
    - Better water quality would help increase water supply
    - Better use of wastewater for other uses
- Comment: This region is very keyed into the desert and nature and there would be public support. We need to think big as well as small in this area.
- Public Education
    - Education about what these strategies are so the public is aware.
    - How the public can get involved?

2. ***Southeast Tucson, Vail and Cienega Creek***

Major categories of strategy missing:

- Establish planning, zoning and building codes across the State to reduce potable water demand, encourage water harvesting and other green stormwater infrastructure, and reduce greenhouse gas emissions (including use of natural gas for heating and cooking).
- Develop demand management and AMA policies to address growth in areas without access to a reliable water supply.

Most promising strategies & why:

- Recover water in area of hydrologic impact and/or recharge Land use and/or AMA policy changes could reduce the amount of growth that occurs outside of areas with access to CAP
    - Wheeling helps address this in Vail
    - Their Assured Water Supply does not include all of their CAP allotment
- Improve Water Delivery Infrastructure to expand delivery to private areas or decreasing public well pumping in the basin edge area. May be able to stop diverting streamflow at the Del Lago dam and release it back to the channel if an alternative supply is available.
- Reduce local groundwater pumping Limit over-pumping and apply conservation policies. The solutions are straight-forward though more complex because there are so many stakeholders and the area is vulnerable to outward growth. address exempt wells and pumping. This is a delicate system, and it doesn't take many wells to impact groundwater levels.
- Maximize use of wastewater Rocking K and Del Lago could use treated wastewater. As growth increases, so does the wastewater flows in this area. Scalping plants might be more viable. Move reclaimed water higher into the watershed
    - While downstream treatment is less expensive, the wastewater recharge isn't returned upstream areas where the groundwater pumping occurred.
    - SHARP is a good example; Vail could apply this in the shallow groundwater areas

Suggestions for implementing promising strategies:

- Recover water in area of hydrologic impact and/or recharge Package wastewater plants
- Improve Water Delivery Infrastructure Install infrastructure that moves water upstream to balance groundwater pumping

    - Big picture, a pipeline from the CAP canal either to recharge or a treatment plant along Sahuarita Road would be a perfect world adaptive strategy on the infrastructure.
    - Can designated providers deliver water by truck to rural out of service area residences?
    - Consider how water is being used in the area - some ranching, some crops, some mining, some small businesses based out of home. Land owners might be open to trucked in water to fill tanks for household use.
    - Some high growth areas (Houghton area) are in Tucson Water's service area and will be served with renewable supplies. May need to focus on future developments outside of the TW service area.
    - Public water providers are moving away from production wells. Some water providers use bulk meters - purchase from water provider and fill tanks for household use.
- Reduce local groundwater pumping Consider conservation incentives, rather than requirements - implement on a household scale. (Carrot, rather than stick.)
    - AZ Land and Water Trust is offering short-term conservation-based incentives, such as paying to fallow land - leasing water rights for a period up to 4 years.
    - Use incentives as they would be very receptive to increasing recharge in upland areas and in those area near the riparian zones.
    - Use a non-water provider funded rebate program for toilets, washing machines, rainwater and grey water systems to incentivize conservation in areas with private wells.
    - If the wells are exempt, there is no water right to buy. Only non-exempt wells will have a water right attached to it.
- Watershed & Riparian Protection
    - Mountain front areas host delicate riparian areas supported by shallow groundwater
    - Riparian habitat could benefit from stream channel enhancements, but the creeks in this area are ephemeral and don't recharge the groundwater. The upper reaches of these creeks run on bedrock and are disconnected from the regional aquifer.
    - Maintaining riparian areas is on the books, but funding is needed to implement. Also need to encourage property owners to maintain riparian areas on their own properties.
- Other Comments
    - Pursue funding for pre- and post-flood attenuation.
    - Keep in mind the strong independent spirit of the people living in the area.
    - Renewable supplies are good for water providers with access to CAP or are Central Arizona Groundwater Replenishment District members. This isn't possible for small water providers that don't already have access to CAP water.
    - People have property right concerns. They are independent and often have private wells, making them less likely to volunteer to conserve water since they have rights to that water.

Parking Lot:

- Background/Context: Major water providers represented in CDO map. Good to see GW stabilization in Oro Valley and rise in southwest portion of the map. Reflects imported water into Metro Water and Marana Water service areas.
- Groundwater flow model only on about half of the Vail/Cienega map. Rincon Creek has not historically had much mountain front recharge, so this area is very susceptible to over-pumping. Geographically, a lot of CAP water is going into the ground 20+ miles to the west, but not in this area. Most dramatic impacts of GW pumping seen at the boundary of the model area (may be slightly exaggerated due to mathematics of the model itself). Most new development in that area will likely be dependent on GW. Vail currently receives wheeled water from Avra Valley, so isn't currently contributing to the GW decline. Little water in the underflow of Cienega Creek - valuable riparian area, but should not be seen as a water resource for human use.

3. ***Green Valley and Sahuarita***

Major categories of strategy missing: None

Most promising strategies & why:

- Natural Channel Design should go hand in hand with recharge projects that get managed recharge credits. This method heals the down cutting of the Santa Cruz River channel.
- Maximize Use of Stormwater to maintain the balance of water pumped out of the aquifer so the static water levels are stabilized. Account for seasonality of natural flows.
- Maximize Use of Wastewater Use water closer to where it is generated to reduce costs.
- Improve Water Deliver Infrastructure Use the CAP water that is allocated to Green Valley.

Suggestions for implementing promising strategies:

- Natural Channel Design
    - Down-cutting of Santa Cruz River in downstream segments near San Xavier District need river restoration. Near Continental okay, but needs work upstream streams. Install gabions along the downstream/northern segment, especially near San Xavier District.
    - Upstream improvements would improve downstream function, especially LID
    - Adopt policies to support strategies, such as maintaining natural functions of channels.
- Watershed & Riparian Protection
    - Bank stabilization strategies, such as tree planting in back areas near San Xavier Farms, are being developed between Co-op farms and Reclamation
    - Upstream improvements would improve downstream function.
- Agriculture & Mining State Trust land manages water for a variety of uses like agriculture, grazing, commercial etc. We manage a variety of Type 2s, IGFRs, surface and groundwater claims. STL is regulated with laws, rules so it is somewhat difficult to manage the lands to account for climate change and other issues we might face.

- Maximize Use of Stormwater cisterns, rain barrels, landscape irrigation, collect clean water from solar panels to avoid contamination by asphalt or cars
    - Incorporate Green Stormwater Infrastructure (GSI) and Low Impact Development (LID) into all new construction (residential and commercial) as a requirement and condition of approval.
    - Methods to Incentivize GSI
        - Pilot program of rooftop collection
        - Policies, ordinances or regulations to encourage rainwater harvesting
        - Rebates to build GSI features for retrofits or in new developments
    - Use public education to implement harvesting.
    - Keep the natural function of the stream, and archaeology
    - Opportunity for LID and green infrastructure:
        - Sahuarita Rd and the planned treatment plant
        - Sahuarita
        - Lee Moore Wash drainage area
        - Median Green, managed through Green Valley Council, fixes roadway medians
    - Account for high-intensity short-duration storms. Reduce nuisance flooding, not 100-year events
    - Address water rights issues with the prior appropriations, like a new legislative bill that will allow for a change in use.
- Maximize Use of Wastewater
    - A regional wastewater treatment plant is proposed near Sahuarita.
    - When wastewater treatment is centralized, the community loses the opportunity to use water where it is generated. This requires piping the water where it is needed, or you have to recharge and reclaim.
    - Use reclaimed water in Corona del Tucson area, near Sahuarita Rd.
- Improve Water Delivery Infrastructure
    - Improve, increase, and fully maximize use of CAP water by improving infrastructure; This would have largest impact of any strategy on water levels and long-term storage.
    - Recharge CAP water at north end for 100-year water storage, rather than in Maricopa
        - Distribute water evenly and as soon as possible
        - Higher in the watershed is better so gradient flow takes stored water to wells
        - The last CAP water priority to be cut is Tier 3, which is Indian Water
    - Locations:
        - Sopori Wash
        - San Xavier Reservation. Cooperate with TON. Use the stabilize stream channel
    - CAP:SAM modeled 600 AF of water in this area.
- Public Education
    - What the GSI strategies are so people are aware.
    - Build in conservation features during early phase of development

    - How they can get involved?
- Seasonality of water needs more discussion as some strategies may not work best in all seasons.
- Policy adaptations:
    - Seasonal thresholds, to maintain riparian vegetation
    - Hydrologic disconnects
- Concerned with areas that have not been developed yet.
- Build a managed recharge project to accrue recharge credits at 95%. Pair the recharge project with a regional wastewater treatment plant near Sahuarita.
- Extend a pipeline from the CAP line to "that area"
- Public education for GI is important in the early phase if building as it is more expensive

Action Items (If Any):

Would like more information on the type of strategies BOR could fund. Could it be used for education activities or policy action?

Parking Lot:

- Many existing cost estimates can be used to begin the economic analysis.
- Incorporating strategies into new design is simpler and more cost-effective than retrofitting.
- Maximize the use of CAP water:
    - Spatially: transport water as far upstream in the watershed; side benefit of maximizing the delivery cost of CAP under the "postage stamp rate"
    - Temporally: use Colorado River water now, rather than later; store the water locally
- FICO is holding pattern until development of FICO.
- Need a backup plan if Colorado River is dramatically reduced. Urgency of responding to this issue needs to be accelerated. We could also do better on education.
- Discussion of funding opportunities, Reclamation, NRCS, CAP and others.

4. ***Sabino Canyon and Tanque Verde Wash***

Major categories of strategy missing:

- Lots of exempt wells in this area; pumping fees?
- Economic incentives/obstacles/barriers: Few incentives exist for exempt well owners to connect to the Tucson Water service area without a threat of wells going dry or becoming contaminated.
- Addressing regional issues
    - Utilities have to recover costs from customers, which can be at odds with the regional goal of protecting water resources. The Tucson Active Management Area augmentation authority was created to try and address issues like this but it does not exist anymore. Is the public willing to pay for the public good? The City provides a financial back stop for Tucson Water, so can we ask City residents to take on financial risk for customers outside the City limits?
    - The City wants to annex land to get more of the state shared revenues but there are also the recent pre-annexation development agreement (PADA)/ equivalent dwelling unit fees that might prevent annexation. There are tensions between growth and anti-growth. The Water Service Area policy also plays a part in this. It limits access based on certain conditions (like having current customers on three sides of a property) but the PADA is another way to get water service.

Most promising strategies & why:

- Natural Channel Design historical stability needs to be supplemented as fires cause later flooding and deposition of sediment
- Maximize Use of Stormwater is promising because there is more seasonal stream flow.
- Improve Water Delivery Infrastructure to deliver renewable water supplies, like reclaimed.
- Reduce Local GW pumping Create incentives for not using wells to stabilize aquifer.
- Recover water in area of hydrologic impact and/or recharge Need balance
- Watershed & Riparian Protection support is needed for vegetation management
- Maximize Use of Wastewater Reclaimed water can be used to irrigate plants

Suggestions for implementing promising strategies:

- Natural Channel Design
    - Need to understand the impact of check dams.
    - Historically channels have been stable. This is changing as new fire regime results in high erosion and deposition of sediment where the channel slope changes
    - Release reclaimed water at pipeline crossings into the creeks to help maintain riparian vegetation during drought years.
    - Vegetation management is needed in the upper watershed to reduce excess runoff.
    - Restore channels by re-introducing beavers. There are some plans for re-introducing in the Cienega Creek area.
    - Prescribed burns could be a policy change. Vegetation selection is important. More advanced planning for locations and types of solutions that

would work best after a fire. This is preferable to using emergency investments to fund solutions.
    - WMG works with various organizations to develop structures to increase infiltration.
- Maximize Use of Stormwater- Add more LID features to capture developed runoff.
    - Create incentives to reduce use of groundwater.
    - RFCD places these structures where they are most effective. Locating GSI just below a burned area where the gradient decreases is subject to sedimentation due to post-fire erosion events.
    - People downstream might object because of surface water rights. This is more of an issue in water courses as opposed to smaller scale in neighborhoods.
    - Allow for additional features for infiltration of stormwater to reduce the impact of additional runoff from development.
- Improve Water Delivery Infrastructure
    - Consider an interconnection and wheeling arrangement with Tucson Water.
- Reduce Local GW pumping - Create incentives for not using well. HUB/Metro provides service in this area (that is partly the red area because it is groundwater fed)
- Recover water in area of hydrologic impact and/or recharge)
- Watershed & Riparian Protection Vegetation management is needed upstream to minimize erosion following fires. Two options were to conduct prescribed burns and research suitable habitat that can be re-established following a fire
- Where would be the best place to locate a project? The Metro HUB area is one of the greatest users of groundwater in the area. There is a great potential for reducing pumping.
    - Opportunities where the lines cross the washes.
    - Riparian vegetation – confluence between Agua Caliente and Tanque Verde
    - Use the vegetation now to get an idea of what is happening.
- Static water levels respond quickly to changes in the groundwater pumping.
- Maximize Use of Wastewater
    - Rethink the use of managed recharge, near or in-stream, to help protect riparian vegetation. Apply a higher priority to is an opportunity to restore flows or at least support mesquite/cottonwood regimes,
    - Currently plans for new reclaimed waterlines.
    - Need more incentives
    - Mt. Lemon recharge facility (WWTP?) is currently prohibited to discharging to Sabino Creek.
    - 49ers golf is irrigated with reclaimed water; the rate is subsidized and overall rates have been going up. If reclaimed rates keep going up, connecting to the reclaim system is less attractive
    - Send reclaimed to Aqua Caliente park for recharge. The reclaimed water line is one mile away from Agua Caliente Park and was estimated to cost approx. $3M.
    - Add outlets from the reclaimed water pipeline where the pipeline crosses washes as a means of supporting riparian areas

- Mapped shallow groundwater that aren't really shallow anymore.
- This is not a high growth area, considered built out. There is push back for increasing the density

Action Items (If Any):

Parking Lot:

- Will the study look at ADWR management plans? What's the relationship between ADWR's management plan and this study? There is no official relationship or policy coordination. ADWR is a partner in the study and coordinates with groundwater modelers. There are conservation features in the CAP:SAM, but no specific details at time of workshop.
- FICO intends to change their orchards to developments in the future.
- Are there conservation requirements for marijuana farms? No one had an answer to this question.

Appendix C – Map of Areas of Concern

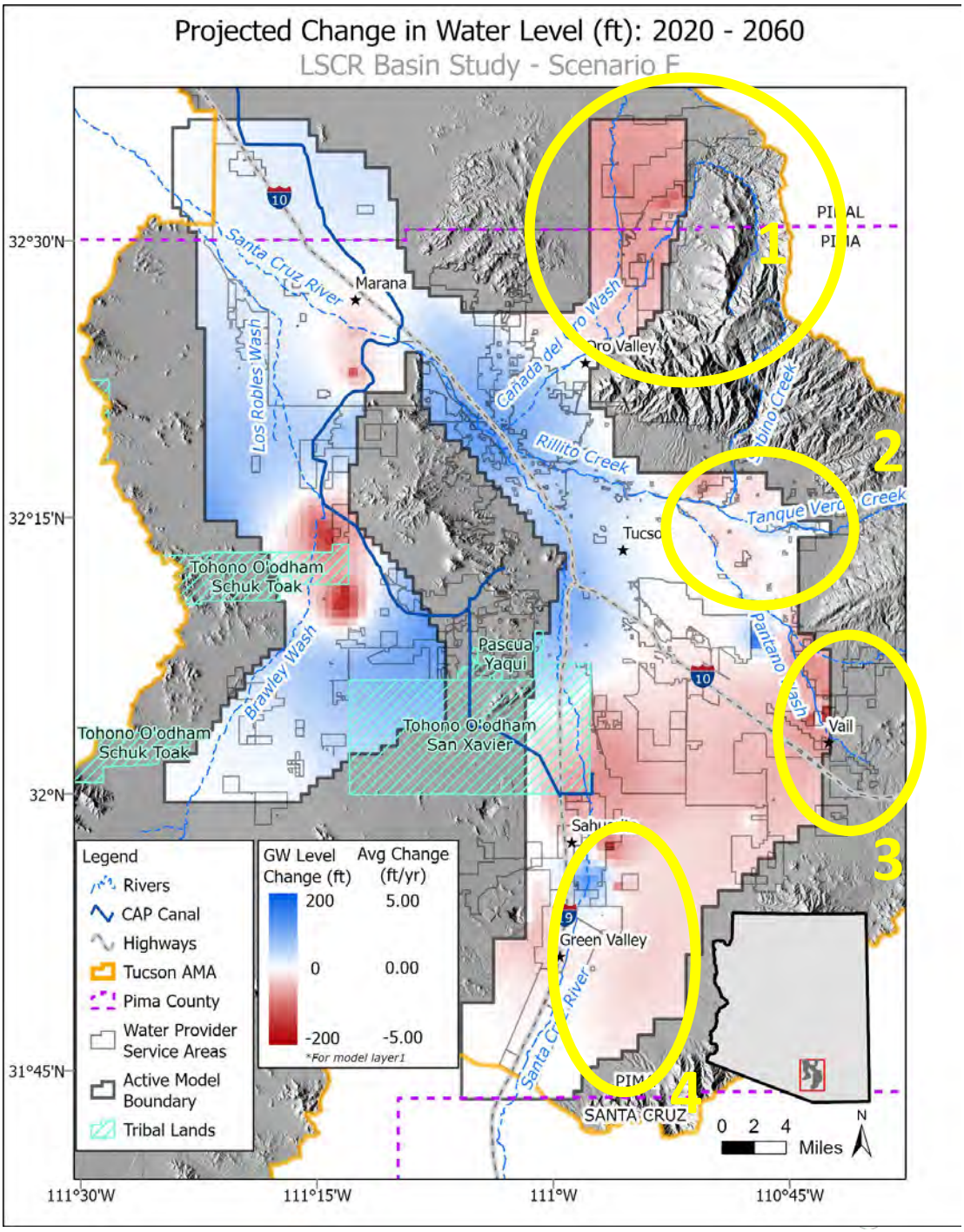


Figure 1 - Areas of Concern: 1- Canada del Oro and Saddlebrooke, 2 - Sabino Canyon and Tanque Verde Wash, 3 - Southeast Tucson, 4 - Green Valley and Sahuarita.

Appendix D – Proposed Adaptation Strategies with Descriptions

Area #1: Sabino Canyon and Tanque Verde Wash (Area of concern identified by stakeholders)			
Option	**Adaptation Strategy**	**Description**	**Specifics for consideration/analysis in this location**
A	Natural Channel Design	Modify stream channels (for example, check dams, soil bank stabilization, side spreading) to increase flood storage, infiltration/recharge, enhance habitat and limit flood erosion	
B	Watershed & Riparian Protection	Some options include: Restore or enhance riparian tree health, tree canopy, seasonal surface flows, and/or groundwater levels. Minimize wildfire loses through prescribed burns and removal of fuel load. Monitor habitat, aquatic and riparian species and groundwater levels for baseline conditions and changes.	
C	Maximize Use of Wastewater	Some options include: Install wastewater reuse infrastructures (home/business graywater systems, secondary treatment and/or tertiary/advanced treatment, local package plants) customized to the water source supply and reuse demand (landscape irrigation, recharge, riparian habitat sustainability) to meet multiple objectives (reduce groundwater withdrawals, restore groundwater levels, and benefit the environment).	.
D	Maximize Use of Stormwater	Some options include: Install Low Impact Development features (berms or collector pipes downstream of impervious surfaces; check dams, basins or cisterns; porous surfaces; native vegetation) to collect rainfall or stormwater runoff, store temporarily (if needed) and then use to recharge aquifers, irrigate plants or supply potable water. Retrofit neighborhoods and design new residential areas with (passive and/or active use of runoff or large-scale projects like Kino Environmental Restoration Project).	

E	Improve Water Delivery Infrastructure	Install infrastructure (i.e., pipelines, reservoirs, pumps) supporting use of renewable supplies (CAP water, reclaimed water, stormwater) in lieu of groundwater pumping.	
F	Reduce Local GW pumping	Some options include: Install meters on exempt wells; limit new wells; and/or use monitoring devices to evaluate household or commercial/industrial water use. Conserve indoor and outdoor water use. Establish conservation surcharges for summer water use.	
G	Recover stored water in area of hydrologic impact and/or change recovery criteria	Modify Tucson Active Management Area management plan and/or Central Arizona Groundwater Replenishment District operations to limit groundwater declines in area of concern. This could require recovery of stored water in the area of hydrologic impact or changes to the allowable decline rates in recovery wells.	
Area #2: Cañada del Oro and Saddlebrooke			
Option	**Adaptation Strategy**	**Description**	**Specifics for consideration/analysis in this location**
A	Natural channel design	Modify stream channels (for example, check dams, soil bank stabilization, side spreading) to increase flood storage, infiltration/recharge, enhance habitat and limit flood erosion	
B	Watershed & Riparian Protection	Some options include: Restore or enhance riparian tree health, tree canopy, seasonal surface flows, and/or groundwater levels. Minimize wildfire loses through prescribed burns and removal of fuel load. Monitor habitat, aquatic and riparian species and groundwater levels for baseline conditions and changes.	
C	Maximize Use of Wastewater	Some options include: Install wastewater reuse infrastructures (home/business graywater systems, secondary treatment and/or tertiary/advanced treatment, local package plants) customized to the water	.

		source supply and reuse demand (landscape irrigation, recharge, riparian habitat sustainability) to meet multiple objectives (reduce groundwater withdrawals, restore groundwater levels, and benefit the environment).	
D	Maximize Use of Stormwater	Some options include: Install Low Impact Development features (berms or collector pipes downstream of impervious surfaces; check dams, basins or cisterns; porous surfaces; native vegetation) to collect rainfall or stormwater runoff, store temporarily (if needed) and then use to recharge aquifers, irrigate plants or supply potable water. Retrofit neighborhoods and design new residential areas with (passive and/or active use of runoff or large-scale projects like Kino Environmental Restoration Project).	
E	Improve Water Delivery Infrastructure	Install infrastructure (i.e., pipelines, reservoirs, pumps) supporting use of renewable supplies (CAP water, reclaimed water, stormwater) in lieu of groundwater pumping.	
F	Reduce Local GW pumping	Some options include: Install meters on exempt wells; limit new wells; and/or use monitoring devices to evaluate household or commercial/industrial water use. Conserve indoor and outdoor water use. Establish conservation surcharges for summer water use.	
G	Recover stored water in area of hydrologic impact and/or change recovery criteria	Modify Tucson Active Management Area management plan and/or Central Arizona Groundwater Replenishment District operations to limit groundwater declines in area of concern. This could require recovery of stored water in the area of hydrologic impact or changes to the allowable decline rates in recovery wells.	

Area #3: Southeast Tucson, Vail and Cienega Creek			
Option	**Adaptation Strategy**	**Description**	**Specifics for consideration/analysis in this location**
A	Natural channel design	Modify stream channels (for example, check dams, soil bank stabilization, side spreading) to increase flood storage, infiltration/recharge, enhance habitat and limit flood erosion	
B	Watershed & Riparian Protection	Some options include: Restore or enhance riparian tree health, tree canopy, seasonal surface flows, and/or groundwater levels. Minimize wildfire loses through prescribed burns and removal of fuel load. Monitor habitat, aquatic and riparian species and groundwater levels for baseline conditions and changes.	
C	Maximize Use of Wastewater	Some options include: Install wastewater reuse infrastructures (home/business graywater systems, secondary treatment and/or tertiary/advanced treatment, local package plants) customized to the water source supply and reuse demand (landscape irrigation, recharge, riparian habitat sustainability) to meet multiple objectives (reduce groundwater withdrawals, restore groundwater levels, and benefit the environment).	.
D	Maximize Use of Stormwater	Some options include: Install Low Impact Development features (berms or collector pipes downstream of impervious surfaces; check dams, basins or cisterns; porous surfaces; native vegetation) to collect rainfall or stormwater runoff, store temporarily (if needed) and then use to recharge aquifers, irrigate plants or supply potable water. Retrofit neighborhoods and design new residential areas with (passive and/or active use of runoff or large-scale projects like Kino Environmental Restoration Project).	
E	Improve Water	Install infrastructure (i.e., pipelines, reservoirs, pumps) supporting use of	

	Delivery Infrastructure	renewable supplies (CAP water, reclaimed water, stormwater) in lieu of groundwater pumping.	
F	Reduce Local GW pumping	Some options include: Install meters on exempt wells; limit new wells; and/or use monitoring devices to evaluate household or commercial/industrial water use. Conserve indoor and outdoor water use. Establish conservation surcharges for summer water use.	
G	Recover stored water in area of hydrologic impact and/or change recovery criteria	Modify Tucson Active Management Area management plan and/or Central Arizona Groundwater Replenishment District operations to limit groundwater declines in area of concern. This could require recovery of stored water in the area of hydrologic impact or changes to the allowable decline rates in recovery wells.	
Area #4: Green Valley and Sahuarita			
Option	**Adaptation Strategy**	**Description**	**Specifics for consideration/analysis in this location**
A	Natural channel design	Modify stream channels (for example, check dams, soil bank stabilization, side spreading) to increase flood storage, infiltration/recharge, enhance habitat and limit flood erosion	
B	Watershed & Riparian Protection	Some options include: Restore or enhance riparian tree health, tree canopy, seasonal surface flows, and/or groundwater levels. Minimize wildfire loses through prescribed burns and removal of fuel load. Monitor habitat, aquatic and riparian species and groundwater levels for baseline conditions and changes.	
C	Maximize Use of Wastewater	Some options include: Install wastewater reuse infrastructures (home/business graywater systems, secondary treatment	

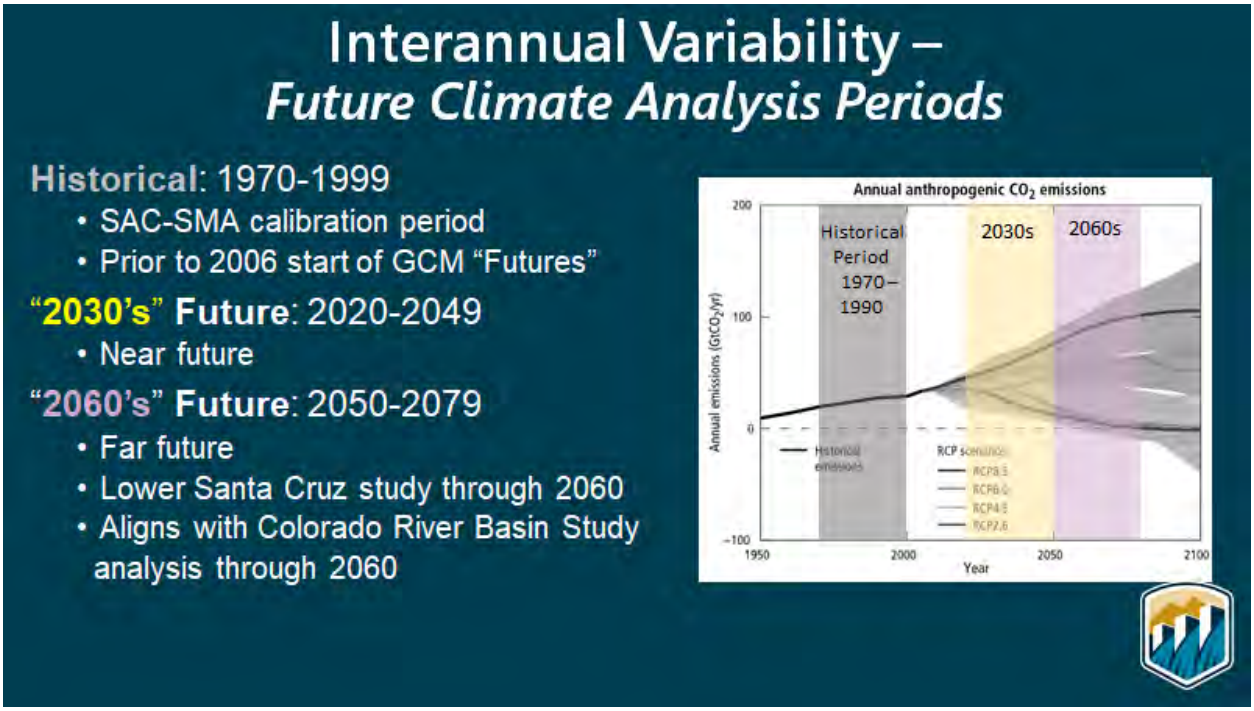
		and/or tertiary/advanced treatment, local package plants) customized to the water source supply and reuse demand (landscape irrigation, recharge, riparian habitat sustainability) to meet multiple objectives (reduce groundwater withdrawals, restore groundwater levels, and benefit the environment).	
D	Maximize Use of Stormwater	Some options include: Install Low Impact Development features (berms or collector pipes downstream of impervious surfaces; check dams, basins or cisterns; porous surfaces; native vegetation) to collect rainfall or stormwater runoff, store temporarily (if needed) and then use to recharge aquifers, irrigate plants or supply potable water. Retrofit neighborhoods and design new residential areas with (passive and/or active use of runoff or large-scale projects like Kino Environmental Restoration Project).	
E	Improve Water Delivery Infrastructure	Install infrastructure (i.e., pipelines, reservoirs, pumps) supporting use of renewable supplies (CAP water, reclaimed water, stormwater) in lieu of groundwater pumping.	
F	Reduce Local Groundwater pumping	Some options include: Install meters on exempt wells; limit new wells; and/or use monitoring devices to evaluate household or commercial/industrial water use. Conserve indoor and outdoor water use in residential, commercial, turf sectors. Establish conservation surcharges for summer water use.	
G	Recover stored water in area of hydrologic impact and/or change recovery criteria	Modify Tucson Active Management Area management plan and/or Central Arizona Groundwater Replenishment District operations to limit groundwater declines in area of concern. This could require recovery of stored water in the area of hydrologic impact or changes to the allowable decline rates in recovery wells.	
H	Agricultural & Mining	Reduce agricultural water using technology (Options include: enhanced laser leveling,	

		soil and leaf temperature sensing) and plant management (tree pruning, understory). Reduce mining water use (Options include: maximize use of reclaimed water for air quality control; use of surfactants and stabilizers to prevent dust events; revegetation of tailings; enhanced mineral processing techniques)	

Appendix E – Response to Questions from Mark Day

Summary:
Mark Day, a member of the Lower Santa Cruz River Basin Study Stakeholder Advisor Group, had a question regarding the way in which the climate change analysis was conducted. See below for his question and the response from the Basin Study staff.

The question was in regard to the following slide presented at the Workshop:



From Mark Day (text italicized):

Here are some of my thoughts about the climate basis illustrated in the slide you sent.

My concern is that the calibration period was quite wet compared to the past 20 years, and based on my investigations, described below, droughts in Arizona tend to go 30 years and more. And that's looking back. If we look forward, then we likely are going to see even more drought and spikey, highly variable swings in precipitation. Looking at past droughts, they were often dotted with a few wet years, but then many more dry years.

My sense is that drought is the 'normal' climate for this area, and that will continue and likely get even dryer on average due to more heat from global warming, but with even more wet spikes. Wish I had a really good graphic handy. I did find one to link to, see below. So, my concern is that what we have is a situation similar to the one where we allocated the Colorado based on a wet period early in the 20th Century, but then the climate has proven to be much dryer since,

thus creating unrealistic expectations for water availability. My training in forecasting is a bit stale by now, but I don't think you can set a valid trend line while not including the most recent 20 years, which are quite different from the previous 30 years.

By the way, I ran this by Bruce Billings, who taught economic forecasting at UA, and he agrees with my viewpoint on leaving out the past two decades of data. Perhaps there is some reason to leave it out, but the validity of the forecast is brought into question. We would certainly hope that the more recent data could be brought into the model as soon as it is available, if not immediately, even if it is common practice to base a model on climate generated with 30 years of weather data.

Lower Santa Cruz River Basin Study Staff Response:

Dear Mr. Day,

We completely understand your concerns and want to assure you that we have not overlooked the recent data (2000-2020) in our work to project future conditions. We are absolutely aware that the recent 20-year drought is significant, and Reclamation has made a point of using this period in our assessment of future conditions as part of our standard practice. In fact, we refer to the post-2002 hydrology as "Stress Test Hydrology." See the following website: https://www.usbr.gov/lc/region/g4000/riverops/crss-alt-hydrology.html

We believe that there may be some confusion about the type of analysis performed for the Lower Santa Cruz River Basin Study (Study). We did not perform a regression analysis whereby a trend is derived from observations over time. Instead, we selected a Global Climate Model simulation based on the specific needs of study partners. Global Climate Models are not built based on precipitation and temperature records in specific locations, but rather represent the physics of the entire globe. The accuracy of the model projecting into the future *does not depend on whether the most recent precipitation and temperature information is included*, but rather on whether the physics of the model can recreate conditions observed during a past series of years. If a model has been demonstrated to perform well in past decades, we can be confident that it will provide useful information when projecting into the future.

Partnering with the University of Arizona, the Study partners evaluated different Global Climate Models to ensure the climate processes important in the region were adequately captured. This led us to select projections generated by the Max-Planck-Institute Earth System Model. Examining the model's ability to simulate aspects of the local climate such as past monsoon season onset gave us confidence in the model physics that allowed us to move forward with the future projections.

That said, in order to be consistent with projections of CAP availability, we were constrained to using the Global Climate Model projections available at the time the Study began in 2016. Our selected projections are part of the international Coupled Model Intercomparison Project 5 (CMIP5). These projections are the foundation of the Colorado River Basin Study, and it was collectively determined by the Study partners that this foundation was needed to be internally consistent with the CAP Service Area Model projections.

Your concern that our climate change projections could be overly optimistic was shared by our Study partners. One area of particular concern was the necessary step of "downscaling" coarse Global Climate Model projections to provide the spatial detail required for basin-scale hydrologic modeling. Partners were concerned that the use of statistically downscaled climate projections, which use historical observations to provide fine-scale detail, might understate the degree of climate change that could take place within the Study area. To address this issue, we employed a "dynamically downscaled" model projection. This type of downscaling provides spatial detail by using a Regional Climate Model that explicitly simulates medium-scale atmospheric processes and does not rely on historical observations. More information on the specific projections and downscaling techniques used is available in the LSCR Basin Study Hydroclimate Analysis at:
https://www.usbr.gov/lc/phoenix/programs/lscrbasin/LSCRBS_Hydroclimate_2021.pdf

We used the outputs of the selected climate model projections to run a surface water model after a rigorous downscaling process to ensure they were appropriate to apply at a local level. The Colorado Basin River Forecast Center's Sacramento Soil Moisture Accounting Model was made available to the team to run these scenarios. This model was calibrated from 1970-1999. While the calibration period was certainly wetter overall, the highly variable nature of precipitation in the region ensured that dry spells and different storm magnitudes were captured in that period, allowing appropriate calibration to a range of events. Calibrating to a range of hydrologic events is more important than reproducing total volumes of precipitation in particular decades, since most of the streams in the area only respond to specific events or flow seasonally.

Again, this model is not a simple regression or trend line. It partitions the incoming precipitation (in this case from the climate models) into different soil zones and accounts for different runoff mechanisms. It does not directly rely on the historical period to develop model forcing inputs, but rather uses a continuous timeseries of precipitation and temperature from the climate models directly.

We do compare our simulations of the future back to model simulations of the period of 1970 - 1999 to account for any inherent bias in the various modeling steps. However, this is only to present the results as a change from the past, not to generate the results themselves. If anything, a comparison to a wetter period would result in a larger absolute change in our results.

In summary, Reclamation and the LSCR Basin Study partners were keenly aware of the need to assess the impact of "worse case" hotter and drier conditions on the Study area. Where possible, action was taken to address methods that could understate the potential severity of climate change on the region.

We appreciate your taking the time to explain your concerns to us. Your feedback has led us to re-examine our use of this slide in our presentation of the Study process to avoid any future confusion. Your efforts will enable us to improve our future communication of the Study's Hydroclimate Analysis.

Appendix F – Adaptation Strategy Descriptions

Lower Santa Cruz River Basin Study – Descriptions of Adaptation Strategies

August 18, 2021

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Map of Projected Change in Groundwater Elevation from 2020 to 2060 under Scenario F (worse case), with four areas of concern:

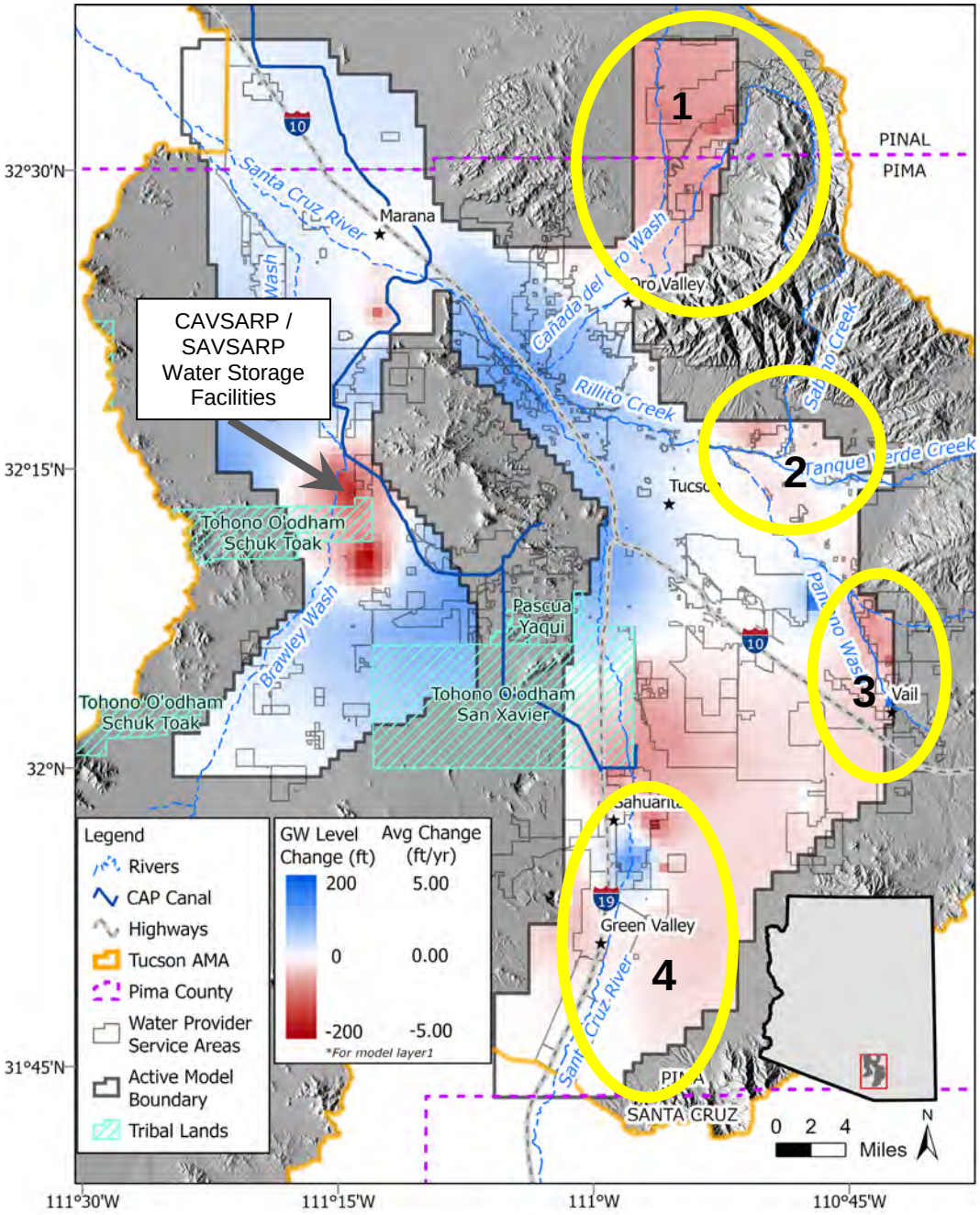


Figure 1 - Projected Groundwater Level Changes between 2020 and 2060 under Scenario F (worse case), with areas of concern

Areas of Concern: (1) Canada del Oro / Saddlebrooke; (2) Sabino Canyon/ Tanque Verde (3) Southeast Tucson and (4) Green Valley

Note: Scenario F has been revised since the February 22nd, 2021 presentation to account for planned Tucson Water infrastructure improvements in the Southeast Tucson area.

Adaptation Strategy Summary Table

See Adaptation Strategy Descriptions for more detail

Strategy ID	Strategy Name	Brief Description	Location	Water Volume (AFY)	Capital Cost	Annual O&M Cost	Treatment Cost (Capital)
CDO-1	CAP Supplies to CDO In-stream Recharge	Pipeline and pump stations to convey water from the Central Arizona Project (CAP) Red Rock Pumping Plant to Cañada del Oro (CDO) Wash area for in-stream recharge.	Cañada del Oro/ Saddlebrooke	5,000	$ 97,860,000	$ 173,000* (excludes energy)	N/A
CDO-2	SCR Reclaimed to CDO In-Stream Recharge	Pipeline to convey reclaimed water flowing out of the Tucson AMA from the Santa Cruz River (SCR) to a tributary of the CDO Wash for in-stream recharge. Includes treatment for PFAS and 1,4 dioxane	Cañada del Oro/ Saddlebrooke	10,000	$ 132,000,000	$ 236,000* (excludes energy, in process of obtaining water treatment cost)	$ 25,000,000
CDO-3	Saddlebrooke area Sub-regional WRF with In-stream Recharge	Sub-regional wastewater reclamation facility (WRF) and pipeline for in-stream recharge.	Cañada del Oro/ Saddlebrooke	1,120	$ 37,000,000	$ 3,300,000	Included in O&M
SC/TV-1	Reclaimed Extension to Isabella Lee Preserve and other sites	Extend Tucson Water (TW) reclaimed water pipeline to replace outdoor use of potable water and expand irrigation at Isabella Lee Preserve.	Sabino Canyon/Tanque Verde	200	$ 8,112,000	$ 106,000* (excludes energy)	N/A

Strategy ID	Strategy Name	Brief Description	Location	Water Volume (AFY)	Capital Cost	Annual O&M Cost	Treatment Cost (Capital)
SC/TV-2	Wheel Tucson Water CAP supplies to Metro HUB Water Company	Use existing and new infrastructure to wheel TW CAP water to Metro Hub service area, replacing the need for local gw pumping	Sabino Canyon/Tanque Verde	900	Infrastructure complete	$ 450,000	N/A
SC/TV-3	Connect Exempt Well Users to Tucson Water System	Extend TW infrastructure to convey renewable CAP supplies to properties relying on exempt wells.	Sabino Canyon/Tanque Verde	217	$ 950,000	$ 150,000	N/A
SET-1	SE Tucson Wheeling via Tucson Water	Construct new interconnections between TW central potable system and Southeast Tucson (SET) water providers to wheel CAP water, reduce local gw pumping	SE Tucson	1,500	$ 1,200,000	$937, 500	N/A
SET-2	Southeast Tucson Area Wastewater Plan	Phased WRFs to provide treated reclaimed water for turf irrigation and recharge in SE Tucson.	SE Tucson	2,700 in 2030; 6,700 in 2060	$ 96,000,000	$ 10,800,000	Included in O&M
GV-1	CAP Supplies to FICO Continental Farms (pecan orchards)	Extend Farmers Investment Company (FICO) Groundwater Savings Facility (GSF) pipeline to convey CAP water to additional pecan orchards in lieu of irrigation with groundwater	Green Valley/ Sahuarita	8,000	$ 6,500,000	In process of obtaining information	In process of obtaining information

Strategy ID	Strategy Name	Brief Description	Location	Water Volume (AFY)	Capital Cost	Annual O&M Cost	Treatment Cost (Capital)
GV-2	CAP Supplies to Canoa Ranch Recharge via FICO Pipeline Extension	Extend FICO GSF pipeline to Canoa Ranch for recharge into basins in the winter months (when not needed for irrigation)	Green Valley/ Sahuarita	2,000* (*could be up to 10,000)	$ 25,000,000	$ 371,000 (excludes energy)	N/A
GV-3	Green Valley Area Wastewater Plan	Phased WRFs to provide treated reclaimed water for turf irrigation and recharge in the Green Valley area.	Green Valley/ Sahuarita	7,500 in 2030; 16,000 in 2060	$ 228,800,000	$ 25,700,000	Included in O&M
REG-1	Stormwater Management using Low Impact Development	Retrofit existing properties and incorporate low impact development (LID) features into new developments to harvest and use stormwater. Build-out takes place from 2020 -2060.	Regional	39,245 (Average over 40 year period)	$ 349,000,000	$ 23,000,000	Included in O&M
REG-2	Stormwater Multi-purpose, Multi-use Basins and Channels	Large multi-benefit retention and detention basins and channels to collect and slow stormwater from impervious areas for flood mitigation, storage and/or habitat restoration	Regional	350	$ 77,000,000	$ 942,000	Included in O&M

Strategy ID	Strategy Name	Brief Description	Location	Water Volume (AFY)	Capital Cost	Annual O&M Cost	Treatment Cost (Capital)
REG-3	Stormwater Management using Upland Restoration	Small, distributed features to restore, protect and enhance surface water resources. Features could provide surface water, improve infiltration and soil moisture, and possibly restore groundwater levels.	Regional	0	$ 1,460,000	$ 73,000	N/A
REG-4	Augmentation with Desalinated Water from the Sea of Cortez	Construct a desalination plant and a pipeline from Mexico's Sea of Cortez to convey desalinated water to Tucson.	Regional	100,000	$ 3,000,000,000	$ 171,800,000	$1,100,000,000

Adaptation Strategy Cañada Del Oro – 1: CAP Supplies to CDO In-stream Recharge

Developed by: Reclamation Phoenix Area Office and Metro Water

Description: This project would convey 5,000 acre-feet per year of raw CAP water off the Central Arizona Project canal to the Canada del Oro / Saddlebrooke area for in-stream recharge. A pump station would be constructed at the CAP Red Rock Pumping Plant, as well as a 31-mile, 18-inch diameter pipeline with 5 pump stations. CAP water would be discharged to a tributary of Cañada del Oro Wash for in-stream recharge. Project would be monitored and regulated to avoid introduction of invasive species

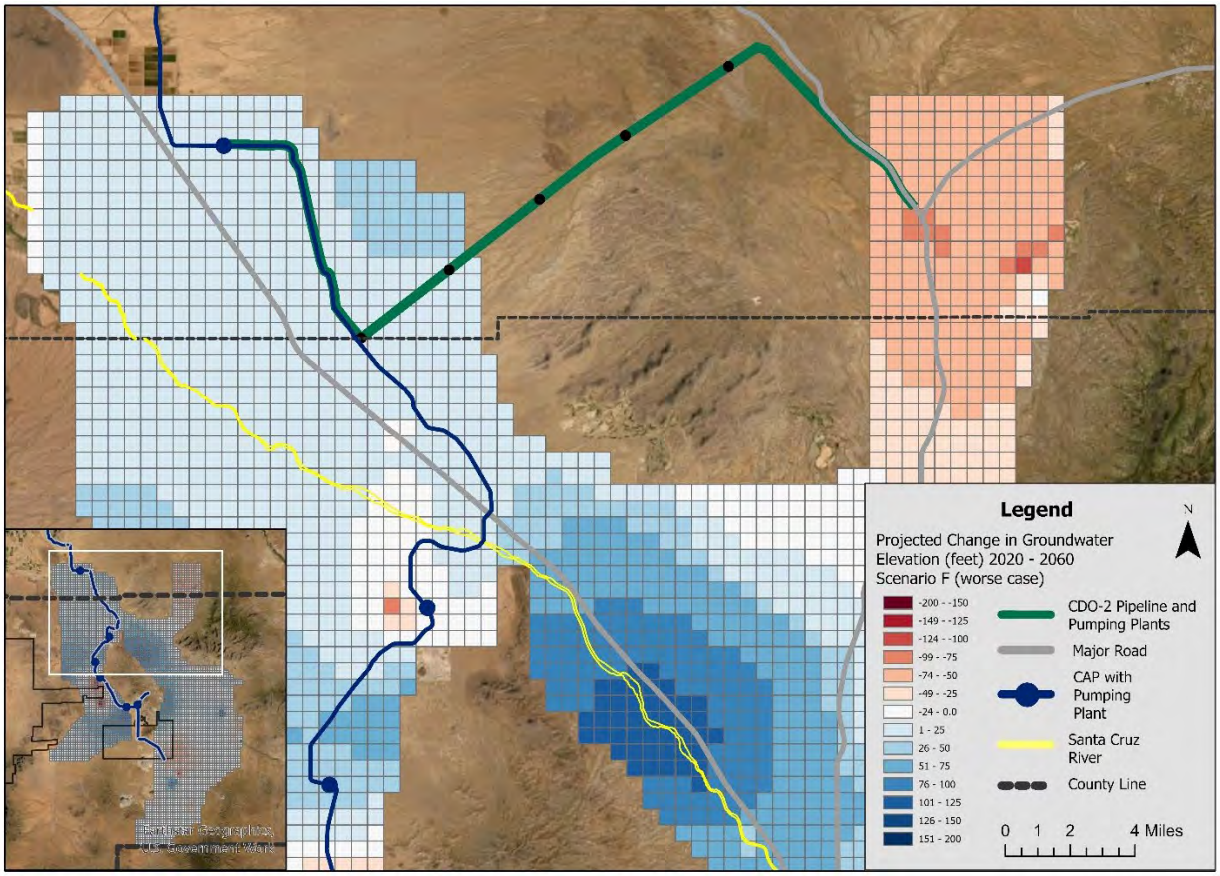


Figure 2 – Map of Adaptation Strategy CDO-1 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 5,000 acre-feet per year raw Central Arizona Project Water

Expected Impacts:

- Recharge would offset expected groundwater pumping associated with housing developments relying on the Central Arizona Groundwater Replenishment District (CAGRD) to meet the Arizona Department of Water Resources' Assured Water Supply Rules.
- Could offset decrease of mountain-front recharge that may occur due to more intense precipitation and less snowmelt due to climate change.
- Artificial recharge higher in the aquifer is likely to decrease depth to groundwater and improve riparian ecosystems.

Preliminary Project Construction Cost:
$ 97,860,000

Operations and Maintenance Cost:
$173,000 (excludes energy costs)

Engineering Cost Estimate Notes:

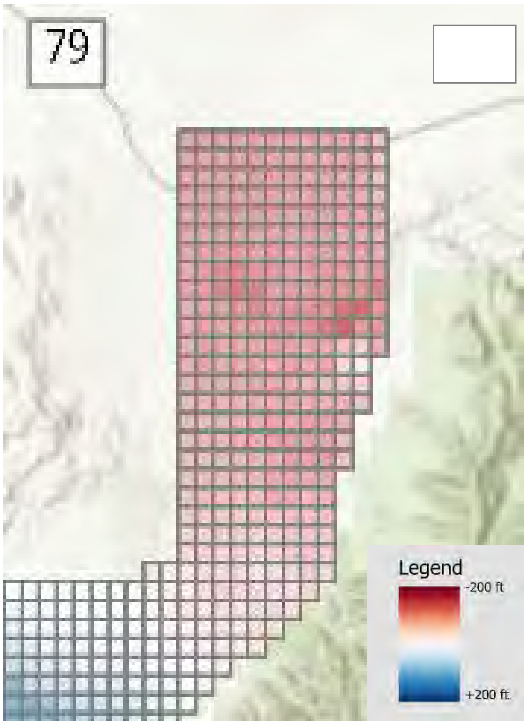
- Energy costs and storage tanks not included.
- Archaeological, environmental, hydrologic and drainage studies not included.
- A value of 10 percent was used for mobilization. A design contingency value of 20 percent was used for all strategies. Estimates include a construction contingency cost of 25 percent.
- Non-contract costs, including environmental mitigation and restoration, cultural resources identification and compliance activities and constructions services estimated at 30 percent of total field costs.

Environmental Issues: Possible desert tortoise along the route and migratory birds.

Cultural Resources Issues: At least eight known cultural resources (e.g., archaeological sites and historic structures) intersect this proposed alignment.

Groundwater Modeling of Adaptation Strategy Impact:

Without Adaptation



With Adaptation

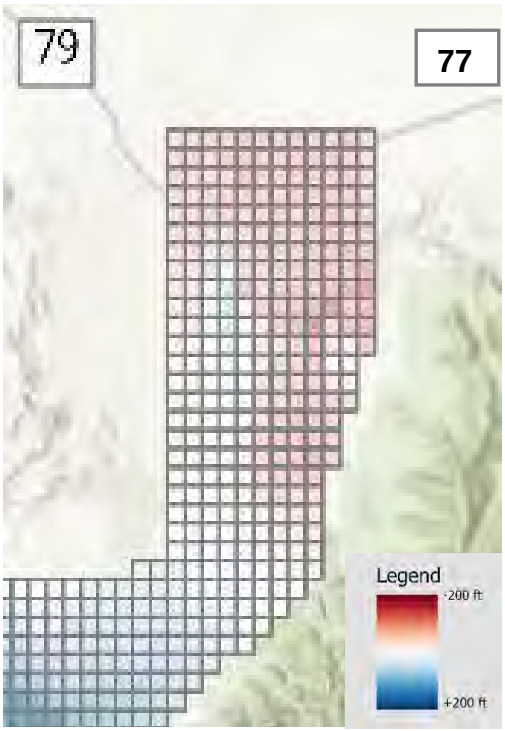


Figure 3 - Groundwater Modeling of the Impact on Adaptation Strategy CDO-1 on the projected changes in groundwater levels between 2020 and 2060 under worse-case Scenario F

Adaptation Strategy Cañada Del Oro – 2: SCR Reclaimed to CDO In-Stream Recharge

Developed by: Reclamation Phoenix Area Office and Metro Water

Description: This strategy utilizes some of the reclaimed water discharged by the Tres Rios Water Reclamation Facility that does not infiltrate in the Lower Santa Cruz Managed Recharge Project Underground Storage Facility and flows into the Pinal Active Management Area. A pump station and pipeline would be constructed to convey 10,000 acre-feet per year of reclaimed water off the Santa Cruz River downstream of Trico Road to the Cañada del Oro / Saddlebrooke area for in-stream recharge. The 30-mile, 24-inch diameter pipeline with 6 pump stations would discharge to a tributary of Cañada del Oro Wash. The reclaimed water would be treated to remove PFAS, 1,4 dioxane and other contaminants of concern ahead of discharge.

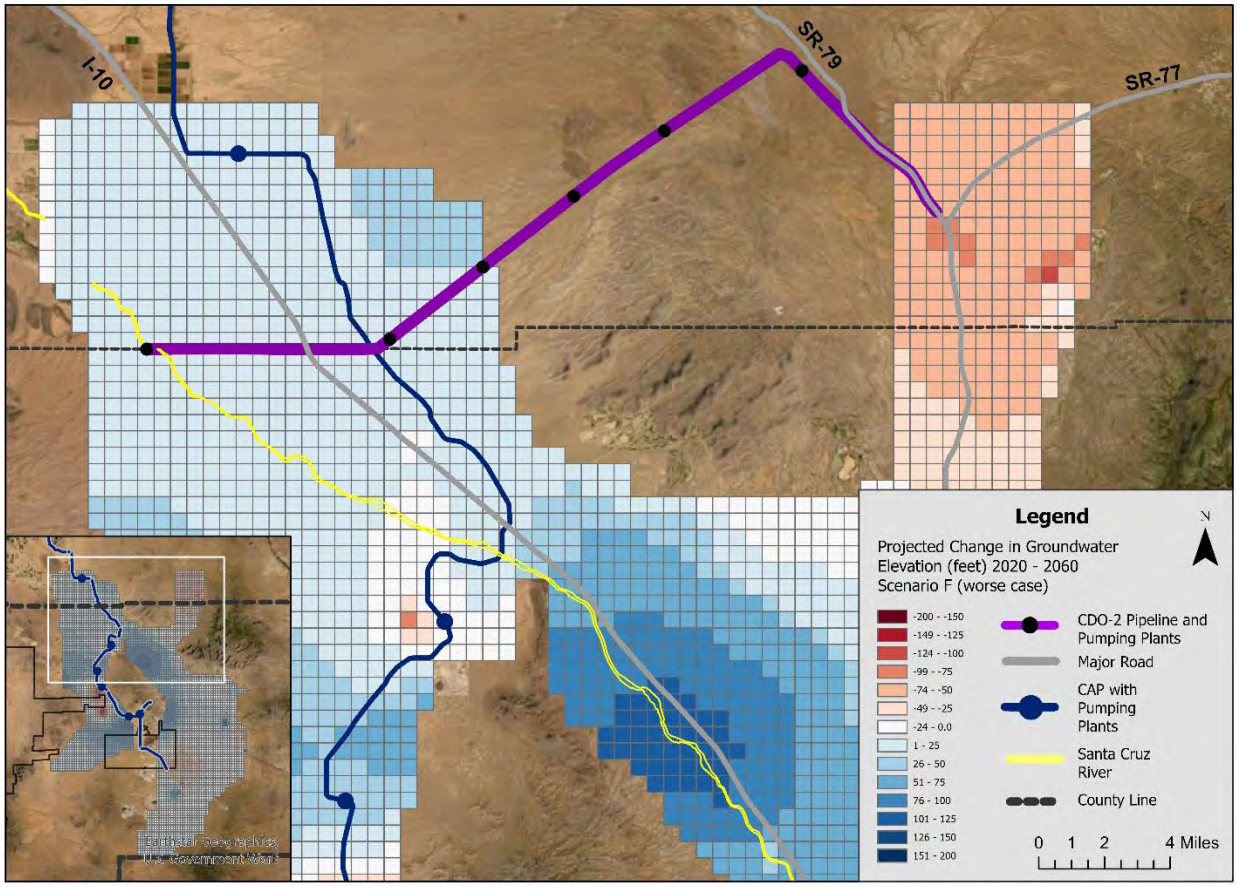


Figure 4 – Map of Adaptation Strategy CDO-2 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 10,000 acre-feet per year reclaimed water treated for PFAS and 1,4 dioxane and other contaminants of concern

Expected Impacts:

- Recharge would offset expected groundwater pumping associated with housing developments relying on the Central Arizona Groundwater Replenishment District (CAGRD) to meet the Arizona Department of Water Resources' Assured Water Supply Rules.
- Could offset decrease of mountain-front recharge that may occur due to more intense precipitation and less snowmelt due to climate change.

- Artificial recharge higher in the aquifer is likely to decrease depth to groundwater and improve riparian ecosystems.

Preliminary Project Construction Cost:
Pipeline and pump stations: $ 132,000,000
Treatment Plant: $ 25,000,000

Operations and Maintenance Cost:
$236,000 (excludes energy and treatment costs)

Engineering Cost Estimate Notes:

- Energy costs and storage tanks not included.
- Archaeological, environmental, hydrologic and drainage studies not included.
- A value of 10 percent was used for mobilization. A design contingency value of 20 percent was used for all strategies. Estimates include a construction contingency cost of 25 percent.
- Non-contract costs, including environmental mitigation and restoration, cultural resources identification and compliance activities and constructions services estimated at 30 percent of total field costs.

Environmental Issues: Possible desert tortoise could be along the route and migratory birds.

Cultural Resources Issues: This alignment intersects thirteen cultural resources, including an archaeological district (a landscape level cultural resource) and large archaeological sites.

Groundwater Modeling of Adaptation Strategy Impact:

Without Adaptation

With Adaptation

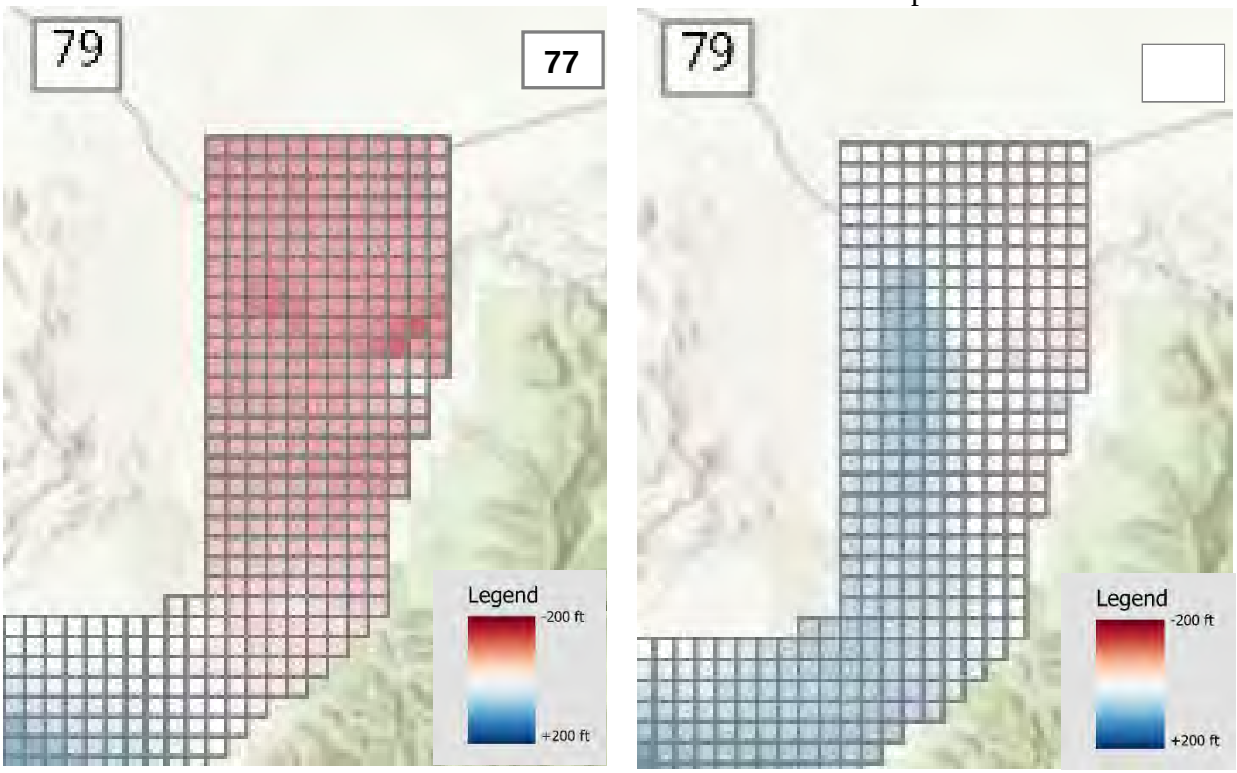


Figure 5 - Groundwater Modeling of the impact on Adaptation Strategy CDO-2 on the projected changes in groundwater levels between 2020 and 2060 under worse-case Scenario F

Adaptation Strategy Cañada Del Oro – 3: Saddlebrooke Area Sub-regional WRF with In-stream Recharge

Developed by: Metro Water and Pima County Regional Wastewater Reclamation Department

Description:
Construct a 1 million gallon per day (about 1,120 acre-feet per year) Sub-regional Water Reclamation Facility with tertiary treatment. A 4-mile pipeline would convey the reclaimed water into to a tributary of Cañada del Oro Wash for in-stream recharge.

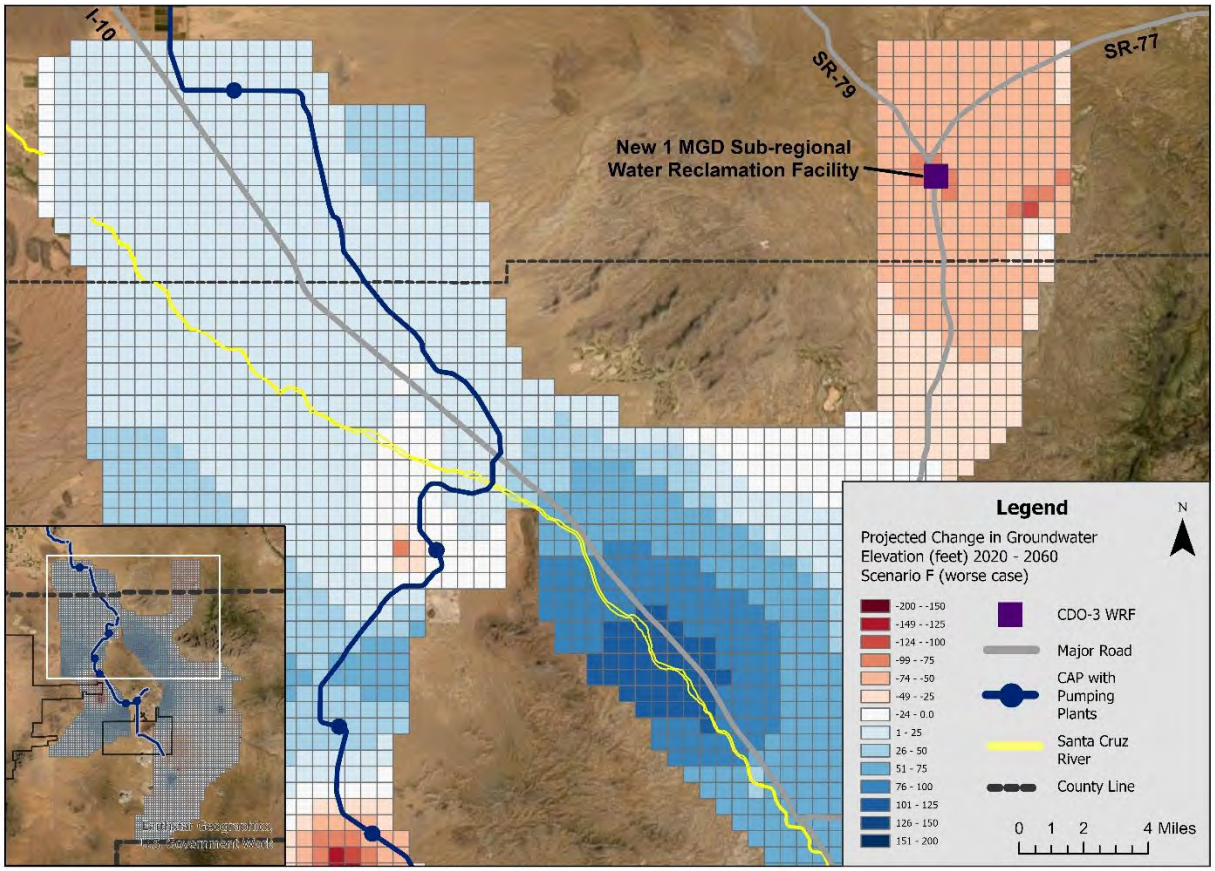


Figure 6 – Map of Adaptation Strategy CDO-3 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 1,120 acre-feet per year reclaimed water

Expected Impacts:

- Recharge would offset expected groundwater pumping associated with housing developments relying on the Central Arizona Groundwater Replenishment District (CAGRD) to meet the Arizona Department of Water Resources' Assured Water Supply Rules.
- Could offset decrease of mountain-front recharge that may occur due to more intense precipitation and less snowmelt due to climate change.
- Artificial recharge higher in the aquifer is likely to decrease depth to groundwater and improve riparian ecosystems.

Preliminary Project Construction Cost:
Treatment Facility: $29,000,000
Pipeline: $8,000,000

Operations and Maintenance Cost:
$3,300,000 per year

Engineering Cost Estimate Notes:

- Cost estimates provided by Pima County Regional Water Reclamation Department

Environmental and Cultural Resources Issues:

- Not analyzed for this strategy

Groundwater Modeling of Adaptation Strategy Impact:

Without Adaptation

With Adaptation

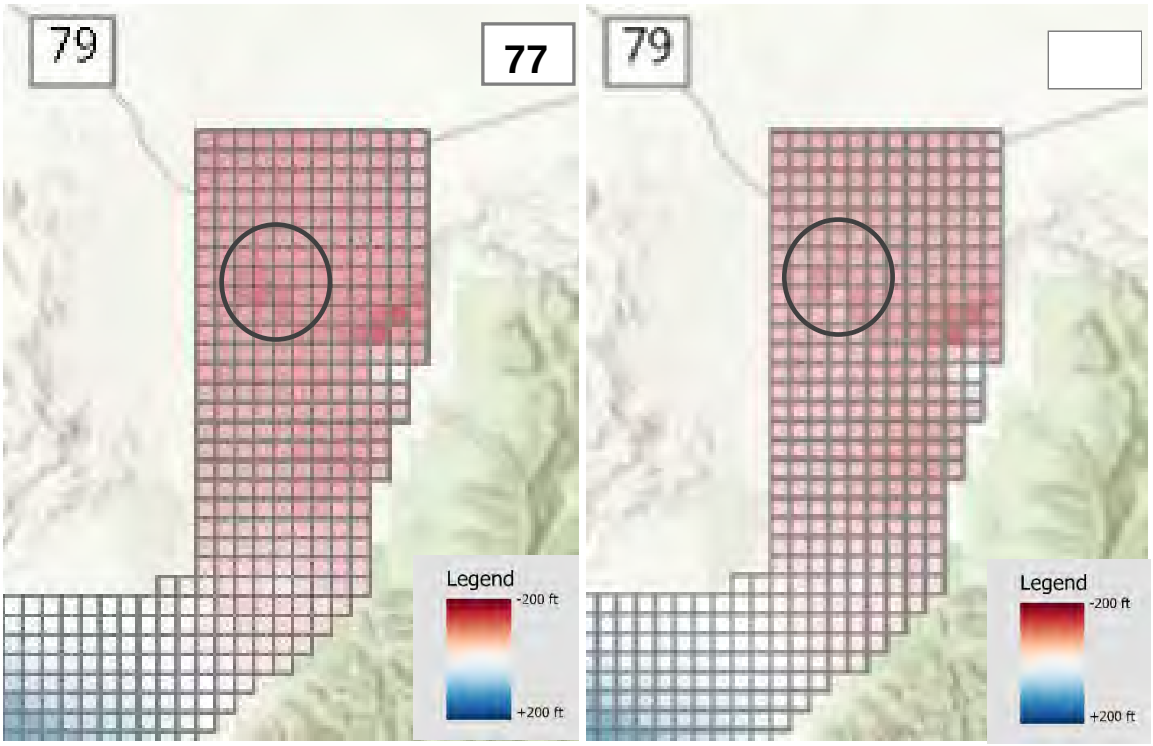


Figure 7 - Groundwater Modeling of the impact on Adaptation Strategy CDO-3 on the projected changes in groundwater levels between 2020 and 2060 under worse-case Scenario F

Adaptation Strategy Sabino Canyon / Tanque Verde – 1: Reclaimed Extension to Isabella Lee Preserve and Other Sites

Developed by: Reclamation Phoenix Area Office and Metro Water

Description:
Using existing capacity, extend Tucson Water Reclaimed System pipeline from Speedway and Houghton Road to convey approximately 200 acre-feet per year of reclaimed water to (a) replace potable water use on local turf facilities and man-made lakes and (b) provide supplemental irrigation to the mesquite bosque at Isabella Lee preserve. This strategy does not involve groundwater recharge.

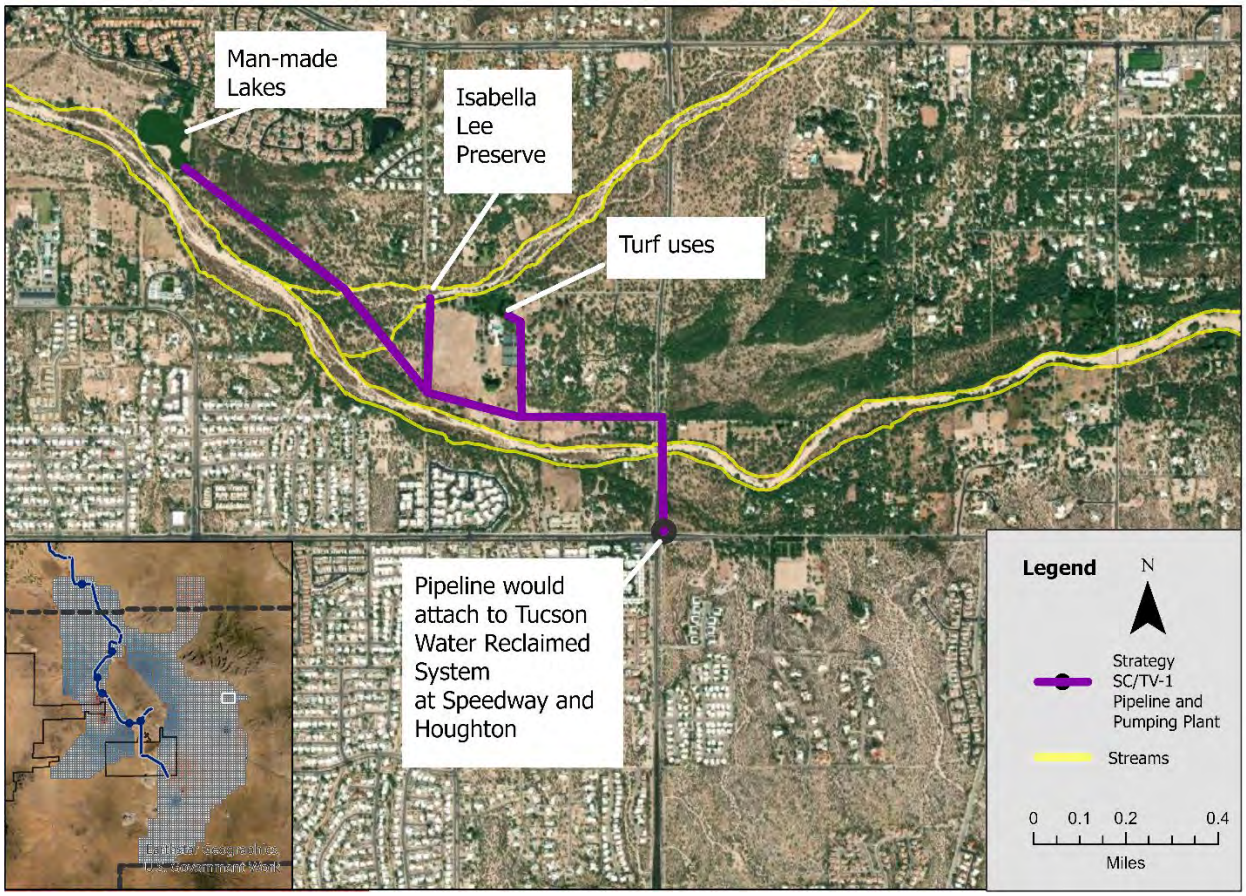


Figure 8 – Map of Adaptation Strategy SC-TV-1

Water Volume: Approximately 200 acre-feet per year reclaimed water

Expected Impacts:

- Reduced groundwater pumping could raise local groundwater levels.
- Improved resilience for vegetation and wildlife at Isabella Lee Preserve mesquite bosque.
- Management of turf and man-made lakes may require changes due to use of reclaimed water.

Preliminary Project Construction Cost:
Pipeline: $ 8,112,000

Operations and Maintenance Cost:
$106,000 (does not include energy costs)

Engineering Cost Estimate Notes:

- Energy costs and storage tanks not included
- Archaeological, environmental, hydrologic and drainage studies not included
- A value of 10 percent was used for mobilization. A design contingency value of 20 percent was used for all strategies. Estimates include a construction contingency cost of 25 percent.
- Non-contract costs, including environmental mitigation and restoration, cultural resources identification and compliance activities and constructions services estimated at 30 percent of total field costs.

Environment and Cultural Resources Issues:

- Not analyzed for this strategy

Groundwater Modeling of Adaptation Strategy Impact:

This strategy does not involve groundwater recharge.

Adaptation Strategy Sabino Canyon / Tanque Verde – 2: Wheel Tucson Water CAP Supplies to the Metro HUB Water Company

Developed by: Metro Water

Description: This project would use existing and new interconnections between Tucson Water's central potable systems to wheel water to providers pumping local groundwater in the Sabino Canyon / Tanque Verde area, specifically the Metro Water HUB Service Area. Existing infrastructure would be deployed to convey 900 acre-feet per year of potable water supplies from Tucson Water to the Metro Hub Service Area to replace locally pumped groundwater.

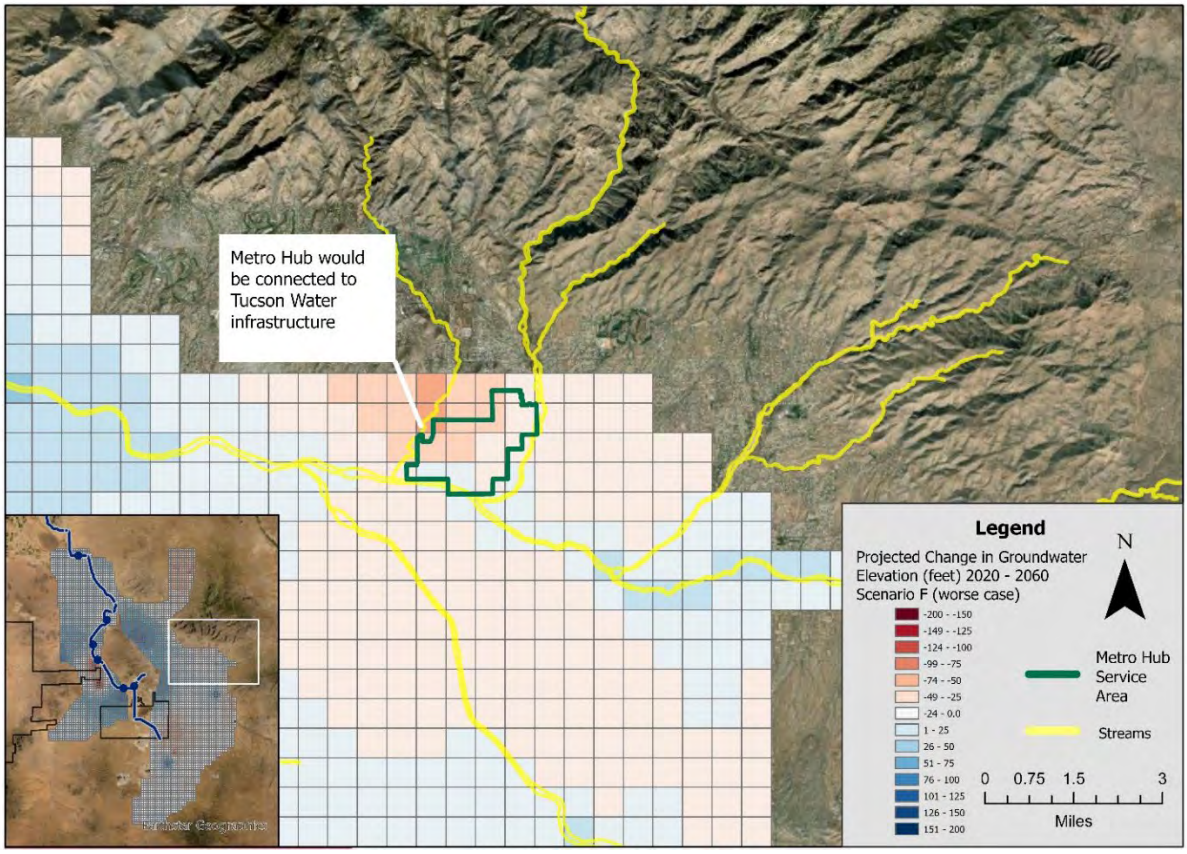


Figure 9 – Map of Adaptation Strategy SC/TV-2 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 900 acre-feet per year of wheeled CAP supplies from Tucson Water

Expected Impacts:

- Reduce groundwater pumping for potable demands in areas of once shallow groundwater.
- Support shallow groundwater levels to enhance natural flows in Sabino Creek.

Environment and Cultural Resources Issues: Not analyzed for this strategy

Preliminary Project Construction Cost:

$0 (infrastructure already exists)

Operations and Maintenance Cost: $450,000 per year (Additional cost of purchasing wheeled water over locally pumped groundwater)

Groundwater Modeling of Adaptation Strategy Impact: Groundwater modeling was not performed for this strategy.

Adaptation Strategy Sabino Canyon / Tanque Verde – 3: Connect Exempt Well Users to Tucson Water Infrastructure

Developed by: Metro Water and Pima County Department of Environmental Quality

Description: Extend Tucson Water infrastructure (within its Designated Service Area) to provide approximately 217 acre-feet per year of potable supplies to 409 exempt well users in the Sabino Canyon / Tanque Verde area, reducing the need for local groundwater pumping

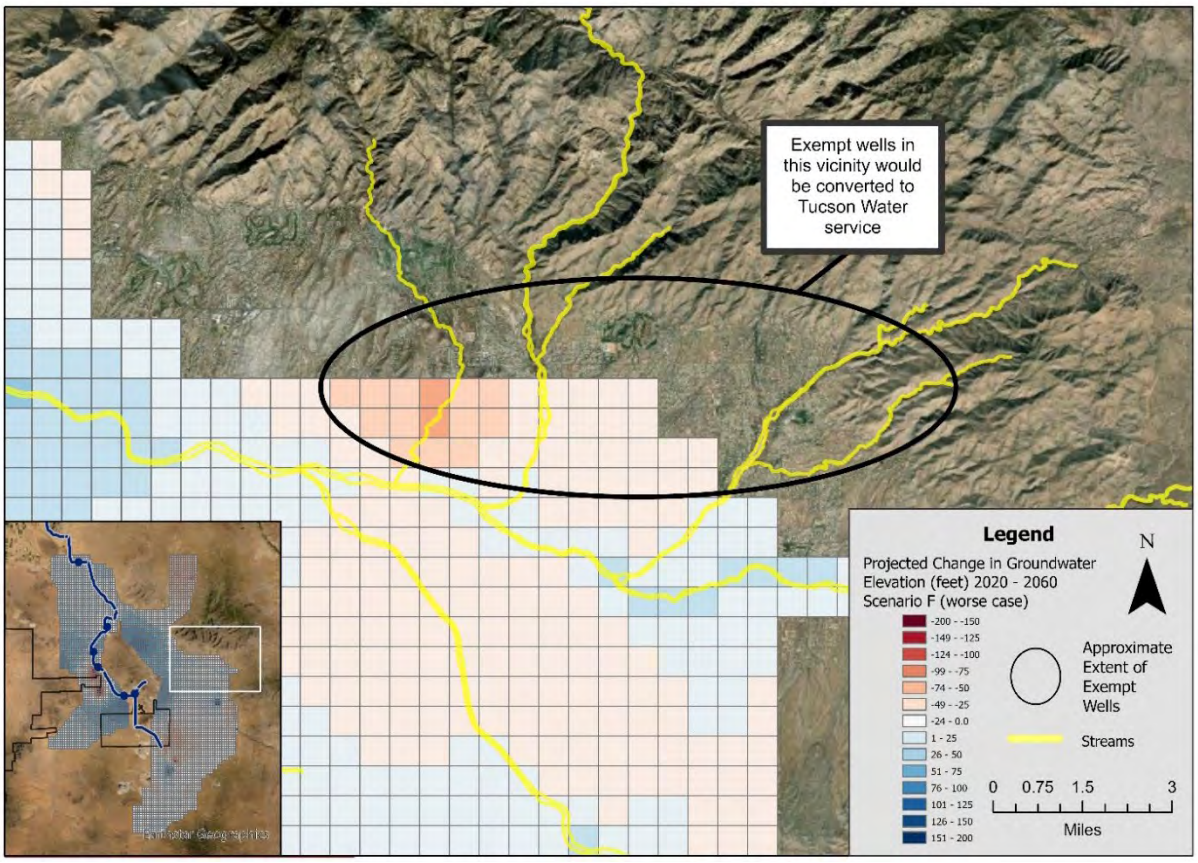


Figure 10 – Map of Adaptation Strategy SC/TV-3 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: Approximately 217 acre-feet per year of Tucson Water CAP supplies to replace local groundwater pumping (estimates developed by Pima County Department of Environmental Quality)

Expected Impacts:

- Reduce groundwater pumping for potable demands in areas of once shallow groundwater
- May support shallow groundwater levels to enhance natural flows in Sabino Creek / Tanque Verde Area

Preliminary Project Construction Cost: $950,000

Operations and Maintenance Cost: Residents would pay Tucson Water's charges for domestic use. Assuming a bill of $30 / month, this comes to an annual cost of $150,000 per year for 409 wells.

Environment and Cultural Resources Issues: Not analyzed for this strategy

Groundwater Modeling of Adaptation Strategy Impact: Groundwater modeling was not performed for this strategy

Adaptation Strategy Southeast Tucson – 1: Southeast Tucson Wheeling via Tucson Water

Developed by: Metro Water

Description:
This project would extend Tucson Water delivery infrastructure to wheel approximately 1,500 acre-feet per year of CAP water to local water companies in the growing area of Southeast Tucson, reducing the need for local groundwater pumping.

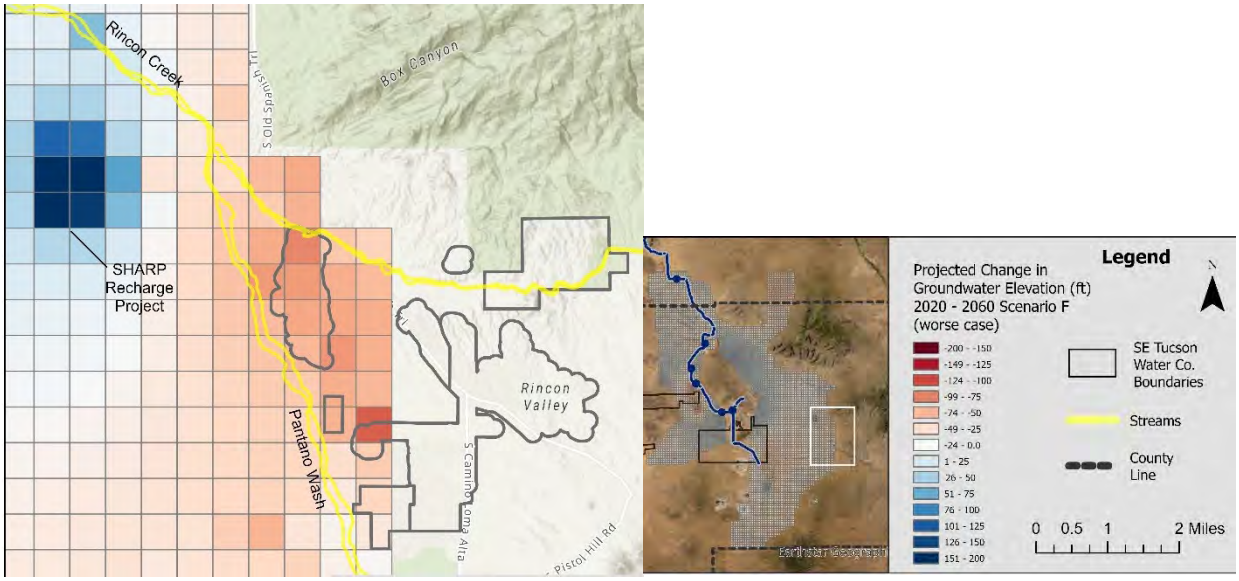


Figure 11 – Conceptual Map of Adaptation Strategy Southeast Tucson-1, overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 1,500 acre-feet per year of potable CAP supplies from Tucson Water would be wheeled to Southeast Tucson providers to replace local groundwater pumping.

Expected Impacts:

- Reduce groundwater pumping for potable demands in areas of once shallow groundwater.
- Could support shallow groundwater levels to enhance natural flows in Rincon Creek and Pantano Wash.
- Residents may experience variation in concentration of dissolved solids.

Preliminary Project Construction Cost:
$1,200,000

Operations and Maintenance Cost:
$937,500 per year (Current Tucson Water rice for wheeled water is $625 per acre-foot, x 1500 AFY)

Environment and Cultural Resources Issues:
Not analyzed for this strategy

Groundwater Modeling of Adaptation Strategy Impact: Groundwater modeling was not performed for this strategy

Adaptation Strategy Southeast Tucson – 2: Southeast Tucson Area Wastewater Plan

Developed by: Pima County Regional Wastewater Reclamation Department

Description:
This project would construct phased wastewater reclamation scalping facilities to provide highly treated reclaimed water to offset groundwater pumping, provide turf irrigation, facilitate indirect potable use and replenish the aquifer in the Southeast Tucson Area. Phasing based on service demand and life-cycle capital and operating costs.

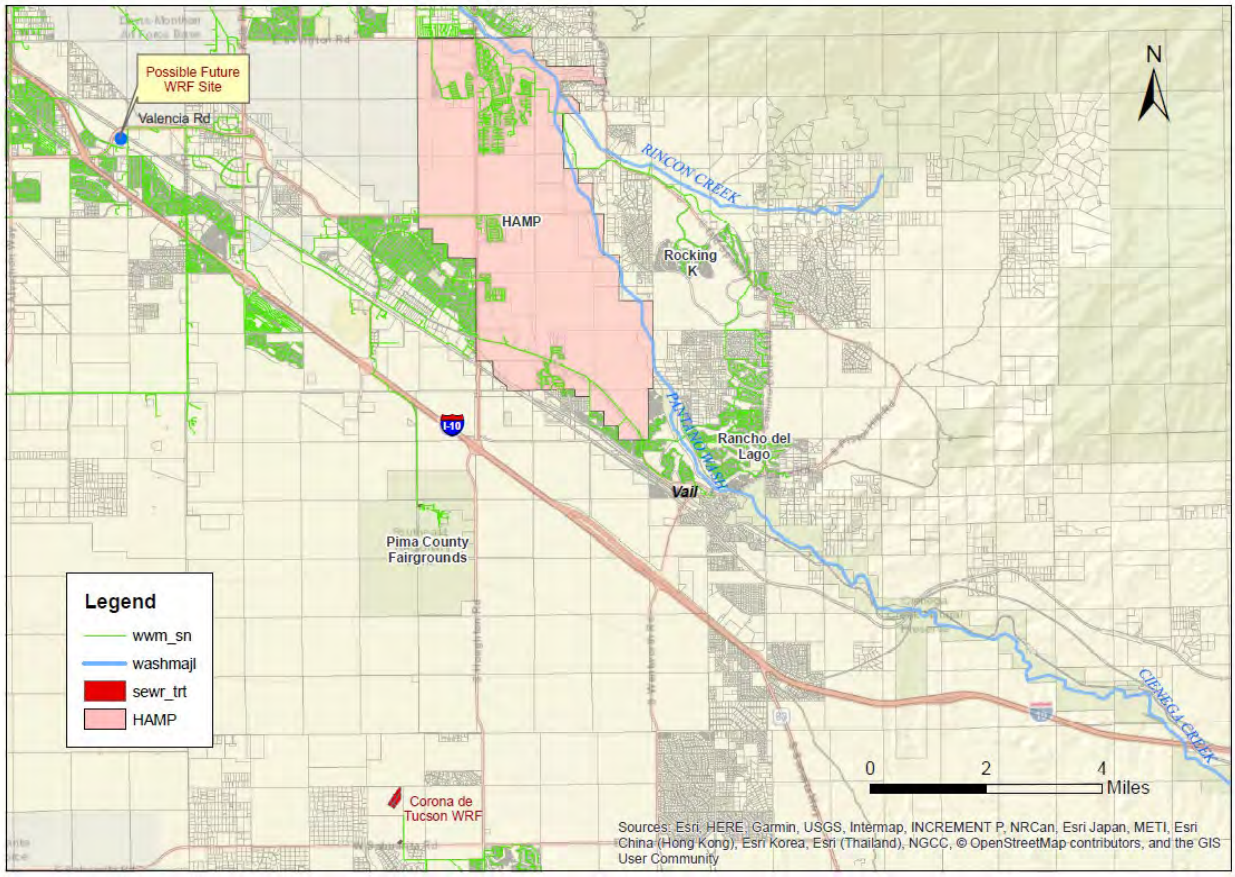


Figure 12 - Pima County Regional Wastewater Reclamation Department Southeast / Southlands Planning Area, Source: PC RWRD

Water Volume: 2,700 acre-feet per year reclaimed water in 2030, increasing to 6,700 acre-feet per year in 2060.

Preliminary Project Construction Cost: $96,000,000

Operations and Maintenance Cost: $10,800,000 per year

Environmental Issues: Invasive species, known areas of Pima Pineapple Cactus

Cultural Resources Issues: Known cultural resources, DeAnza Trail, archaeological sites, historical structures

Groundwater Modeling of Adaptation Strategy Impact: Groundwater modeling was not performed for this strategy

Adaptation Strategy Green Valley – 1: CAP Supplies to FICO Continental Farms

Developed by: Farmers Investment Company, Reclamation Phoenix Area Office

Description: Extend Farmers Investment Company (FICO) Groundwater Savings Facility Pipeline south from terminus at Sahuarita Road to Continental Farms (pecan orchards) to provide 8,000 acre-feet per year of Central Arizona Project water for irrigation. Entities providing water to the Groundwater Savings Facility would earn Long-Term Storage Credits for replacing groundwater with a renewable source. Pumping would be required to convey the CAP water uphill.

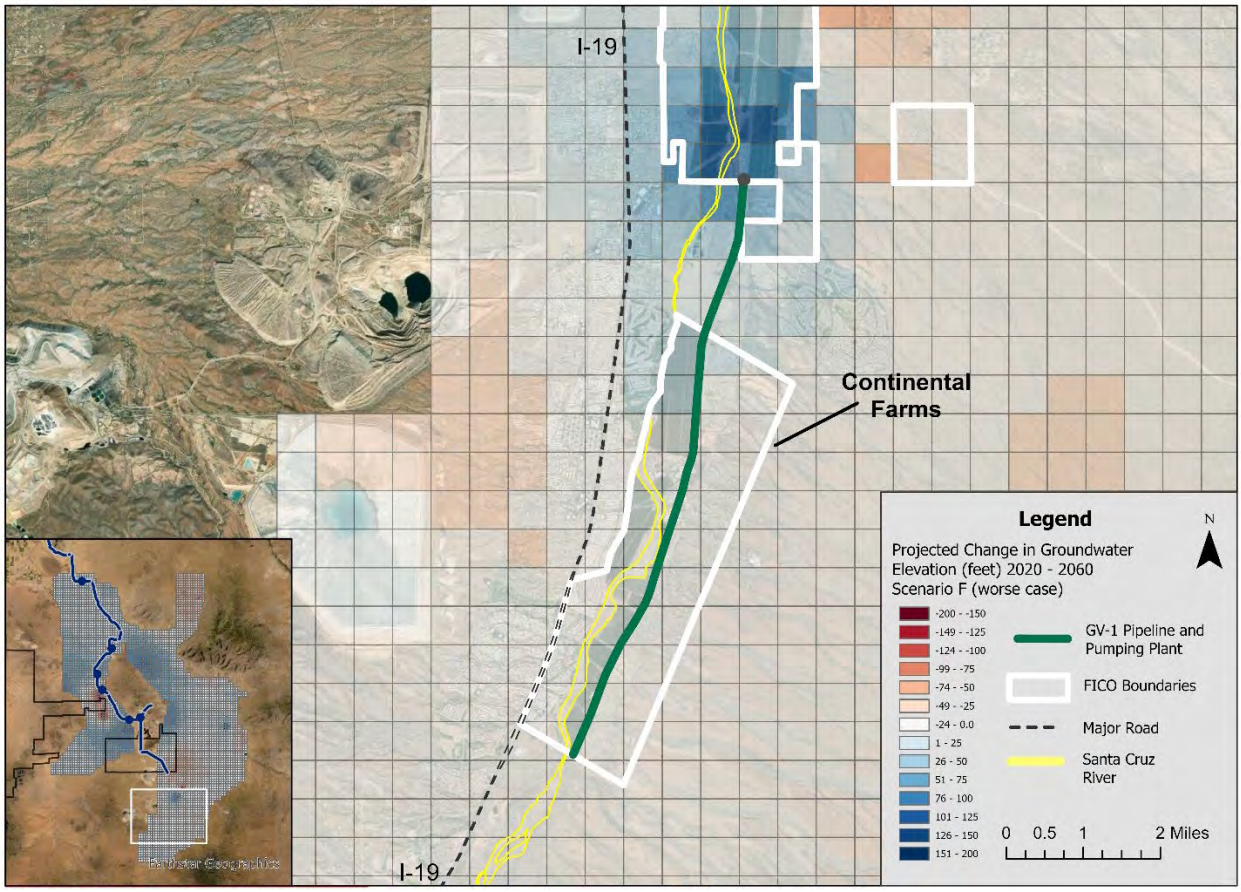


Figure 13 – Map of Adaptation Strategy GV-1 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 8,000 acre-feet per year Central Arizona Project delivered for irrigation in lieu of groundwater pumping.

Expected Impacts:

- Replacing groundwater pumping would reduce stress on the aquifer and allow natural recharge to raise groundwater levels over time.

Preliminary Project Construction Cost:
$6,500,000

Operations and Maintenance Cost:
In process of obtaining information

Environmental Issues:

- Likely similar to Adaptation Strategy Green Valley-2, in which species of concern include the Sonoran Desert tortoise, which would have to be avoided. The other concerns are the migratory birds that may be nesting along the Santa Cruz River. A survey should be performed to rule out impacts to the Pima Pineapple Cactus.

Cultural Resources Issues:

- Likely similar to Adaptation Strategy Green Valley -2, in which the alignment intersects eight cultural resources, including an archaeological district (a landscape-level cultural resource) and large archaeological sites, as well as a Rural Historic District.

Groundwater Modeling of Adaptation Strategy Impact:

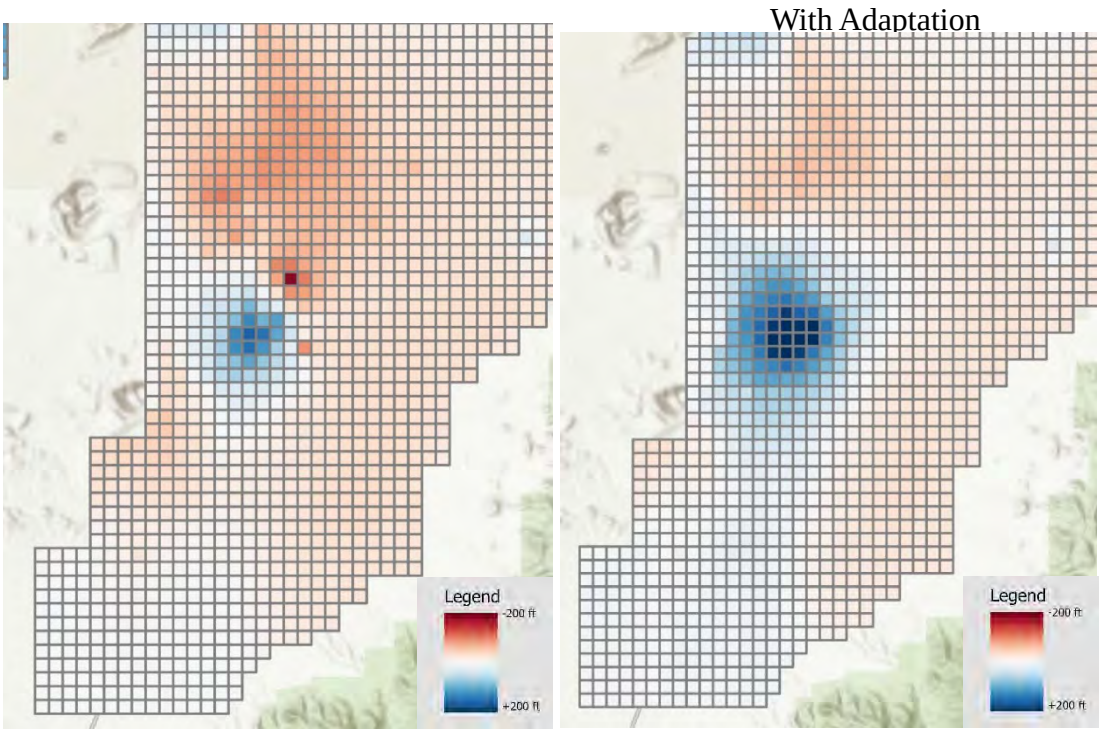


Figure 14 - Groundwater Modeling of the impact on Adaptation Strategy GV-1 on the projected changes in groundwater levels between 2020 and 2060 under worse-case Scenario F

Adaptation Strategy Green Valley – 2: CAP Water to Canoa Ranch Area Recharge

Developed by: Reclamation Phoenix Area Office and Metro Water

Description: Construct extension of FICO Groundwater Savings Facility Pipeline from terminus at Sahuarita Road south to Canoa Ranch area. This strategy will provide CAP water for recharge during the winter months, when FICO pecan orchards do not require irrigation. It includes a constructed recharge facility with basins to prevent the introduction of invasive species via CAP water. This feature may not be necessary if CAP water is filtered ahead of recharge. ***Note:*** *While this analysis considers 2,000 acre-feet of water per year, it is possible that a total of 8,000 -10,000 acre-feet per year of CAP water could be available between the months of October and March.*

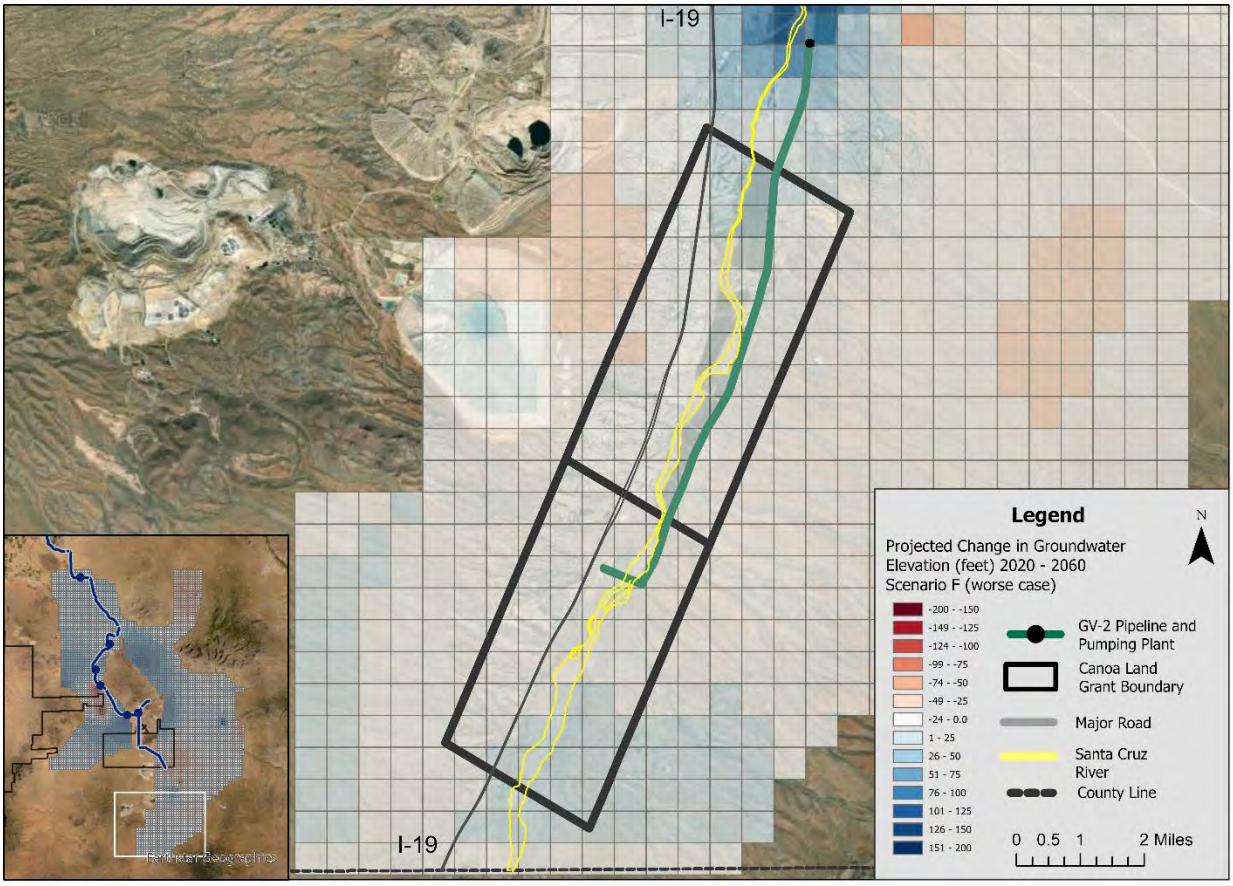


Figure 15 – Map of Adaptation Strategy GV-2 overlaid on the modeling results showing the projected change in groundwater elevation from 2020 – 2060 under worse-case Scenario F

Water Volume: 2,000 acre-feet per year Central Arizona Project supplies delivered during the winter months when FICO pecan orchards are not being irrigated. (*Note: While this analysis considers 2,000 acre-feet of water per year, it is possible that a total of 8,000 -10,000 acre-feet per year of CAP water could be available between the months of October and March*.)

Expected Impacts:

- Recharge would offset expected groundwater pumping associated with housing developments relying on the Central Arizona Groundwater Replenishment District (CAGRD) to meet the Arizona Department of Water Resources' Assured Water Supply Rules.

- Artificial recharge is likely to decrease depth to groundwater and improve degraded riparian habitat.

Preliminary Project Construction Cost:
$25,000,000

Operations and Maintenance Cost:
$371,000 per year (excludes energy costs)

Engineering Cost Estimate Notes:

- Energy costs and storage tanks not included
- Archaeological, environmental, hydrologic and drainage studies not included
- A value of 10 percent was used for mobilization. A design contingency value of 20 percent was used for all strategies. Estimates include a construction contingency cost of 25 percent.
- Non-contract costs, including environmental mitigation and restoration, cultural resources identification and compliance activities and constructions services estimated at 30 percent of total field costs.

Environmental Issues:

- The species of concern for this project include the Sonoran Desert tortoise which would have to be avoided. The other concerns are the migratory birds that may be nesting along the Santa Cruz River. A survey should be performed to rule out impacts to the Pima Pineapple Cactus.

Cultural Resources Issues:

- This alignment intersects eight cultural resources, including an archaeological district (a landscape-level cultural resource) and large archaeological sites, as well as a Rural Historic District.

Groundwater Modeling of Adaptation Strategy Impact:

Without Adaptation

With Adaptation

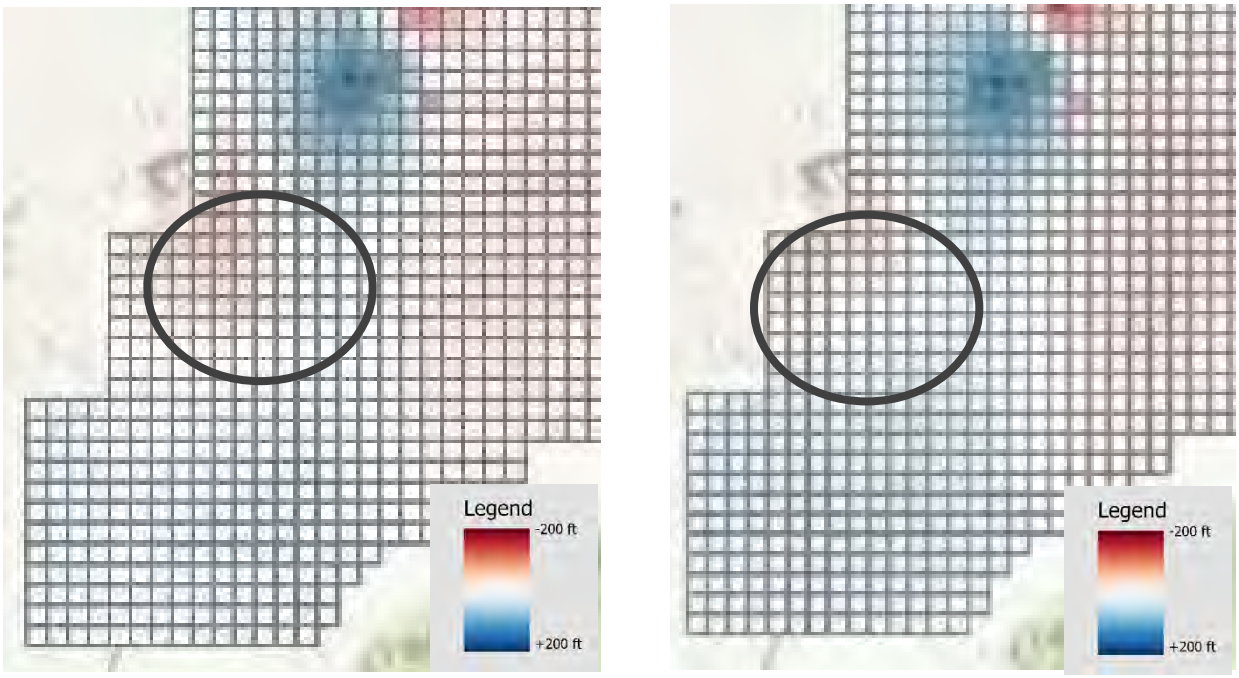


Figure 16 - Groundwater Modeling of the impact on Adaptation Strategy GV-2 on the projected changes in groundwater levels between 2020 and 2060 under worse-case Scenario F

Adaptation Strategy Green Valley – 3: Green Valley Area Wastewater Plan

Developed by: Pima County Regional Wastewater Reclamation Department

Description: This project would construct phased wastewater reclamation scalping facilities to provide highly treated reclaimed water to offset groundwater pumping, provide turf irrigation, indirect potable use and replenish the aquifer in the Green Valley area. Phasing based on service demand and life-cycle capital and operating costs.

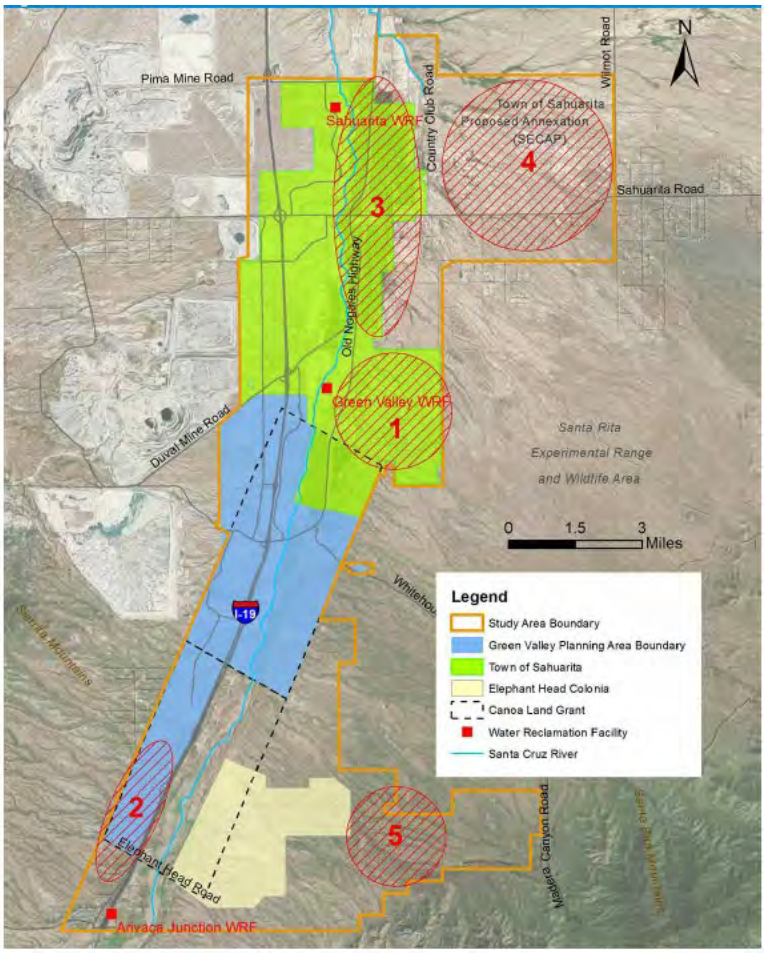


Figure 17 - Pima County Regional Wastewater Reclamation Department Green Valley Planning Area Source: PCRWRD

Water Volume: 7,500 acre-feet per year reclaimed water in 2030, increasing to 16,000 acre-feet per year in 2060.

Preliminary Project Construction Cost: $228,800,000

Operations and Maintenance Cost: $25,700,000 per year

Environmental Issues: Invasive species, known areas of Pima Pineapple Cactus

Cultural Resources Issues: Known cultural resources, DeAnza Trail, archaeological sites, historical structures

Groundwater Modeling of Adaptation Strategy Impact: Groundwater modeling was not performed for this strategy

Adaptation Strategy Regional – 1: Stormwater Management using Low Impact Development

Developed by: Pima County Department of Environmental Quality, Pima Association of Governments, Reclamation Phoenix Area Office

Examples: Constructed basin

Rain harvesting with 2,500-gallon collection tank

Description:

This strategy offsets non-renewable water supplies with the renewable stormwater, reducing the imbalance between water supply and demand. Restoration features would be constructed to utilize storm and rainwater resources generated off of impervious surfaces in order to improve infiltration and soil moisture in urban areas. Features could consist of:

1. Features that catch and direct rainfall or stormwater runoff to storage features and features that utilize the harvested water:
    a. Berms, swales or check dams
    b. Collector pipe/inlets, like curb cuts, downstream of impervious surfaces
    c. Infiltration structures such as bioretention basins and porous surfaces
    d. Desert-adapted vegetation for landscape
2. Storage features that offset existing demand for potable water or reclaimed water
    a. Cisterns or rain barrels to store rainwater
    b. Constructed basins to infiltrate the water or hold it for later use

Estimated Stormwater Yields and Preliminary Project Construction Costs for Storage Features*:

*Costs apply to four areas of concern described by LSCR Basin Study only, assumes 40-year lifespan

Strategy	# of Features	Build-out period (years)	Estimated Water Volume Captured in 2060 (acre-feet)	Preliminary Construction Cost Estimate Midpoint ($ million)	Annual O&M Cost Estimate Midpoint ($ million)
Retrofit existing developments	63,865	10	8,730	$59	$4.5
Incorporate LID into all future developments	387,810	40	84,070	$290	$18.5
Total	451,675		92,800	$349	$23.0

Estimation of Water Volume Method:

The water volume was calculated based on the number of storage features, size of the feature, rainfall depth converted to harvestable water, and the number of times a feature could be filled with the harvestable water. Due to the difference in rainfall depth between historical and future conditions, the number of retrofit features was calculated using historical rainfall and the number of future LID features was calculated using predicted rainfall depths developed during the LSCR Basin Study surface water modeling.

A Geographic Information System (GIS) was used to identify parcels in the four areas of concern as described in the LSCR Basin Study groundwater modeling results and Figure 1. The retrofit data was summarized to calculate the number of features feasible for each group of parcel sizes less than 50 acres. The future features in new developments were based on the growth of housing units from 2020 to 2060 in CAP:SAM Scenario F (worse case). For both retrofit and future features, a participation rate was assigned based on parcel size or zoning code, a likely level of interest by the public or business, and preference for cost effective features.

For simplicity, it was assumed that retrofitting existing properties would take place at a constant rate over a 10-year period beginning in 2020 and the build out of new development features would take place at a constant rate over a 40-year period beginning in 2020. The average annual volume across the period, for both retrofitting existing properties and new development, was calculated at about 39,245 AF per year, growing to 92,800 AF by 2060.

Expected Impacts:

- Offsets use of potable or reclaimed water uses
- Increases and sustains vegetation
- Reduces temperatures which abates the Urban Heat Island effect
- Decreases peak flows reducing flooding
- Improved surface water quality
- No water rights infringements if gathering “new” water created by impervious development.

Environmental Issues: Environmental issues would be specific to the particular site.

Cultural Resources Issues: Cultural resources issues would be specific to the particular site.

Groundwater Modeling of Adaptation Strategy Impact:

This strategy does not incorporate groundwater recharge.

References:

City of Tucson, Pima County et al, 2015. Green Infrastructure and Low Impact Development Guidance Manual.

Pima County, 2018. Climate Adaptation Through Green Infrastructure Low Impact Development +Trees: A GI Action Pan for Pima County.

Adaptation Strategy Regional – 2: Stormwater Multi-purpose, Multi-use Basins and Channels

Developed by: Pima County Department of Environmental Quality and Pima County Regional Flood Control District

Example:

Left: Passive recreation for bird watching Right: Active recreation (baseball and soccer)
Kino Environmental Restoration Project (KERP) kerp-urban-oasis-booklet2021.pdf (pima.gov)

Description:
This strategy would construct large multi-benefit basins and channels that collect and slow down stormwater to allow for infiltration and percolation into the vadose zone and groundwater system. Large multi-use stormwater basins and channels, whether they are retention or detention, collect stormwater from impervious areas to mitigate flooding, reduce pollutants in urban runoff, store water for later use, or habitat restoration.

3. Multi-use Retention Basin
    a. Retain the additional runoff caused by impervious surfaces due to urbanization
    b. Designed to only capture a certain volume of storm runoff then after that volume is met, the runoff flows downstream
    c. Captured runoff may contain contaminated from streets requiring the water to be cleaned up before it could be used for potable purposes
4. Multi-use Detention Basin
    a. Designed to slow down runoff while allowing some runoff to continue downstream at a slower rate
    b. Runoff can still feed downstream riparian areas during smaller events
5. Multi-Purpose, Multi-Use Channels
    a. Many basins can have multi-objective functions, such as passive and active recreation. Terracing the basin will allow for usage of some of the park while part of the park is inundated during smaller storm events.
    b. Channels can be built to enhance infiltration and incorporate recreational opportunities.

KERP is an example of the kinds of multi-purpose, multi-use functions that could be added to the four following projects:

Project Location	Area of Concern	# of Projects	Cost ($M)	Estimated water stored	Source of information
Upper Lee Moore Wash regional basins	Green Valley, SE Tucson	1	$5.7	NA	RFCD, 2010 RFCD, 2020
CDO Wash – Twenty-Seven Wash basin downstream of impervious areas	Cañada del Oro	1		NA	RFCD, 2020
Upper SCR regional basin in Canoa Ranch	Green Valley	1		NA	RFCD, 2012
Massingale Basin, dry wells in retention basin to accelerate recharge	Cañada del Oro	4	$0.8	201 AF/Y	RFCD, 2021

NA – site specific information not available.

Estimate of Water Volume: Using the information from the Massingale Basin provided by Pima County Regional Flood Control District, Reclamation estimates that each project could capture an average of 50 acre-feet per year. This figure compares well with the average water volume from KERP at 78 acre-feet per year. Using this method, an estimated 350 acre-feet per year could be collected from the four sites listed above.

Preliminary Project Construction Cost: Using example costs from the KERP project, ($11,000,000 construction cost in 2001), Reclamation estimates the capital cost of the projects for the four sites described above at $77,000,000.

Operations and Maintenance Cost: Using current example costs from the KERP project ($210,000 per year for landscape maintenance, vector control, debris removal and public safety), Reclamation estimates the annual O&M cost for the four sites described above facilities to be $942,000. (Note: these costs do not include maintenance of irrigated grass fields.)

Expected Impacts:

- Flood Control – designed to reduce the peak flow runoff rates
- Water Harvesting – retains water in constructed pond and makes it available for irrigation needs
- Economic – uses stormwater for irrigation instead of purchases of potable water and reduces the amount of reclaimed water purchased
- Public Recreation – active (ball fields and sports complex) and passive (ramadas, and walking and biking paths, and bird watching)
- Environmental benefits include open water, marsh vegetation communities, riparian trees, mesquite bosque, grass land, and Arizona upland vegetation attracting a wide variety of wildlife and wildlife watchers as well as reducing pollutants in urban runoff.

Environmental Issues: Not having enough stormwater to keep the ponds full. If there is not enough stormwater, reclaimed water or potable water can be used as backup.

Cultural Resources Issues: State Historic Preservation Office clearance would be needed for any Federal or State funded project

Groundwater Modeling of Adaptation Strategy Impact:
This strategy does not incorporate groundwater recharge.

References:
RFCD, 2010. Lee Moore Wash Basin Management Study, Volume 3, Implementation Plan.

RFCD, 2012. Groundwater and surface water assessment of Canoa Ranch.

RFCD, 2020. 2020 Floodplain Management Plan

RFCD, 2021. Massingale Retention Basin Flood Mitigation and Stormwater Harvesting, July 1, 2021 memorandum from Jake Smith to Eleonora Demaria and Evan Canfield

kerp-urban-oasis-booklet2021.pdf (pima.gov)

Adaptation Strategy Regional – 3: Stormwater Management using Upland Restoration

Developed by: Pima Association of Governments, Pima County Department of Environmental Quality, Reclamation Phoenix Area Office

Examples:

Check dam, November 2009 (left) and December 2020 (middle)
(Nichols, M.H., Polyakov, V.O., Nearing, M.A., Hernandez M, 2016)
Rainwater collector (right) by Arizona Trail Association

Description: The goal of this strategy is to improve watershed resilience to support environmental water needs. Small, distributed features would be constructed to improve environmental conditions in uplands. Stormwater and rainwater harvesting, natural channel design, and erosion/grade control techniques would be used to restore, protect and enhance surface water resources. Features would include:

1. Stormwater Rock Detention: Construct check dams, media lunas, zuni bowls, and other grade control structures using rocks (earthworks). Utilize passive stormwater harvesting to provide ephemeral water sources for wildlife tanks. Use natural channel design, such as induced meander, in arroyos, tributaries and mountain front creeks.
2. Wildlife Drinkers: Where consistent water is needed for wildlife and hiking safety, use active rainwater harvesting cisterns to sustain spring habitat, ponds, wildlife drinkers, and ranch tanks. Utilize active rainwater harvesting to provide sustained water sources for wildlife tanks.

Appropriate locations include undeveloped (or less developed) tributaries, headwaters, and mountain front systems near springs or perennial and intermittent streams with riparian habitat and perched/ shallow groundwater.

Note: management of invasive species may be necessary to maintain conditions. May need to deepen ponds over time.

Volume of Water: Unquantified. Offset groundwater use or recycled water use for restoration projects. Key water supply for environmental needs in undeveloped areas where other types of delivery are not feasible.

Preliminary Project Construction Cost: As an example, treating four locations at risk in the Study Area (Davidson Canyon, Sabino Creek, Rincon Creek, Canada Del Oro Wash), with total of 60 features, would cost approximately $1,460,000.

Operations and Maintenance Cost: Features are estimated to have about a 20-year lifespan. Discounting inflation, the average annual cost over 20 years to replace an investment of $1,460,000 is $73,000 per year.

Expected Impacts:

- Increase soil moisture by approximately ~10%*
- Increase baseflow of perennial and intermittent discharge volume by approximately 28%*
- Increase surface Water Availability ~5 km downstream and ~1 km upstream*
- Slow storm flows, decrease peak flows, and maintain floodplain
- Decrease dry days on creeks
- Improve shallow groundwater level
- Reduce headcutting and retain sediments
- Increase in riparian vegetation health and abundance and increase aquatic habitat
- Increase carbon sequestration
- Support wildlife, protects threatened and endangered species
- Can be used as refugia populations of species for emergency salvage operations
- Support recreation and rancher industries (*A 2019 Audubon Study showed that recreation along rivers, lakes, and streams contributes $13.5 billion to Pima County's economy annually.)*
- Provide ecosystem services (*Chadsey, 2016 found that Sabino Creek has a net value of $146 million – $230 million over a 100-year lifespan in ecosystem services.)*

*(*Example site, Norman, 2020)*

Environmental Issues:
Strategy would need to comply with the following laws and regulations:

- Federal Clean Water Act (CWA) Section 404
- CWA Section 401 certification from the State
- National Environmental Protection Act
- Endangered Species Act
- Various local riparian protection, erosion hazard, and floodplain ordinances

Cultural Resources Issues:

- State Historic Preservation Office clearance would be needed for any Federal or State funded project.

Groundwater Modeling of Adaptation Strategy Impact:
Groundwater modeling has not been performed for this strategy.

References:

Audubon Arizona, Southwick Associates. 2019. The Economic Impact of Arizona's Rivers, Lakes, and Streams. Accessed May 2021. (https://www.audubon.org/economic-impact-arizonas-rivers-lakes-and-streams)

Chadsey, M., Mojica, J., 2016. The Value of Ecosystem Services in Lower Sabino Creek. Earth Economics, Tacoma, WA. sabino-creek-economic-valuation-report-2016.pdf (watershedmg.org)

Nichols, M.H., Polyakov, V.O., Nearing, M.A., Hernandez, M. 2016. Semiarid watershed response to low-tech porous rock check dams. Soil Science. 181(7):275-282. doi: 10.1097/SS.0000000000000160 (https://www.tucson.ars.ag.gov/unit/publications/PDFfiles/2513.pdf)

Norman, L.M., 2020. Ecosystem Services of Riparian Restoration: A Review of Rock Detention Structures in the Madrean Archipelago Ecoregion. Air, Soil and Water Research 13. (https://journals.sagepub.com/doi/full/10.1177/1178622120946337)

Adaptation Strategy Regional – 4: Augmentation with Desalinated Water from the Sea of Cortez

Developed by: Pima County

Description: This project would augment Pima County water supplies by 100,000 acre-feet per year by constructing a pipeline to convey desalinated ocean water from the Sea of Cortez in Mexico to the Southern Avra Valley Storage and Recovery Project (SAVSARP) in Tucson. A desalination facility would be constructed near Puerto Libertad, Mexico. The 196-mile pipeline would require five pump stations for elevation lift of 3,853 feet from Puerto Libertad to Tucson. The pipeline would follow a 36-inch natural gas pipeline through Northern Mexico (north of Altar Municipality) all the way to Avra Valley. Power is available through a 240 kilo-Volt (kV) electrical transmission lines that run north from Puerto Libertad to serve the communities of Caborca and Altar.

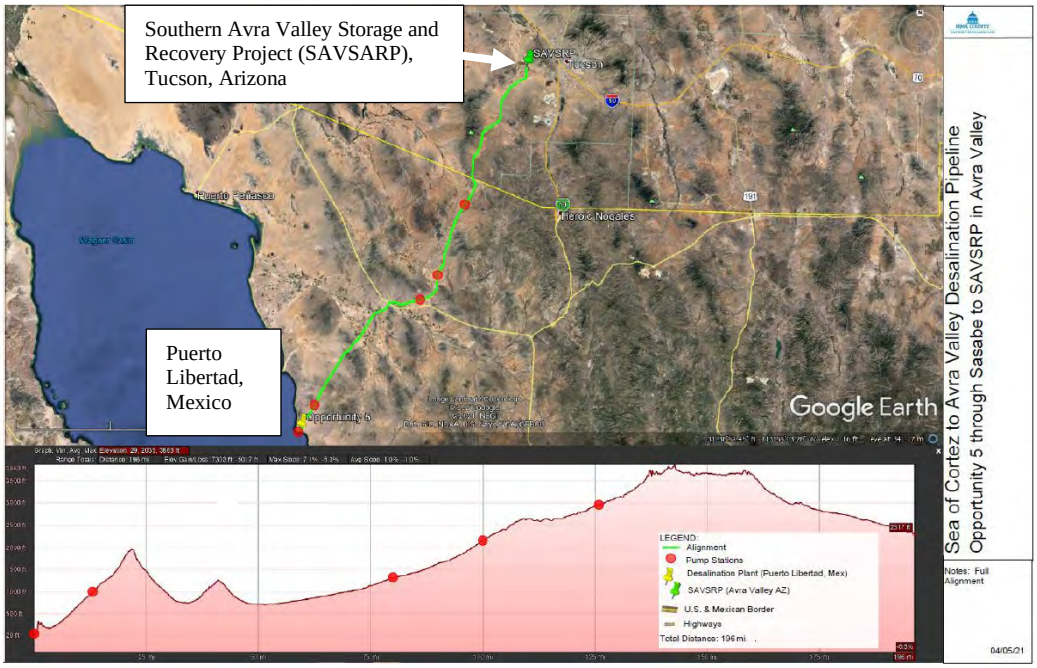


Figure 18 – Adapted from Pima County Board of Supervisors Memorandum of Water Resources Management of the Lower Santa Cruz River Basin and Augmenting Pima County Water Supply from the Sea of Cortez

Water Volume: 100,000 acre-feet per year

Preliminary Project Construction
Treatment Cost $1,100,000,000 ($1.1 billion)
Pipeline Cost: $3,000,000,000 ($3.0 billion)

Operations and Maintenance Cost:
Treatment: $73,800,000
Pipeline: $98,000,000

Environmental Issues: Alignment avoids known sensitive areas in southern Arizona and northern Mexico to minimize the complexity of the project, such as the Tohono O'odham Nation, the Buenos Aires National Wildlife Refuge in southern Arizona, and the Sierra del Pinacate National Reserve in Mexico. Impacts on wildlife and native plants from ground disturbance would occur during construction.

Cultural Resources Issues: Crossing of First Nation Lands will be avoided. Cultural survey to be conducted on final alignment.

Groundwater Modeling of Adaptation Strategy Impact: Groundwater modeling has not been performed for this strategy.

More information available at:
Pima County Board of Supervisors Memorandum: Water Resources Management of the Lower Santa Cruz River Basin and Augmenting Pima County Water Supply from the Sea of Cortez

Appendix G – Economic and Trade-off Analyses

BUREAU OF RECLAMATION

Lower Santa Cruz River Basin Study

Economic and Trade-Off Analysis

Arizona, Lower Colorado Region

U.S. Department of the Interior

September 2021

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Lower Santa Cruz River Basin Study
Economic and Trade-Off Analysis

Arizona, Lower Colorado Region

prepared by

Bureau of Reclamation
Technical Service Center
Economic Analysis Group
Matthew Elmer, Ph.D.

reviewed by

Bureau of Reclamation
Technical Service Center
Economic Analysis Group
Nicholas Rumzie

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Abbreviations

AF Acre-Foot/ Feet

AMA Active Management Area

ASARCO –American Smelting and Refining Company (subsidiary of GrupoMexico)

AWBA – Arizona Water Banking Authority

AWS – Assured Water Supply

BCR – Benefit-Cost Ratio

BT – Benefit Transfer

CAGRD – Central Arizona Groundwater Replenishment District

CAP – Central Arizona Project

CAP:SAM – Central Arizona Project Service-Area Model

CDO – Cañada del Oro

CPI – Consumer Price Index

CS – Consumer Surplus

D&S – Directives and Standards

DTW – Depth to Water

EPA – U.S. Environmental Protection Agency

EIA – U.S. Energy Information Administration

FICO – Farmers Investment Co

FY21 – Fiscal Year 2021 (October 2020 thru September 2021)

GPHUD – Gallons per Housing Unit Day

GSF – Groundwater Savings Facility

GV – Green Valley

GW - Groundwater

HU – Housing Unit

IDC – Interest During Construction

LID – Low Impact Development

LSCR – Lower Santa Cruz River

LTSC – Long-Term Storage Credit

MB – Market-Based

MCDA – Multi-Criteria Decision Analysis

NPV – Net Present Value

O&M – Operation and Maintenance

PR&G – Principles, Requirements and Guidelines for Water and Land Related Resources

Implementation Studies

PV – Present Value

Reclamation – Bureau of Reclamation

REG – Regional

SCR – Santa Cruz River

SRP – Salt River Project

SC/TV – Sabino Canyon and Tanque Verde

SET – Southeast Tucson

TW – Tucson Water

WRF – Wastewater Reclamation Facility

WTA – Willingness to Accept

WTP – Willingness to Pay

1.0 Introduction

This Technical Memorandum describes the economic and trade-off analysis performed for the Lower Santa Cruz River (LSCR) Basin Study. A map of the study area is shown in Figure 1.1, which is identical to the Tucson Active Management Area (AMA) as defined by the Arizona Department of Water Resources.

An economic analysis generally compares monetized costs and benefits to examine whether the total benefit outweighs the total cost for an action, indicating whether the action is considered economically feasible. A preliminary-level economic analysis is provided here to assess the adaptation strategies considered for the LSCR Basin Study. The analysis includes the cost of construction, the cost of operation and maintenance (O&M), and the water reliability benefit associated with each strategy. To estimate water reliability benefits, the Central Arizona Project Service Area Model (CAP:SAM) projections are used to examine water supply and demand and potential shortages for municipal providers in the study area from 2021-2060. See Appendix C, the Supply and Demand Assessment Technical Memorandum for more information on the CAP:SAM model and its supply and demand projections for the Basin Study.

For select strategies, a groundwater pumping benefit is also calculated. Pumping groundwater to the surface is an important cost for water providers. This cost is a function of the depth to water (DTW) for a particular well and the energy costs associated with pumping water to the surface. Some of the adaptation strategies involving groundwater recharge would impact the DTW for wells pumped by certain water providers. Thus, these strategies have an additional benefit of reducing the cost of groundwater pumping for providers, which can be estimated in a straightforward manner.

All monetary estimates are at a preliminary level and only for a 40-year period of analysis. This analysis also excludes several costs and benefits that could not be monetized for the LSCR Basin Study. An economic analysis is not required for Basin Studies, so the analysis provided here serves only to motivate and inform future assessments of the adaptation strategies at a more detailed level.

A trade-off analysis is broader than an economic analysis and allows for both quantified and unquantified effects to be systematically evaluated together in a single assessment, considering a diverse range of impacts along economic, environmental, and social dimensions. A trade-off analysis is a mandatory component of a Basin Study and serves to identify the strengths and weaknesses of each adaptation strategy. A trade-off analysis is also consistent with the Council on Environmental Quality Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies (PR&G) for evaluating water resource projects, which recommends considering both quantified and unquantified measures. Building from the economic analysis, a trade-off analysis is conducted to evaluate the performance of each adaptation strategy along the monetized costs and benefits previously mentioned, as well as several additional criteria measured qualitatively using a low to high scale. The trade-off analysis serves as a screening tool to help identify which adaptation strategies warrant further consideration and assessment.

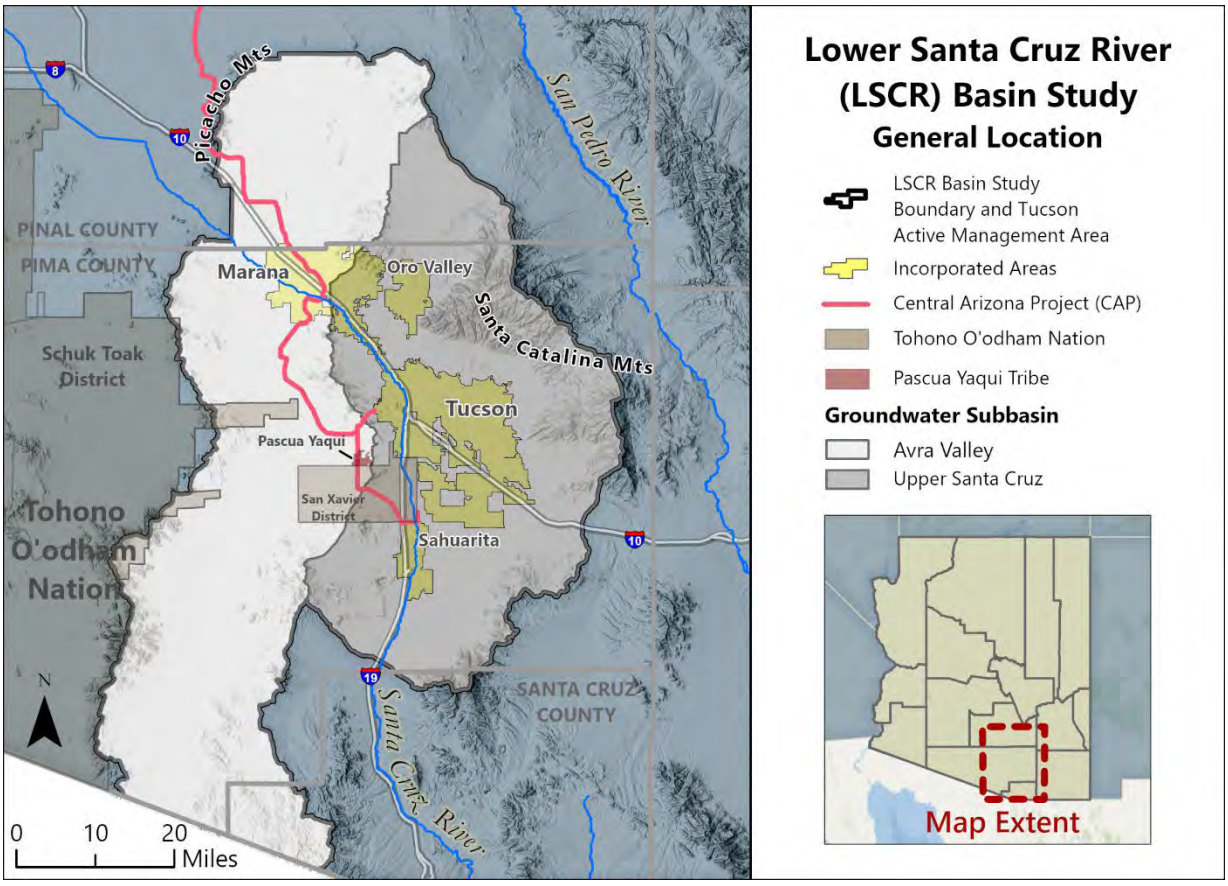

Figure 1.1 – Lower Santa Cruz River Basin Study Area (identical to the Tucson AMA)

1.1 Existing Guidance

The Bureau of Reclamation (Reclamation) Directive and Standards (D&S) for Basin Studies establishes Reclamation's requirements for reviewing, conducting, and approving Basin Studies. As stated in the guidance (WTR 13-01), Basin Studies are technical assessments and do not provide recommendations or represent a statement of policy or position of Reclamation, the Department of the Interior, or the funding partners. Basin Studies also do not propose or address the feasibility of any specific project, program, or plan and do not represent a commitment for provision of Federal funds. According to WTR 13-01 Section 9, each Basin Study must include four key elements: (1) projections of future water supply and demand, considering specific impacts resulting from climate change; (2) analysis of how existing water and power infrastructure and operations will perform given any current imbalances between water supply and demand and in the face of changing water realities due to climate change and population growth; (3) development of appropriate adaptation and mitigation strategies to meet current and future water demands; and (4) a quantitative or qualitative trade-off analysis of the adaptation and mitigation strategies identified.

For the fourth Basin Study element, a trade-off analysis, the guidance states that the analysis is supposed to examine all proposed strategies in terms of their ability to meet the study objectives, the

extent to which they minimize imbalances between water supply and demand and address the possible impacts of climate change, the level of stakeholder support, the relative cost (when available), the potential environmental impacts, or other attributes common to the strategies (WTR 13-01 Section 9 Part D). The analysis is also supposed to identify potential institutional, legal, and regulatory constraints affecting the strategies considered and identify possible next steps or analyses that could build on the results of the Basin Study. When available, existing information must be used to satisfy the required elements.

The trade-off analysis conducted for the LSCR Basin Study is consistent with these requirements and includes both quantitative and qualitative measures, relying on both existing information and new information generated for the Basin Study. Although not required for the Basin Study, the monetized effects are evaluated separately for a cursory economic analysis (cost-benefit comparison) to provide additional information and a simplified preliminary assessment of economic feasibility.

1.2 Adaptation Strategies

For the LSCR Basin Study, a total of 15 adaptation strategies were evaluated. Some of these strategies were developed for the Basin Study, while others were previously developed outside the Study. See Appendix F, the Adaptation Strategies Technical Memorandum for more details on how the strategies were developed, defined, and selected for the Basin Study, with details on the underlying components. In general, the strategies considered for a Basin Study are much broader than alternatives considered in other studies, which can make it challenging to compare strategies in a consistent manner. The strategies reflect supply-side and demand-side approaches, structural and non-structural courses of action, varied scales of impact, and different levels of detail from a range of sources. The key commonality across the strategies presented here is that they focus on reducing future water supply and demand imbalances in the LSCR study area. Many also target the "hydrological disconnect" within the groundwater aquifer (groundwater pumping in a different location than groundwater recharge and/or replenishment).

Four geographic areas of concern were identified within the study area based on projected declines in groundwater levels. The four areas of concern, shown in Figure 1.2, are the Cañada del Oro/ Saddlebrooke area (CDO); Sabino Canyon/Tanque Verde area (SC/TV); the Green Valley/Sahuarita area (GV); and the Southeast Tucson and Cienega Creek area (SET). Most of the adaptation strategies target one of these four areas of concern, while a few are considered regional strategies (REG) and focus on the LSCR study area more broadly. Table 1.1 provides a brief description of each strategy considered in the economic and trade-off analysis. Going forward, the strategy abbreviations are used for simplicity, which are specified in reference to the area of concern.

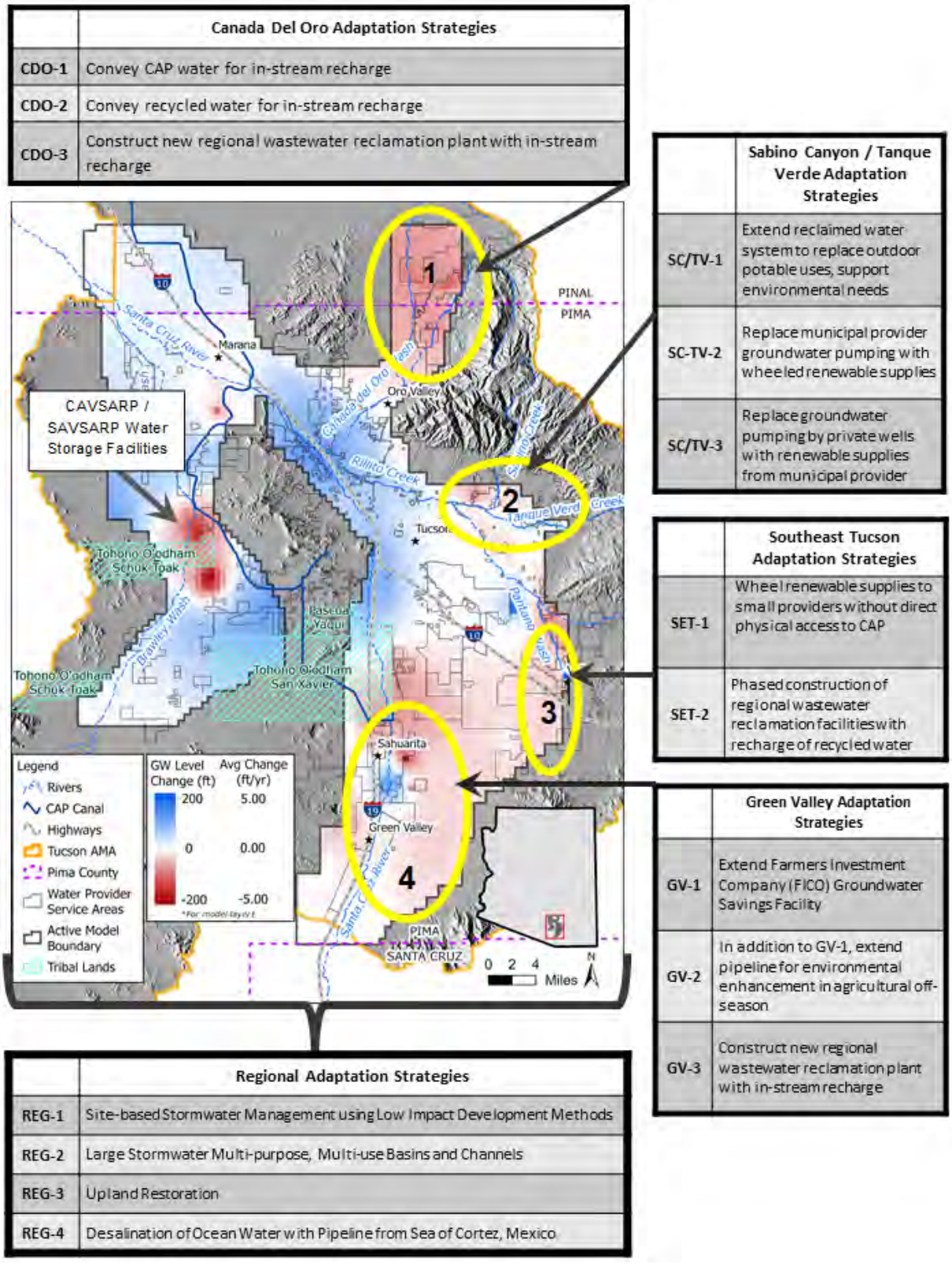

Figure 1.2 – Map of Projected Change in Groundwater Elevation from 2020 to 2060 Under Scenario F (Worse Case), with Four Areas of Concern and Locations of Adaptation Strategies

Table 1.1 – Adaptation Strategies Evaluated

Strategy Abbreviation	Adaptation Strategy	Location	Description
CDO-1	CAP water to CDO area with In-stream Recharge	Cañada del Oro/ Saddlebrooke	Construct pump stations and a pipeline to convey water from the Central Arizona Project (CAP) Red Rock Pumping Plant to the Cañada del Oro (CDO) Wash area for in-stream recharge.
CDO-2	SCR Reclaimed water to CDO area with In-Stream Recharge	Cañada del Oro/ Saddlebrooke	Construct pump stations and a pipeline to convey reclaimed water in the Santa Cruz River (SCR) past Trico Road to the Cañada del Oro (CDO) Wash area for in-stream recharge. Includes treatment for PFAS and 1,4 dioxane.
CDO-3	Saddlebrooke area Sub-regional WRF with In-stream Recharge	Cañada del Oro/ Saddlebrooke	Construct a new sub-regional wastewater reclamation facility (WRF) in the Saddlebrooke area with a pipeline for in-stream recharge.
SC/TV-1	TW Reclaimed System Extension to Isabella Lee Preserve and other sites	Sabino Canyon/ Tanque Verde	Extend Tucson Water (TW) reclaimed water pipeline to replace outdoor use of potable water at new sites and support irrigation at Isabella Lee Preserve.
SC/TV-2	Wheel TW Renewable Supplies to Metro Water District Hub Service Area	Sabino Canyon/ Tanque Verde	Use existing and new infrastructure to connect the Metro Water District's Hub Service Area to the Tucson Water central potable system. Wheel renewable supplies, replacing need for local groundwater pumping.
SC/TV-3	TW Renewable Supplies to Exempt Well Owners	Sabino Canyon/ Tanque Verde	Connect exempt well owners to Tucson Water central potable system to provide renewable supplies, retire exempt wells.
SET-1	TW Wheeling to SE Tucson Providers	SE Tucson, Cienega Creek	Construct new interconnections between TW central potable system and Southeast Tucson (SET) water providers, wheel renewable supplies, reducing local groundwater pumping.
SET-2	SET Wastewater Plan	SE Tucson, Cienega Creek	Phased construction of Water Reclamation Facilities to provide reclaimed water to SE Tucson.
GV-1	CAP Supplies to FICO Continental Farms (pecan orchards)	Green Valley/ Sahuarita	Extend Farmers Investment Co (FICO) Groundwater Savings Facility (GSF) pipeline to convey CAP water to additional pecan orchards in lieu of irrigation with groundwater.
GV-2	CAP Supplies to Canoa Ranch Recharge via FICO Pipeline Extension	Green Valley/ Sahuarita	Extend FICO GSF pipeline to Canoa Ranch for recharge into basins in the winter months (when pipeline is not needed for irrigation).

Strategy Abbreviation	Adaptation Strategy	Location	Description
GV-3	Green Valley Area Wastewater Plan	Green Valley/ Sahuarita	Phased construction of Water Reclamation Facilities to provide reclaimed water to the Green Valley (GV)/Sahuarita area.
REG-1	Stormwater Management using Low Impact Development	Regional	Retrofit existing properties and incorporate low impact development (LID) features into new developments to harvest and use renewable stormwater at the residential scale. Build-out takes place from 2020-2060.
REG-2	Stormwater Multi-purpose, Multi-use Basins and Channels	Regional	Construct large multi-benefit retention and detention basins to collect and slow stormwater from impervious areas for flood mitigation, storage and/or habitat restoration.
REG-3	Upland Restoration	Regional	Perform upland restoration using small, distributed features to restore, protect and enhance surface water resources. May improve infiltration and soil moisture and restore groundwater levels.
REG-4	Augmentation with Desalinated Water from the Sea of Cortez	Regional	Construct a desalination plant on Mexico's Sea of Cortez with a pipeline to convey desalinated water to the Tucson region.

1.3 Evaluation Criteria

To evaluate the adaptation strategies, a set of criteria was developed and tailored to the study. The evaluation criteria were based on the scope and objectives of the study while also considering the most likely effects to result from the strategies. Major decisions for the Study were made by the Project Team, which represents the Study cost-share partners. The cost-share partners included the Southern Arizona Water Users Association, Arizona Department of Water Resources, Pima Association of Governments, Cortaro-Marana Irrigation District, University of Arizona, and Central Arizona Water Conservation District, also referred to as "Central Arizona Project". In consultation with the Project Team, criteria developed during the Adaptation Strategy Workshops were combined or removed to avoid redundancy. The criteria were ultimately selected to help distinguish between strategies and identify the key strengths and weaknesses of each strategy. In total, 10 criteria were defined and used to evaluate adaptation strategies. Criteria 1-3 measured impacts in monetary terms, while the remaining criteria were measured qualitatively using a low-high scale. The monetized criteria (water supply reliability benefit, capital cost, and O&M cost) were the focus of the economic analysis.

For the trade-off analysis, the monetized criteria and qualitative criteria were evaluated together. The qualitative criteria included aquifer benefit, impacts on water quality, riparian conditions, flood risk, and quality of life, as well as whether the strategy leverages existing resources and whether there are major barriers to implementation. The qualitative criteria were scored through online polling by representatives of the cost-share partners involved in the LSCR Basin Study and were intended to

capture impacts from adaptation strategies that could not easily be quantified or monetized. For simplicity, all criteria were defined as either a "cost" or "benefit" to indicate directionality, but the criteria span economic, social, and environmental considerations. Table 1.2 provides a brief overview for the set of 10 evaluation criteria used to evaluate the 15 adaptation strategies.

Table 1.2 – Evaluation Criteria Used for the Trade-Off Analysis

Criterion	Description	Measurement	Directionality
(1) Water Supply Reliability Benefit	Benefit from reducing future shortages anticipated for the study area.	Monetized	Benefit
(2) Capital Cost	Cost of construction or implementation (upfront cost).	Monetized	Cost
(3) O&M Cost	Cost of operation and maintenance (ongoing cost).	Monetized	Cost
(4) Aquifer Benefit	Improvements in groundwater levels to reduce pumping costs, prevent subsidence, or improve general aquifer condition.	0 to 3	Benefit
(5) Quality of Life Benefit	Improvements in recreation, aesthetics, health, safety, heat island effect, or cultural resources.	0 to 3	Benefit
(6) Leverage Existing Resources	Utilizes or enhances existing investments or infrastructure.	0 to 3	Benefit
(7) Barriers to Implementation	Obstacles from public perception, regulations, administrative complexity, or physical limitations.	-3 to 0	Cost
(8) Riparian Impact	Changes to riparian habitat and conditions.	-3 to 3	Cost/Benefit
(9) Water Quality Impact	Changes in the chemical, physical, or biological characteristic of water resources.	-3 to 3	Cost/Benefit
(10) Flood Risk Impact	Changes in flood risk (probability or consequences).	-3 to 3	Cost/Benefit

As mentioned, criteria 1-3 were monetized and the focus of the economic analysis. The benefit of reduced groundwater pumping costs was also included for select strategies that were assessed using a groundwater model. For the trade-off analysis, aquifer benefit (criterion 4) was used instead of reduced groundwater pumping cost. "Aquifer benefit" reflects a broad qualitative criterion, part of which includes a groundwater pumping benefit, as well as consideration for land subsidence and general aquifer condition. For the trade-off analysis, criteria 4-6 captured benefits with impacts measured qualitatively from 0 to 3, criterion 7 was defined as a cost measured from -3 to 0, and criteria 8-10 were measured from -3 to 3 since impacts could be positive or negative, depending on the strategy under consideration.

All 10 criteria were evaluated for the trade-off analysis to identify strategy strengths and weaknesses. The performance along each criterion was then combined to derive an overall score for each adaptation strategy. This was used to compare strategies in three ways: 1) within each area of concern, 2) across the areas of concern, and 3) overall across all strategies considered. To account

for the fact that some criteria might be viewed as more important than others, polling was also conducted to gather subjective preferences and incorporate "importance weights" into the trade-off analysis based on the preferences of the partners involved in the Basin Study. Both the unweighted results (all criteria treated equal) and weighted results (more influence for more important criteria) are presented here.

2.0 Water Supply Reliability Benefit

2.1 Introduction

The benefit of additional water supply and improved reliability depends on several factors. For the Basin Study, a water supply reliability benefit was estimated based on CAP:SAM projections of water supply and demand in the study area and the potential for future imbalances (shortages). In this setting, the benefit of additional water supply was based on the extent of future shortages in the area and the ability of each adaptation strategy to mitigate those future shortages. A water reliability benefit was estimated using both a benefit transfer (BT) approach as well as a market-based (MB) approach. Both approaches are considered acceptable under the PR&G and Reclamation guidance, but they are fundamentally quite different, and each has pros and cons. Both methods were explored to ensure the robustness of the water reliability benefit estimates provided for the Basin Study.

Willingness to pay (WTP) can be defined as the dollar amount that an individual is willing to give up in order to acquire a good or service. The BT approach relies on previous studies and applies their estimates to the study area based on shortages at the household level and household WTP to avoid a shortage. Under the BT approach, CAP:SAM information on housing growth, households under shortage, and shortage severity was combined with WTP estimates from prior studies to estimate a reliability benefit for each strategy. The MB estimate instead focuses on renewable water supply and demand from a regional market perspective to examine how future shortages may affect water prices and wellbeing for municipal users in the study area. Under this approach, the benefit was calculated based on water supply and demand from CAP:SAM and compared the shortage volume and changes in wellbeing with, versus without, a strategy in place. Rather than looking at household WTP to avoid a shortage, this approach focused on the WTP for the volume of water generated by a strategy based on recent water transactions in the study area.

Shortages may arise from reduced water supply, increased water demand, or a combination of both. Shortages in the study area are only anticipated for municipal users, not for non-Indian agricultural or tribal use, so the focus was on municipal providers for calculating the water supply reliability benefit. (Within the study area, non-Indian agriculture users have grandfathered groundwater pumping rights. The tribes within the study area have water rights settlements providing high-priority Central Arizona Project water for their use. In the case of the San Xavier and Schuk Toak Districts of the Tohono O'odham Nation, only a portion of the CAP entitlement is used on tribal lands, so shortages to tribal agriculture are extremely unlikely.)

Under Arizona's Assured Water Supply (AWS) rules, municipal providers are required to use renewable water, or offset groundwater use with replenishment, above a small groundwater allowance. In some locations replenishment water can only be obtained through the Central Arizona

Groundwater Replenishment District (CAGRD). The CAGRD is a division of the Central Arizona Project. It provides a mechanism for landowners and water providers to demonstrate an Assured Water Supply consistent with the AWS rules. CAGRD members pay an established rate per acre-foot of water to replenish the volume of groundwater they pump within an Active Management Area. The price is based on the CAGRD's cost of obtaining renewable supplies plus overhead. More information on the CAGRD is provided in Section 3.2 of Appendix C, the Supply and Demand Assessment Technical Memorandum.

CAP:SAM treats unmet demand as groundwater use that is subject to AWS rules, recognizing that it is yet to be determined how that pumping will be offset with renewable supplies in the future (this quantity is sometimes referred to as the "CAGRD need"). To estimate the benefit of renewable water provided by each strategy, this unmet portion of demand was treated as the shortage volume for renewable supplies. This was done to capture Arizona's existing legal framework which requires future municipal use to be met by directly using renewable supplies or through offsetting groundwater use with renewable supplies within the same AMA.[1]

For the LSCR Basin Study, six CAP:SAM projections of future supply and demand were generated, each reflecting a different projection of renewable water shortages in the study area. Each scenario included a projected sequence of shortages of Colorado River water to the Central Arizona Project through 2060. These projections served as "what if" scenarios to demonstrate the range of future shortages to municipal water providers within the study area. For the economic and trade-off analysis, the Project Team chose to focus on CAP:SAM Scenario F, which reflects rapid, outward population growth and more severe level of climate change. A future under Scenario F would require the most adaptation of the six CAP:SAM scenarios.

The rationale for this decision was that in a risk-management context, it is more useful to be prepared for a high-risk scenario because it provides managers with information that can be used to protect their customers and/or other water interests under a wide range of outcomes. Therefore, the benefit estimates provided here apply only to conditions under Scenario F. In general, the benefit would likely be lower for the other CAP:SAM scenarios due to less need for (and benefit from) the water volume and reliability provided by a strategy.

2.2 CAP:SAM Water Supply and Demand Projections

In support of the Basin Study, CAP:SAM scenarios were generated for the period 2018-2060. Here attention is placed on the 40-year period from 2021-2060. CAP:SAM produces projections for the majority of water supply and demand in the study area as well as the entire 3-county CAP service area (Maricopa, Pinal, and Pima counties). The model includes public and private water utilities, irrigation districts, tribes, and other user categories such as the CAGRD, the Arizona Water Banking

[1] The CAP:SAM projections for municipal water providers include residential demand as well as some non-residential demand (e.g., commercial, industrial, and construction use). Remaining industrial demand is modeled in CAP:SAM at the AMA level and represents use that is not served by a municipal provider, generally reflecting groundwater use that is not subject to AWS rules (e.g., Type-1 and Type-2 non-irrigation grandfathered rights or withdrawal permits). Here attention is placed on municipal providers and renewable use that is subject to AWS rules. See Section 3.1 of Appendix C, the Supply and Demand Assessment Technical Memorandum for more information on the regulation of water use in the Tucson AMA.

Authority (AWBA), and industrial users such as mines and power plants. See Appendix C, the Supply and Demand Assessment Technical Memorandum, for more details on the development of the CAP:SAM projections and assumptions used for the Basin Study.

CAP:SAM simulates a wide range of future conditions, including rates and patterns of growth, shortage impacts, effluent reuse, aquifer recharge and recovery, and complex supply portfolio management decisions. The model accounts for numerous sources of water supply and the major elements of Arizona's elaborate legal and regulatory framework that affect the availability and accounting of those supplies. As a systems model, CAP:SAM generates different supply and demand conditions and then approximates how water users might respond to changing conditions. Many of the future responses are influenced by the set of laws, rules, rights, and practices that comprise water management in the region.

Like any model, CAP:SAM simplifies phenomena that have many layers of additional complexity. For example, while CAP:SAM simultaneously simulates supply and demand for more than 100 entities, it does not model the distribution of those supplies and demands within an individual water provider or irrigation district. In addition to complexity, future supply and demand encompass several elements of uncertainty, so CAP:SAM strikes a balance between unmanageable complexity and unreasonable simplification.

The model tracks the total legal and physical supply availability for several water supply types in each projection year. Supply categories include effluent, Salt River Project (SRP) water, CAP water, local surface water, and groundwater, many of which are further divided into subcategories. The model estimates water deliveries to the state-certified facilities that generate Long-Term Storage Credits (LTSCs), with debits and credits occurring through time.

Demand by CAGRD members is also included, and it is assumed that supplies are limited by currently known CAGRD resources. The model also simulates transfers, leases, exchanges, reallocations, and priority conversions, which includes only existing or currently proposed transactions. Lastly, in the process of fulfilling annual demands, CAP:SAM makes projections of effluent use. This effluent use includes non-potable reclaimed distribution (i.e., "purple pipe") and any recovered effluent that is indirectly satisfying potable demand (i.e., water that is physically groundwater, but legally recharged effluent).

The CAP:SAM scenarios differed primarily in the rate of population growth, spatial distribution of growth, water use efficiency, and climate-related factors such as the magnitude and frequency of shortages to the Colorado River, crop evapotranspiration, and surface water availability within the 3-county service area. Municipal demand varied among the scenarios, but per-capita use generally trended downward to reflect observed long-term trends associated with improvements in water use efficiency and societal tastes and preferences.

Agricultural demand was based on cropped acres, crop mix, consumptive use, and irrigation efficiency. Gradual improvements in agricultural efficiency were also included in each scenario, and demand was based on crop mix, substitution of higher water use crops, and changes in consumptive use due to climate change. CAP:SAM also includes assumptions about tribal water use, including use

on tribal lands (predominantly irrigation), off-reservation storage, and off-reservation leasing. Leased tribal supplies were included in individual water provider portfolios.

To help differentiate the effects of observed long-term declines in water use from future growth-related trends, CAP:SAM separately considers existing and new municipal demand. Existing municipal demand represents baseline water use, while new demand is simulated on the basis of housing units (HUs) that are projected to be located within each water provider's service area. Demand includes the use from the housing unit itself as well as a fraction of the ancillary demands (e.g., new parks, commercial land uses, etc.). CAP:SAM spatially distributes HUs among water providers based on a geographic reference projection of housing units by provider, by time. The geographic projections are based on growth modeling that incorporates a large number of factors, including demographic data, construction data, planned developments, land uses, employment patterns, and transportation infrastructure.

The outputs from CAP:SAM served as key inputs into calculating the water supply reliability benefit for each adaptation strategy. For the BT estimate, HU shortage severity was evaluated based on the shortage of renewable water relative to total water demand for households (renewable and non-renewable). For the MB estimate, the shortage volume for municipal providers was evaluated based on renewable supply and demand. It is important to emphasize that the CAP:SAM projections do not reflect any official projection of future supply and demand in the region, but rather, represent plausible "what if" scenarios based on the best available information at the time of the Study. In practice, it is impossible to know the true benefit of increased water supply since it will ultimately depend on several unknown factors, such as future drought conditions, population growth, water efficiency improvements, price sensitivity, and policy decisions.

Table 2.1 and Table 2.2 summarize projected shortages for the LSCR study area from a household perspective (used for the BT estimate) and from a supply and demand perspective for municipal providers (used for the MB estimate). Table 2.1 shows Scenario B, which reflects slow compact growth and a less severe level of climate change. Table 2.2 shows Scenario F, which was the focus of the economic and trade-off analysis and reflects rapid, outward growth and a more severe level of climate change. Scenario B and Scenario F represent the extremes of the six CAP:SAM scenarios considered. Both Scenario B and Scenario F reflect similar declines in gallons per housing unit day (GPHUD) across the period, but otherwise, Scenario F embodies more rapid growth and more severe shortages, which stems from both growth and climate conditions.

Table 2.1 – Renewable Demand and Shortage in LSCR Study Area, Scenario B

Year	Housing Units (HUs)				Municipal Renewable Use		
	Total HUs	GPHUD[a]	HUs Under Shortage	HUs Shortage Severity[b]	Municipal Renewable Demand (AF)	Municipal Shortage Volume (AF)	Municipal Shortage Size[c]
2020	421,526	320	48,889	21%	130,484	3,513	2.7%
2030	450,425	298	54,892	29%	130,164	4,812	3.7%
2040	480,447	279	78,118	26%	130,425	5,933	4.6%
2050	507,818	270	84,183	35%	133,956	7,843	5.9%
2060	534,622	268	90,082	42%	141,327	9,831	7.0%

[a] Reflects the average of GPHUD for existing and new housing.

[b] Includes renewable and non-renewable use.
[c] Includes renewable use only.

Table 2.2 – Renewable Demand and Shortage in LSCR Study Area, Scenario F

Year	Housing Units (HUs)				Municipal Renewable Use		
	Total HUs	GPHUD[a]	HUs Under Shortage	HUs Shortage Severity[b]	Municipal Renewable Demand (AF)	Municipal Shortage Volume (AF)	Municipal Shortage Size[c]
2020	425,531	321	50,796	22%	131,630	3,668	2.8%
2030	479,963	302	83,894	29%	140,473	6,994	5.0%
2040	568,733	284	106,380	43%	158,574	11,869	7.5%
2050	725,632	273	178,984	42%	196,363	19,393	9.9%
2060	929,474	267	270,256	55%	222,251	40,303	18.1%

[a] Reflects the average of GPHUD for existing and new housing.
[b] Includes renewable and non-renewable use.
[c] Includes renewable use only.

The project team decided to focus on Scenario F since it represents the highest-risk case of the six CAP:SAM scenarios considered. Water reliability benefits were therefore estimated for Scenario F and reflect the benefit under more adverse climate change and rapid population growth. In general, the benefit would be lower for the other CAP:SAM scenarios due to lower household growth, less renewable demand, fewer households under shortage, a smaller shortage volume, and a lower shortage severity for households, overall meaning less need for (and benefit from) the water provided by a strategy. In addition to variation across the CAP:SAM supply and demand scenarios, the MB benefit estimate varied depending on the assumed price sensitivity (elasticity of demand), and the BT estimate varied depending on the benefit per household adopted from previous studies. As such, the economics literature was reviewed for both approaches, and a sensitivity analysis was provided to show how varying key assumptions influences the estimates.

2.3 Estimation Methodology

The water supply reliability benefit for each adaptation strategy was calculated using a BT approach as well as a MB approach. These approaches are fundamentally different, and each relies on unique assumptions and data. The BT method is based on previous economic studies, many of which use contingent valuation surveys and hypothetical questions to estimate WTP to avoid a shortage at the household level. The WTP for a typical household to avoid a shortage is then multiplied by the number of HUs supported by a strategy, which depends on the HUs expected to experience a shortage and the severity under CAP:SAM Scenario F. There is also a volume component, specifically in years when the water volume provided by a strategy is less than the shortage gap, in which case the HUs supported is proportionally adjusted based on the proportion of the shortage offset.

The MB method is instead based on market transactions and the volume of water associated with each adaptation strategy. Recent transactions for LTSCs within the AMAs of Arizona were used to approximate the average price per acre-foot (AF) of water, and a supply and demand framework was used to model shortages and changes in consumer wellbeing across the study period. The benefit of

a strategy was then determined by comparing the shortage volume and changes in consumer wellbeing with, versus without, a strategy in place. While the BT and MB approaches are quite different, both approaches evaluate water shortages and WTP to avoid shortages, so estimated benefits should be relatively similar for both methods. Furthermore, both approaches relied on the CAP:SAM projections and some key underlying assumptions made for the Basin Study.

2.3.1 Key Assumptions

The first major assumption was that the annual water volume associated with each adaptation strategy reflects an increase in water availability, representing previously un- or under-utilized renewable water that could help to reduce future shortages. In reality, the link to offsetting water shortages varies by strategy and may be direct or indirect, and the annual reliability of the water provided by each strategy is also likely to vary. There were also no assumptions as to who the beneficiaries of the water might actually be, other than assuming the benefit accrues to those expected to experience a future shortage under CAP:SAM Scenario F. Capturing the nuances of each strategy was not practical for the Basin Study, but these features are important to consider for future analyses.

Baseline conditions were based on CAP:SAM modeling for the 3-county CAP service area, but benefits were assumed to accrue only to the LSCR study area (Tucson AMA). Any excess water volume beyond what is needed to offset the annual shortage volume in the study area was assumed to be stored and available to reduce future shortages. Under this approach, the water volume associated with each strategy is fully utilized by the study area by the end of the study period (2060) under CAP:SAM Scenario F. Low Impact Development (REG-1) and the Sea of Cortez Pipeline (REG-4) are two exceptions, providing water beyond the shortage volume in the LSCR study area. For these strategies, additional water was assumed to benefit users in the 3-county CAP service area outside the Tucson AMA. This need does not necessarily entail transporting water to beneficiaries outside the study area, but could, for example, reflect reduced CAP demand and increased CAP availability for other users in the region. Without including spillover benefits for these two strategies, the benefit estimates would not reflect the full volume of water and full reliability benefit provided by these strategies. Put differently, since these two strategies have such a large impact on water volume, they were modeled as benefiting the LSCR study area as well as the broader 3-county region (Maricopa, Pinal, and Pima Counties) that shares water resources.

A 40-year benefit was estimated for each adaptation strategy assuming that benefits accrue from 2021-2060. In practice, the construction and implementation time would determine when benefits start to accrue and lead the benefits to begin at different points in time for each strategy. Furthermore, the lifecycle of each strategy is likely to vary, and a 40-year estimate may only reflect a snapshot of the lifecycle benefit. That said, the implementation time and lifecycle is unknown for each strategy, so a simplified cost-benefit framework was used that ensured consistency and allowed for comparisons across the strategies. This entailed comparing a 40-year stream of benefits to construction cost and a 40-year stream of O&M costs. In effect, the construction cost was modeled as a lump-sum upfront cost in 2020, followed by 40 years of O&M costs and reliability benefits for the period 2021-2060. All future costs and benefits were discounted with the present value (PV)

calculated using the fiscal year 2021 (FY21) federal planning rate for water resource projects of 2.5%.

The last key assumption for estimating benefits was that the reliability benefit for each strategy is at the wholesale level and associated with raw water at the point of supply. Distinguishing between wholesale and retail values is important, as retail values include the value added from treatment and distribution to end users for potable use, which often constitutes a large portion of retail water bills. For the BT estimate, retail values were adjusted to the wholesale level based on the average proportion of water utility costs associated with wholesale costs. For the MB estimate, the value of LTSCs were used to proxy WTP for a unit of water, already reflecting a wholesale value prior to any value added from treatment or distribution. Under both approaches, no effort was made to account for differences in water quality. That said, future assessments should consider the quality of water provided by each strategy, which could then influence the wholesale benefit by requiring more or less treatment before end use. Although the monetary benefit estimates provided here focus only on water quantity, water quality was 1 of 10 criteria considered for the trade-off analysis and used to compare strategies.

2.3.2 Benefit Transfer Estimation

Most of the previously completed water supply reliability studies have relied on survey data to estimate WTP and benefits. Surveys are used to ask water users how they would react to different magnitudes of shortages and various frequencies/probabilities of shortage, ultimately estimating household WTP to avoid those shortages. In some studies, the question is posed in terms of the willingness to accept (WTA) payment for a reduction in reliability. WTA is generally expected to be higher than WTP for two basic reasons. First, WTA is not bound by income as a constraint while WTP is bound by a household's available disposable income. Second, WTA represents a change to a less desirable level of utility while WTP represents a change to a more desirable level of utility. The improvement in conditions associated with WTP may be from a level of utility that is acceptable and, due to the law of diminishing returns, would not be valued as highly as a decrease in utility to a level that might not be acceptable without large compensation.

Unfortunately, the use of surveys and hypothetical conditions to derive estimates of WTP and WTA can generate imperfect and biased results. Furthermore, the estimates from other studies were only applicable to the LSCR study area if the populations and study settings are reasonably similar. Unfortunately, there have only been a handful of water reliability studies completed to date, none of which look at Arizona, and no studies have been conducted in recent years. This is why a MB estimate was also provided, relying on recent market conditions in the study area to serve as a robustness check on the BT estimates. Six previously completed water reliability benefit studies are briefly summarized below and were used to inform the BT estimates for adaptation strategies.

A study by Carson and Mitchell (1987) completed for The Metropolitan Water District of Southern California estimated an annual WTP to avoid various shortage percentages at different intervals with a range of estimated WTP from $83 to $258 annually per household in 1987 dollars. Using the consumer price index (CPI) for the West Census Region, this equates to $205 to $637 annually per household in 2021 dollars. Unless otherwise noted, all dollar values are stated in 2021 dollars (first

half) based on adjustments using the CPI for the West Census Region (indices for only the first half of 2021 were available at the time of this analysis).

A study by Barakat and Chamberlin (1994) estimated the mean monthly WTP of residential water customers in southern California to avoid water supply shortages with a mean monthly WTP estimated to range from $11.13 to $16.93 per household per month in 1993 dollars. In 2021 dollars, this equates to $258 to $392 annually per household. The lowest value was for a 10% reduction once every 10 years and the highest was for a 50% reduction once every 20 years. There were several iterations in between the range of values, with different reductions in service and frequency of occurrence.

Howe et al. (1994) examined the value of water supply reliability for three cities along the Colorado Front Range (Boulder, Aurora, and Longmont), looking at the WTP and WTA for decreasing and increasing probabilities of annual shortage events, respectively. They estimated WTP for Boulder to range from $4.67 to $5.32 per customer per month and WTA to range from $4.53 to $5.44 per customer per month in 1992 dollars. The results for WTP for Aurora ranged from $5.82 to $6.51 per customer per month and WTA ranged from $6.65 to $8.73 per customer per month in 1992 dollars. The results for WTP for Longmont ranged from $5.99 to $7.97 per customer per month and WTA ranged from $11.08 to $16.06 per customer per month in 1992 dollars. Across all estimates, this corresponds with a range of $108 to $383 annually per household in 2021 dollars.

Griffin and Mjelde (2000) estimated the WTP for an increase in water supply reliability, and the WTA for a decrease in reliability, for seven Texas cities. The mean WTP was $8.47 per household per month and the predicted WTP from the model was $9.76 in 1995 dollars. The mean WTA was $12.66 and predicted WTA was $13.20 in 1995 dollars. In 2021 dollars, this corresponds with a range of $187 to $291 annually per household.

A study by Koss and Khawaja (2001) estimated mean monthly WTP in ten California water districts to range from $11.67 per household per month (a 10% shortage 1 out of every 10 years) to $16.92 per household per month (a 50% shortage 1 out of every 20 years) in 1993 dollars. In 2021 dollars, this corresponds with a range of $270 to $392 annually per household.

A 2003 study prepared for the Municipal Water District of Orange County (Orange County Business Council, 2003) focused on one region using information from the Barakat and Chamberlin (1994) study. The study indicated a WTP that ranged from $11.16 to $17.30 per household per month in 1993 dollars. In 2021 dollars, this equates to $259 to $401 annually per household. The lower bound estimate is based on a 20% shortage 1 in 30 years while the upper bound estimate represented a 50% shortage 1 in 20 years.

The estimates of WTP and WTA reported from these studies correspond with residential demand and end use of treated municipal water. In other words, these estimates correspond with household retail values, not wholesale values. The estimates from these studies are summarized later on, but first, a conversion of retail values to wholesale values is discussed. This adjustment is necessary since the adaptation strategies considered for the LSCR Basin Study provide raw water at the wholesale level, meaning it is important to remove any value added from treatment and distribution to end users for potable use.

2.3.2.1 Converting Retail Values to Wholesale Values

The reliability benefit estimates from previous studies are at the retail level, so an adjustment is needed to evaluate reliability benefits at the wholesale level. One approach to estimate the value attributable to the wholesale portion of water supplies is to estimate and remove the municipal water supply costs that are necessary to provide retail service after base supplies are obtained. These retail costs are primarily related to treatment and distribution, meaning the expenditures associated with these two categories represent the primary difference between retail and wholesale values. Estimating the exact treatment and distribution costs for the different municipal water providers included in the LSCR Basin Study was not feasible, so general water supply cost information was used to determine the average percentage of retail value attributable to wholesale water supplies.

In 2009 the U.S. Environmental Protection Agency (EPA) surveyed community water systems and provided estimates of the percentages of water supply costs attributable to different aspects of providing water service. It was assumed that water treatment and distribution costs are associated entirely with providing retail water service, while other capital costs, purchased water, and security were assumed to be entirely part of the cost of providing wholesale water supplies. At least a portion of non-capital expenses were assumed to be attributable to wholesale service costs, but the proportion associated with wholesale supplies was unknown, so the proportion for capital expenses was applied to non-capital expenses.

For the capital-related expenses in the EPA (2009) report, treatment cost and transmission and distribution cost represented about 70% of total capital expenses, meaning about 30% of capital expenses reflect wholesale expenses. Assuming this percentage also applies to non-capital expenditures that have both a retail and wholesale component, the average overall wholesale portion of water supply costs can be approximated. Table 2.3 provides an overview of the findings from the EPA (2009) report and the assumptions used here to arrive at the average wholesale proportion, which was estimated to be about 36.49% of total water supply costs.

Table 2.3 – Wholesale Portion of Water Supply Cuts

Expense Category	Total Expense	Wholesale Factor	Wholesale Portion
Capital Expenses			
Transmission and Distribution System	3.35%	0	0.00%
Treatment	1.78%	0	0.00%
Land	0.09%	1	0.09%
Water Source	0.63%	1	0.63%
Storage	0.64%	1	0.64%
Other	0.77%	1	0.77%
Non-Capital Expenses			
Purchased Water	8.90%	1	8.90%
Security	0.44%	1	0.44%
Payments to Reserve Funds	2.60%	0.3	0.78%
Payments to General Fund	0.40%	0.3	0.12%
Depreciation	5.00%	0.3	1.50%
Income Taxes	1.20%	0.3	0.36%
Debt Service	8.50%	0.3	2.55%
Other Routine Operating Expenses	65.70%	0.3	19.71%
Total	**100.00%**	**-**	**36.49%**

Under this approach, the wholesale portion was estimated to constitute about 36.49% of municipal water supply total cost, so this proportion was used to convert retail values from past benefit studies to wholesale values. Note that the percentages in Table 2.3 are representative of all systems combined, while the cost breakdown would likely differ for each system based on the type of system and system size. Table 2.4 summarizes the household reliability benefits estimated in previous studies on an annual per household basis in 2021 dollars. The table includes the original retail estimates and the wholesale values that are calculated as 36.49% of retail values.

Table 2.4 – Annual Household Reliability Benefit Estimates from Previous Studies

Study	Retail Values		Wholesale Values	
	Low	High	Low	High
Carson & Mitchell, 1987	$205	$637	$75	$233
Barakat & Chamberlin, 1994	$258	$392	$94	$143
Howe et al., 1994	$108	$383	$39	$140
Griffin & Mjelde, 2000	$187	$291	$68	$106
Koss & Khawaja, 2001	$270	$392	$99	$143
Orange County Business Council, 2003	$259	$401	$94	$146

Wholesale values are calculated as 36.49% of retail values.

Across the studies shown, the average annual wholesale benefit estimate is $115 per household with a median estimate of $103, minimum of $39, and maximum of $233. This highlights the range of potential wholesale benefits for a typical household to avoid a shortage, which varies primarily due to the severity and frequency of shortage. None of these studies were directly applicable to the LSCR study area and the severity and frequency of shortages expected. As such, attention was

placed on the median estimate across all studies and $100 per household was used to calculate a "best" BT estimate. The household benefit was then varied from $50 to $200 to estimate a low and high BT estimate, respectively. This large range highlights the uncertainty around the reliability benefit generated for a typical household in the study area. Benefits were estimated annually based on the number of households expected to experience a shortage under CAP:SAM Scenario F and annual benefits were discounted and summed from 2021-2060 to estimate a 40-year benefit.

2.3.3 Market-Based Estimation

In a standard supply and demand framework, a shortage reflects a gap between supply and demand, which can arise from a demand increase, supply decrease, or both. When this happens for a good or service, such as renewable water, it puts upward pressure on prices, adversely affecting water users. The MB reliability benefit estimate focuses on renewable water supply and demand from a regional market perspective to examine how future shortages may affect water prices and wellbeing for municipal users in the study area. Under this approach, the benefit was calculated based on water supply and demand from CAP:SAM and comparing the shortage volume and changes in wellbeing with, versus without, a strategy in place. Rather than looking at household WTP to avoid a shortage, this approach focused on the WTP for the volume of water generated by a strategy based on recent water transactions in the study area.

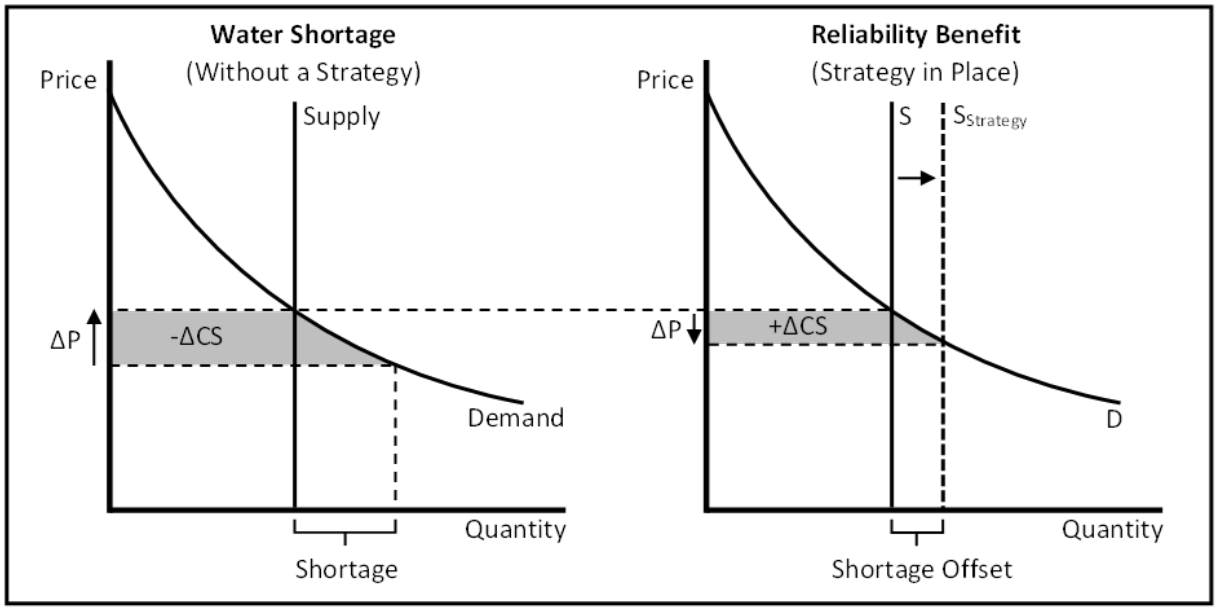

Figure 2.1 – Water Shortage and Water Supply Benefit

The demand curve for renewable water represents WTP, which also reflects the marginal benefit derived from each unit of water. When users pay a price below their WTP, they receive a gain known as consumer surplus (CS). CS is a monetary measure of wellbeing for consumers and can be calculated according to the area under the demand curve, above the price paid by users. This means that price changes will affect CS, all else equal. The first step in calculating the MB reliability benefit was to estimate the baseline price effects and changes in CS associated with future water shortages

projected under CAP:SAM Scenario F for 2021-2060. The water volume provided by each strategy was then used to estimate the reliability benefit across a 40-year period, which comes from comparing changes in CS under the baseline with changes when a strategy is in place.

For many goods and services, the supply curve slopes upward, reflecting that producers are willing and able to provide more of the good or service at higher prices. However, the supply of water in the study area is limited, due to physical availability as well as regulatory restrictions. Water supply was therefore assumed to be fixed, or perfectly inelastic, which is reflected by a vertical supply curve. A perfectly inelastic supply is a reasonable assumption where the quantity of a good or service is relatively fixed, as with renewable water availability in the study area. Under this framework, changes in CS can be measured using information on: (1) the size of shortage; (2) the price elasticity of demand; and (3) the average price of water.

Shifts in supply and demand cause adjustments in price over time, reflecting either a shortage (upward pressure on price) or a surplus (downward pressure on price). Under CAP:SAM Scenario F, municipal water demand is expected to grow significantly, and supply is expected to remain relatively fixed due to limited renewable water supplies and AWS rules on groundwater pumping. This is expected to lead to growing water shortages over time and puts upward pressure on the price of renewable water in the area. The left-hand graph in Figure 2.1 illustrates a shortage in renewable supplies, which can result from a decline in supply, increase in demand, or a combination of both. Regardless of the cause, a shortage puts upward pressure on price and decreases CS, as depicted in the left-hand graph.

The change in price (P) associated with a shortage was calculated for each year (t) according to Equation 2.1, which is a function of the price elasticity of demand (ε_D), shortage volume (S), and the current quantity of renewable water use (Q).

$$\Delta P_t = \left(\frac{S_t}{Q_t + S_t}\right)\left(\frac{1}{\varepsilon_D}\right) \qquad (2.1)$$

This equation states that price changes are a function of renewable water shortages, measured as a proportion of total renewable use, and the shape of water demand, which is defined by the price elasticity of demand. The price elasticity of demand was assumed to remain fixed across the study period. Annual changes in CS were then calculated according to Equation 2.2.

$$\Delta CS_t = -(\Delta P_t)(Q_t) + 0.5(\Delta P_t)(S_t) \qquad (2.2)$$

The first term in Equation 2.2 reflects the shaded rectangle areas shown in Figure 2.1, while the second term approximates the shaded triangle areas assuming a linear hypotenuse (i.e., a linear demand between the new and old price).[2] An increase in renewable water from implementing a strategy will offset some of the shortage and reduce upward pressure on price, generating a positive change in CS as shown in the right-hand graph of Figure 2.1. Increases in supply and decreases in demand (e.g., from conservation) were treated equivalently, with both helping reduce the gap between supply and demand and diminishing the upward pressure on prices. The water reliability

[2] A geometric approximation is required since the functional form of demand is unknown, meaning integration cannot be used to calculate CS changes. For small incremental changes, this simplification has minimal influence on estimation.

benefit for each strategy was measured by comparing annual changes in CS under the baseline (without a strategy) to CS changes with a strategy in place, as shown in Equation 2.3.

$$Reliability\ Benefit_t = \Delta CS_{With_t} - \Delta CS_{Without_t} \quad (2.3)$$

Annual benefits varied from year-to-year, differing based on the municipal shortage volume and annual water volume provided by each strategy. As with the BT estimate, benefits under the MB estimate were estimated annually under CAP:SAM Scenario F and annual benefits were discounted and summed from 2021-2060 to estimate a 40-year benefit. If a strategy provided more water than is necessary to offset the annual shortage volume, it was assumed that additional water is used to help address future shortages, as previously discussed. As with the BT estimate, the MB benefit was estimated focusing on renewable supplies at the wholesale level, prior to any treatment or distribution that would add to the value of the water. The CAP:SAM projections provided information on the annual shortage volumes expected for the study area, while the following sections discuss the assumptions used for the price elasticity of demand and price of raw water.

2.3.3.1 Price Elasticity of Demand

Price elasticity of demand measures the relationship between the price of water and the quantity demanded. This captures the shape of the demand curve, reflecting how consumers alter their water use when price changes. Mathematically, it measures how a percent-change in price leads to a percent-change in the quantity demanded. This is measured as a ratio, as shown in Equation 2.4. For the MB estimate, the elasticity of demand is used to measure the relationship in the opposite direction, determining how quantity (a water shortage) affects price, which was previously shown in Equation 2.1. It is assumed that demand is isoelastic, meaning that price elasticity is constant across all parts of the demand curve.[3] This allows the measure of elasticity to be applied across different levels of water use and across various price levels.

$$\varepsilon_D = \frac{\%\Delta Q}{\%\Delta P} \quad (2.4)$$

The elasticity of demand is generally negative, reflecting that demand is downward-sloping due to an inverse relationship between price and the quantity demanded. As such, it is common practice to take the absolute value for easier interpretation. An absolute value is therefore used throughout this document. In this case, the elasticity of demand ranges from 0 to infinity. An elasticity of 0 implies no relationship between price and the quantity demanded. An elasticity of 1 (unit-elastic) implies that there is a one-to-one relationship, meaning a one-percent change in price corresponds with a one-percent change in the quantity demanded (and vice versa). An elasticity between 0 and 1 (inelastic) means the quantity demanded changes less than the percent-change in price. This is often the case for water demand, since water is a necessity with no close substitutes, meaning the quantity demanded is minimally influenced by changes in price. An elasticity greater than 1 (elastic) means the quantity demanded changes more than the percent-change in price. This reflects consumption that is

[3] In practice, price elasticity of demand can vary for several reasons. For example, at different levels of water use, at different prices, at different levels of income, and across different seasons. However, the level of detail provided by CAP:SAM did not permit for these differences to be captured and modeling varied elasticities would have added significant complexity with minimal additional value.

more responsive to price changes, which is often associated with non-essential goods and services with several close substitutes.

The elasticity of demand tends to vary across time, with a more inelastic relationship between price and quantity in the short-run, and a more elastic relationship in the long-run. This is because in the long-run consumers have more time to adjust their behavior and respond to changes in price. For example, there is more time for residential users to shift towards more efficient appliances and water use preferences. Since this assessment was focused on long-term effects across a 40-year period, a long-run elasticity was most applicable.

The economics literature has an extensive number of studies that measure the elasticity of demand for water. The overwhelming majority of this work has focused on residential water demand, with less attention on agricultural demand and very little research looking at commercial and industrial demand. Studies have also tended to focus on short-run estimates, with only a handful providing long-run estimates. The economics literature was reviewed to identify the most relevant estimates of long-run demand elasticity for residential users in the study area. There have been several meta-analyses conducted that survey the economics literature, along with a handful of individual studies that examine water demand in Arizona. These studies are summarized below and were used to inform the MB reliability benefit estimate.

The earliest meta-analysis, Espey et al. (1997), reviewed 24 journal articles published between 1967 and 1993 encompassing 124 elasticity estimates. They found that 90% of the estimates were between 0 and 0.75, with an average short-run elasticity of 0.51 and a median of 0.38. Across all studies, short-run elasticities were found to range from 0.03 to 2.23, while long-run elasticities were more elastic, ranging from 0.1 to 3.33 with a median of 0.64. Later, Dalhuisen et al. (2003) examined 64 studies and 314 estimates between 1963 and 2001. They found an average short-run elasticity of 0.41 and a median elasticity of 0.35, with long-run estimates generally more elastic by 0.28. Worthington and Hoffman (2008) examined 37 studies from 1980 to 2006, many of which were outside the United States. They found that price elasticity ranged from 0 to 0.5 in the short run, and 0.5 to 1 in the long run. The most recent meta-analysis of residential water demand, Sebri (2014), examined 100 studies encompassing 638 estimates from 2002-2012. They found an average price elasticity of 0.37 and a median elasticity of 0.29, with long-run elasticities that were more elastic by 0.2.

These meta-analyses highlight the extensive literature that has developed around estimating the price elasticity of residential water demand. These studies indicate that price elasticity is generally inelastic and that long-run elasticities tend to be more elastic. That said, the estimates vary across studies for several reasons, many of which are associated with conditions in the study location. The most relevant estimates are therefore those that are most applicable to the study area. There have been a handful of studies that estimate price elasticity for residential water demand in Arizona, with many focusing on the Tucson area.

Young (1973) estimated the price elasticity of demand for municipal water in Tucson. He found that short-run elasticity was about 0.63 from 1946-1964 and decreased to 0.41 for the period 1965-1971. Agathe and Billings (1980) also looked at residential water demand in Tucson, but for the period 1974-1980. They found short-run elasticity to range from 0.18 to 0.36 and long-run elasticity to range from 0.27 to 0.71. A similar study, Billings and Agathe (1980), focused on the features of

increasing block rates and found short-run elasticity to range from 0.27 to 0.49 for the period 1974-1977. Agathe et al. (1986) again looked at block pricing in Tucson, and using a simultaneous equation demand model, found a short-run elasticity of 0.14 and long-run elasticity of 0.62. Finally, Agathe and Billings (1987) estimated short-run price elasticity at different levels of income, finding elasticity to range from 0.56 for low income to 0.4 for high income. Unfortunately, many of these studies rely on the same dataset and the estimates are somewhat outdated. There have been a few more recent studies, but they focus on the Phoenix area instead of Tucson.

A more recent study, Klaiber et al. (2012), examined residential water demand in the Phoenix metropolitan area from 2000-2003, focusing on how price responsiveness varies with season and drought conditions. They found an elasticity of 1.54 in the winter and 0.68 in the summer when conditions were normal, falling to 1.17 in the winter and 0.3 in the summer when conditions were dry. Another recent study, Yoo et al. (2014), also estimated demand in Phoenix, but focused on water availability and climate change. They found a short-run elasticity of 0.66 and a long-run elasticity of 1.55. These estimates are notably larger (more elastic) than past estimates, from both the Tucson area and economics literature more broadly. However, the authors argue that their estimates are consistent with previous studies looking at California (e.g., Pint, 1999) and Texas (e.g., Hewitt and Hanemann, 1995). Table 2.5 summarizes the previous residential demand studies for Arizona.

Table 2.5 – Price Elasticity of Demand Estimates from Previous Arizona Studies

Study	Short-Run Elasticity	Long-Run Elasticity
Young, 1973	0.41 – 0.63	-
Agathe and Billings, 1980	0.18 – 0.36	0.27 – 0.71
Billings and Agathe, 1980	0.27 – 0.49	-
Agathe et al., 1986	0.14	0.62
Agathe and Billings, 1987	0.40 – 0.56	-
Klaiber et al., 2012	0.30 – 1.54	-
Yoo et al., 2014	0.66	1.55

None of these Arizona residential demand studies offered a perfect match for the LSCR Basin Study. The estimates are either for the Tucson area, but outdated, or more recent, but for the Phoenix area. Rather than relying on any single study and estimate of elasticity, it was deemed most appropriate to test a probable range of elasticities to demonstrate how the MB estimate varies with future price sensitivity. The range of estimates shown in Table 2.5 was used to inform the chosen elasticity for the MB reliability estimates. As previously mentioned, it was most appropriate to focus on a long-run elasticity for estimating a 40-year benefit for the Basin Study. To calculate a "best' MB estimate, a long-run elasticity of 0.5 was assumed, which is consistent with past Arizona studies as well as other studies across the economics literature. Price elasticity was then varied from 0.25 to 1 to estimate a low and high MB estimate, respectively. This large range highlights the uncertainty around the price sensitivity for a typical household in the study area.

It is important to note that the price elasticity estimates from the economics literature are based on final retail demand, and there are no known estimates for wholesale demand for raw water. That said, wholesale demand for raw water used by municipal systems is likely to be more inelastic than retail demand for several reasons. For one, only a portion of a municipal system's cost is attributed

to raw water, while other costs such as treatment and distribution are also part of the price that gets passed on to final users. Also, some water revenues may come from fees and taxes, not solely from charges for use. Municipal systems also operate under different incentives than final users, generally with the goal of obtaining raw water supplies to fulfill final demands, with minimal control over the quantity demanded, other than from passing along costs and altering price structures. All these features imply that a change in the price of raw water is likely to generate less of a quantity response at the wholesale level relative to the retail level.

2.3.3.2 Price of Water

In Arizona, water comes from a variety of sources and users face a variety of prices. Since the MB estimate is focused on wholesale demand, attention was placed on the average price of raw water in the LSCR study area. Under the PR&G and Reclamation guidance, recent market transactions can be used to value a unit of water in the study area. Ideally, these reflect water transactions between willing sellers and buyers, meaning the transaction price represents a good proxy for WTP for a unit of water.[4] A formal market for renewable water supplies does not exist in Arizona, but a growing number of transactions between willing buyers and sellers of LTSCs has become more regular and has been well documented in Arizona (Bernat et al., 2020). Recent LTSC transactions were evaluated and used here to approximate WTP for a unit of raw renewable water in the study area.

The observed transactions for LTSCs provide a reasonable proxy for WTP since they are a tool to meet renewable requirements under Arizona's AWS rules. In many instances, LTSCs represent the most likely alternative supply for municipal providers to supplement shortages in water supplies. To determine the average transaction price for a LTSC and proxy WTP for a unit of water, publicly available LTSC transactions were queried from the CAGRD[5] and AWBA.[6] In total, 38 transactions were identified for the period 2008-2020 with nearly 1 million AF conveyed between state agencies, tribes, municipal providers, industrial users, and investment firms. As done elsewhere, historic values were adjusted to 2021 dollars using the CPI for the West Census Region.

Looking at the inflation-adjusted (real) LTSC transactions, there appears to be an upward trend in real prices across the period. This is likely due to growing water scarcity and more severe water shortages over time. To bring the sample observations to a 2021 perspective, historic transactions were adjusted using the average year-over-year change in real prices across the period ($26.75 per AF per year). The time-adjusted average LTSC transaction price was then used for the MB estimate and used to capture WTP at the start of the period (2021). Table 2.6 summarizes the 38 LTSC transactions before and after the time adjustment.

[4] Note that water transactions often entail legal transactions rather than any physical transfer of water.
[5] CAGRD transactions are available at: https://www.cagrd.com/water-supply-program/agreements-and-acquisitions
[6] AWBA transactions are available at: https://waterbank.az.gov/agreements

Table 2.6 – Summary Statistics for LTSC Transactions within the Tucson AMA, 2008-2020

Statistic	Sample Observations ($/AF)	Time-Adjusted Observations ($/AF)
Average	$330.16	$465.32
Median	$328.91	$443.06
Minimum	$163.39	$285.75
Maximum	$560.54	$684.14
Standard Deviation	$132.94	$104.44

Note: The sample values reflect 38 transactions CPI-adjusted to 2021 dollars. The time-adjusted values reflect a $26.75 per AF per year adjustment across the period to adjust historic values to a 2021 perspective.

As shown, prior to adjusting for time, the average price is about $330 per AF, with a median of $329 per AF and a range from $163 to $561 per AF. After adjusting values to a 2021 perspective, the average is about $465 per AF, which was used to proxy WTP for a unit of raw renewable water in the study area in 2021. To put this value into perspective, for 2021/2022 the CAGRD rate is $789 per AF of replenishment for users in the Tucson AMA.[7] This is the amount that many municipal users in the LSCR area will face as they continue to rely on groundwater and the CAGRD to offset groundwater pumping subject to AWS rules. This means that some users in the study area may actually pay much more than the average LTSC transaction price used for the MB reliability benefit estimate. For these users, the benefit would be greater than estimated here.

2.4 Reliability Benefit Estimation Results

As previously discussed, both a BT water reliability benefit estimate and MB water reliability benefit estimate were provided for the adaptation strategies identified for the LSCR Basin Study. The BT estimate was based on household WTP to avoid a shortage and the number of HUs supported by each strategy. The MB estimate was based on average WTP for a unit of water in the study area and the volume of water provided by each strategy. The BT "best" estimate assumed a benefit per housing unit supported ($HU) of $100, with $HU=$50 and $HU=$200 used to calculate a low and high benefit estimate, respectively. The MB "best" estimate assumed a price elasticity of demand (ε_D) of 0.5, with ε_D=1 and ε_D=0.25 used to calculate a low and high benefit estimate, respectively. Both estimates were for a 40-year period under CAP:SAM Scenario F and reflected the PV discounted using the FY21 federal planning rate of 2.5%. Table 2.7 summarizes the annual water volume provided by each strategy (used for the MB estimate), the average annual HUs supported by each strategy (used for the BT estimate), the 40-year BT best estimate, and the 40-year MB best estimate.

[7] CAGRD water rates are available at: https://www.cap-az.com/departments/finance/water-rates

Table 2.7 – Best Estimate for Water Supply Reliability Benefit, Scenario F

Adaptation Strategy	Annual Water Volume (AF)	Average Annual HUs Supported[e]	40-Year Benefit, BT Best Estimate ($ millions)	40-Year Benefit, MB Best Estimate ($ millions)
CDO-1	5,000	48,540	$133.19	$127.44
CDO-2	10,000	92,108	$230.28	$236.11
CDO-3	1,120	10,880	$30.02	$28.70
SC/TV-1	200	1,943	$5.36	$5.14
SC/TV-2	900	8,743	$24.12	$23.08
SC/TV-3	217	2,110	$5.82	$5.58
SET-1	1,500	14,572	$40.20	$38.40
SET-2	4,033[c]	36,186	$88.32	$94.62
GV-1	8,000	75,055	$196.21	$196.63
GV-2	2,000	19,429	$53.60	$51.12
GV-3	10,333[c]	90,923	$223.66	$233.89
REG-1[a]	39,245[c]	252,260	$552.72	$929.42
REG-2	350	3,400	$9.38	$8.99
REG-3[b]	0	0	$0.00	$0.00
REG-4[a]	100,000[d]	1,340,547	$3,003.73	$2,685.92

[a] Water volume exceeds the shortage volume in the LSCR study area for the study period, so additional water was assumed to benefit users in the 3-county area outside the LSCR study area.
[b] Water volume is for environmental needs in areas where delivery is not feasible to support municipal use.
[c] Water volume grows across the period; this represents the average annual volume.
[d] Annual water volume set at the maximum desalination capacity.
[e] HUs supported varies annually based on the CAP:SAM scenario; this represents the average annual HUs supported.
Note: Benefit estimates reflect the PV discounted using the FY21 federal planning rate of 2.5%.

As shown in Table 2.7, both the BT approach and MB approach provided similar benefit estimates, at least under the assumptions used. Note that some strategies provided a constant annual water volume across the period, while for others the volume grows over time. The table also shows the average annual HUs supported by each strategy, but note that this varies across the period based on CAP:SAM Scenario F. Even though GPHUD decreases over time, the strategies generally support fewer HUs over time since the shortage severity grows (outweighing reductions in GPHUD). In this way, the severity of shortage is incorporated into the BT estimate. In practice, the benefit per HU might also vary with severity, meaning that even though less HUs are supported when shortages get more severe, the benefit per HU might increase. That said, for simplicity, the benefit per HU was assumed to remain constant based on the range estimated in past studies

Due to the opposing forces of GPHUD declining but shortage severity increasing across the period, in general, the HUs supported by a strategy first increases but then decreases across the period. This was the case for all strategies other than REG-1 (LID) and REG-4 (Sea of Cortez Pipeline), where HUs supported increases across the entire period since these strategies meet the entire shortage volume in the LSCR study area in all years. For these two strategies, additional water was assumed to benefit users in the 3-county CAP Service Area outside the LSCR study area, as previously discussed. Without including spillover benefits for these strategies, the benefit estimates would not reflect the full volume of water and full reliability benefit provided by these strategies. To highlight

the uncertainty around the best benefit estimates in Table 2.7, Table 2.8 shows the low and high benefit estimates under the BT approach and MB approach.

Table 2.8 – Estimate Range for Water Supply Reliability Benefit, Scenario F

Adaptation Strategy	40-Year Benefit, BT Estimates ($ millions)			40-Year Benefit, MB Estimates ($ millions)		
	Low ($HU=$50)	Best ($HU=$100)	High ($HU=$200)	Low (ε_D=1)	Best (ε_D=0.5)	High (ε_D=0.25)
CDO-1	$66.60	$133.19	$266.38	$63.72	$127.44	$254.87
CDO-2	$115.14	$230.28	$460.56	$118.05	$236.11	$472.21
CDO-3	$15.01	$30.02	$60.03	$14.35	$28.70	$57.41
SC/TV-1	$2.68	$5.36	$10.72	$2.57	$5.14	$10.28
SC/TV-2	$12.06	$24.12	$48.24	$11.54	$23.08	$46.16
SC/TV-3	$2.91	$5.82	$11.64	$2.79	$5.58	$11.16
SET-1	$20.10	$40.20	$80.40	$19.20	$38.40	$76.80
SET-2	$44.16	$88.32	$176.64	$47.31	$94.62	$189.23
GV-1	$98.11	$196.21	$392.43	$98.31	$196.63	$393.26
GV-2	$26.80	$53.60	$107.20	$25.56	$51.12	$102.24
GV-3	$111.83	$223.66	$447.32	$116.95	$233.89	$467.78
REG-1[a]	$276.36	$552.72	$1,105.44	$464.71	$929.42	$1,858.84
REG-2	$4.69	$9.38	$18.76	$4.50	$8.99	$17.98
REG-3[b]	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
REG-4[a]	$1,501.86	$3,003.73	$6,007.46	$1,342.96	$2,685.92	$5,371.84

[a] Water volume exceeds the shortage volume in the LSCR study area for the study period, so additional water was assumed to benefit users in the 3-county area outside the LSCR study area.
[b] Water volume is for environmental needs in areas where delivery is not feasible to support municipal use.
Note: Benefit estimates reflect the PV discounted using the FY21 federal planning rate of 2.5%.

Both the BT and MB approaches are considered acceptable under the PR&G and Reclamation guidance, but they are fundamentally quite different. Here, the MB estimates are deemed preferable to the BT estimates since they rely on recent market transactions in Arizona, making them more relevant to the study area than relying on previous reliability benefit studies outside Arizona. As such, the MB estimate range was used for the economic analysis, while the MB best estimate was used for the trade-off analysis. That said, as shown in Table 2.8, both methods provided similar estimates under the framework and assumptions used here, suggesting that both approaches are valid and that the estimates are fairly robust to using either approach. This is useful to keep in mind for any future economic analyses that might consider using either approach to estimate reliability benefits.

3.0 Economic Analysis

3.1 Introduction

The economic analysis focused on the monetized costs and benefits of each adaptation strategy to evaluate the economic feasibility of strategies over a 40-year period from 2021-2060. This included the water reliability benefit for municipal users estimated in the previous section, as well as the cost

of construction, and the cost of O&M. For some strategies, the groundwater pumping benefit was also evaluated. Costs and benefits were evaluated from a national perspective consistent with federal guidance under the PR&G. The economic analysis provided here is preliminary, looking only at a 40-year snapshot while relying on simplifying assumptions and excluding several costs and benefits that could not be easily monetized for the LSCR Basin Study.

3.2 Groundwater Pumping Benefit

In the study area, groundwater users are either exempt from AWS rules (e.g., using grandfathered rights) or required to replenish groundwater use with renewable supplies beyond a small groundwater allowance. In either case, most groundwater users do not pay for the water itself, only the cost to pump the water to the surface. The cost to pump groundwater depends on depth to water (DTW) and the cost of energy used for pumping, meaning the cost is unique to each user. For the LSCR Basin Study, a handful of the adaptation strategies were evaluated using groundwater modeling. For these strategies, changes in DTW were evaluated to calculate a monetary benefit associated with a reduced pumping cost for wells affected by recharge.

Several of the other strategies would also likely affect groundwater aquifers and provide a groundwater pumping benefit, but only those strategies developed early on and with sufficient engineering details could be evaluated in terms of a monetary pumping benefit. For these strategies, the monetized groundwater pumping benefit was included in the economic analysis. Meanwhile, this monetized benefit was not included in the trade-off analysis, but instead, was replaced by a qualitative criterion for aquifer benefit. This reflects a broader measure, part of which includes a groundwater pumping benefit, as well as consideration for land subsidence and general aquifer condition. The qualitative criterion was used to capture a wider range of effects linked with groundwater conditions and to give all 15 strategies due consideration for the trade-off analysis. This section covers only the monetized groundwater pumping benefit that was included in the economic analysis, particularly for those strategies where recharge was evaluated using groundwater modeling.

Information on energy prices and DTW can be used to calculate the cost to pump groundwater. Adapted from Rogers and Alam (2006), the cost to pump a particular volume of groundwater (GW) in year (t) can be calculated according to Equation 3.1, where the pumping cost (C) for a particular well (i) is a function of the DTW, the price of energy (P_E), and a constant (θ) reflecting the amount of energy required to lift one acre-foot of water one foot in elevation.

$$C_{it} = \theta(GW_{it})(P_{E_t})(DTW_{it}) \quad (3.1)$$

Rogers and Alam (2006) provide measures of θ for electricity, natural gas, diesel, and propane. To estimate pumping cost, natural gas was the assumed electricity source, which is the majority energy source for Arizona according to the U.S. Energy Information Administration (EIA, 2021). The most recent natural gas prices published by the EIA for Arizona are for 2019, so these values were used here and adjusted to 2021 dollars using the CPI for the West Census Region, as done elsewhere. Using this information, the average cost to lift one acre-foot of water one foot in elevation is estimated at about $0.23 per AF. Table 3.1 summarizes the pumping cost per AF associated with different levels of DTW, ranging from 100-500 ft to show how pumping cost varies with groundwater levels under the assumptions used here. To estimate a pumping benefit for each

affected well, what ultimately matters is the change in DTW resulting from a strategy, and the volume of water pumped from the well under the particular CAP:SAM scenario.

Table 3.1 – Pumping Cost (per AF) at Different Groundwater Levels

Depth to Water (ft)	Pumping Cost ($/AF)
100	$22.63
200	$45.26
300	$67.89
400	$90.52
500	$113.15

To calculate the groundwater pumping benefit for each strategy, the annual cost to pump groundwater was compared with, versus without, a strategy in place for affected wells. In other words, the benefit was calculated as the cost difference for pumping with a strategy in place. The pumping benefit was calculated annually and summed across affected wells (*i=1,…,I*) according to Equation 3.2.

$$Pumping\ Benefit_t = \sum_{i=1}^{I} C_{Without_{it}} - C_{With_{it}} \quad (3.2)$$

The difference between pumping cost with, versus without, a strategy in place is tied to differences in DTW, which was based on the volume of recharge associated with a strategy and the subsequent groundwater modeling. Meanwhile, the volume of water pumped, and price of energy were assumed to be the same. The volume of water varies across CAP:SAM scenarios, but attention was placed on Scenario F, as done elsewhere. Of the six scenarios, this scenario reflects the most groundwater pumped, and thus the largest groundwater pumping benefit from strategies. As done for the reliability benefit estimates, pumping benefits were estimated annually and discounted (using the FY21 rate of 2.5%) and summed from 2021-2060 to estimate a 40-year pumping benefit. For simplicity, the real price of energy was held constant across the period, but the benefit would be greater if real energy prices increase across the period and vice versa.

For the LSCR Basin Study, 5 of the 15 strategies were evaluated in the groundwater model (CDO-1, CDO-2, CDO-3, GV-1, and GV-2). These strategies are focused on recharge and sufficient information was available to model the location of recharge and model changes in DTW. Table 3.2 summarizes the 40-year groundwater pumping benefit for these select strategies, along with the recharge volume modeled.

Table 3.2 – Groundwater Pumping Benefit for Selected Strategies, Scenario F

Adaptation Strategy	Recharge Volume	40-Year Pumping Benefit[a]
CDO-1	5,000	$925,811
CDO-2	10,000	$1,880,136
CDO-3	1,120	$194,062
GV-1	8,000	$5,007,378
GV-2	2,000	$1,090,863

[a] Annual benefits vary; the 40-year benefit reflects the PV discounted using the FY21 federal planning rate of 2.5%.

In comparison to the water reliability benefit estimates, the groundwater pumping benefits were quite small in magnitude. For the economic analysis, the groundwater pumping benefit estimated for these strategies was added to the reliability benefit. As previously discussed, this monetized benefit was not included in the trade-off analysis, but instead, replaced by a qualitative criterion for aquifer benefit.

3.2 Construction and O&M Costs

The cost estimates for the 15 strategies considered for the LSCR Basin Study were preliminary and came from a variety of sources and efforts by partners involved in the study. The cost estimates ranged from Class 4/Class 5 engineering estimates for structural strategies to "back-of-the-envelope" simplified calculations for non-structural strategies. It is generally desirable for all cost estimates to be consistent and rely on a similar framework and set of assumptions, but this was not possible for the LSCR Basin Study and the wide range of adaptation strategies considered. There were thus expected to be several inconsistencies across the cost estimates, and future studies should consider developing more refined cost estimates. See the Appendix F, Adaptation Strategies Technical Memorandum for more details on how the cost estimates were developed for each adaptation strategy. Table 3.3 summarizes the construction (upfront) cost and O&M (ongoing) cost estimates for each adaptation strategy.

Table 3.3 – Adaptation Strategy Construction and O&M Costs

Adaptation Strategy	Construction Cost ($ millions)	Annual O&M Cost ($ millions)
CDO-1	$97.86	$0.17
CDO-2	$157.00	$6.24
CDO-3	$37.00	$3.30
SC/TV-1	$8.11	$0.11
SC/TV-2	$0.00	$0.45
SC/TV-3	$0.95	$0.15
SET-1	$1.20	$0.94
SET-2	$96.00	$10.80
GV-1	$6.50	$0.26
GV-2	$25.04	$0.37
GV-3	$228.80	$25.70
REG-1	$348.80	$23.00[a]
REG-2	$77.00	$0.94
REG-3	$1.46	$0.07
REG-4	$4,100.00	$171.83

[a] Cost grows across the period; this represents the average annual O&M.

Construction cost generally includes the cost of facilities and pipelines and any sort of infrastructure investment necessary to implement a strategy, including the cost of constructing a treatment facility when relevant. The O&M cost generally includes the ongoing cost for operation and includes the cost of labor, equipment, and energy associated with a strategy continuing to provide benefits. Note that the O&M cost doesn't include a component for replacement cost since the lifecycle is unknown

for the major components of each strategy. Due to the diversity of the adaptation strategies considered, there was a wide variation in the components included under the capital and O&M cost estimates for each strategy. Comparisons across strategies were therefore imperfect and served only to help screen adaptation strategies, and the economic analysis is considered preliminary with a wide uncertainty range around all monetary estimates.

An economic analysis generally includes an assessment of interest during construction (IDC), which represents the difference between funds appropriated for construction and the economic cost of capital invested in the project when the project is brought into service at the end of construction. This difference represents an economic cost that can be thought of as an opportunity cost for funds that could be invested elsewhere if they were not tied up in project construction. IDC could not be calculated for the LSCR Basin Study adaptation strategies since the construction/implementation time was unknown for each strategy. Furthermore, since some strategies are non-structural, IDC was not necessarily an applicable concept, or would at least vary in application. For example, infrastructure built by a government entity would entail a different opportunity cost than LID investments undertaken by households, and even different levels of government would entail different calculations of IDC (e.g., IDC for federal projects is typically calculated from a national perspective and based on the federal planning rate). That said, future studies should consider including estimates of IDC where appropriate and feasible, which would add to the total economic cost of a strategy.

3.3 Cost-Benefit Comparison

An economic analysis generally culminates into a comparison of total cost and total benefit over a specified period of time. This section provides a 40-year cost-benefit comparison for each strategy that includes the cost of construction, the cost of O&M, the water reliability benefit for municipal users, and the groundwater pumping benefit for select recharge strategies. Both a net present value (NPV) and benefit-cost ratio (BCR) are presented for each strategy, recognizing that the estimates are only at a preliminary level and exclude several costs and benefits that could not be monetized. NPV highlights the magnitude of net benefit (benefit less cost) while the BCR highlights the benefit generated for each dollar spent. It is possible to have a high BCR and low NPV, or vice versa, so both a high BCR and high NPV is generally preferable in terms of economic feasibility.

The economic analysis was constrained to the 40-year period defined for the LSCR Basin Study. It is important to note that the BCR (and NPV) would likely be larger with a longer study period due to upfront costs being spread across more years. This is particularly true for those strategies with a very large upfront cost. The analysis provided here is intended to motivate and inform future assessments of adaptation strategies at a more detailed level. Table 3.4 shows the 40-year total cost estimate for each strategy, which encompasses the construction cost and PV of 40 years of O&M costs discounted using the FY21 federal planning rate of 2.5%.

Table 3.4 – 40-Year Total Cost Estimate

Adaptation Strategy	Construction Cost ($ millions)	40-Year O&M Cost[a] ($ millions)	40-Year Total Cost ($ millions)
CDO-1	$97.86	$4.45	$102.31
CDO-2	$157.00	$160.45	$317.45
CDO-3	$37.00	$84.91	$121.91
SC/TV-1	$8.11	$2.73	$10.84
SC/TV-2	$0.00	$11.58	$11.58
SC/TV-3	$0.95	$3.86	$4.81
SET-1	$1.20	$24.12	$25.32
SET-2	$96.00	$277.89	$373.89
GV-1	$6.50	$6.69	$13.19
GV-2	$25.04	$9.55	$34.59
GV-3	$228.80	$661.27	$890.07
REG-1	$348.80	$942.66	$1,291.46
REG-2	$77.00	$24.24	$101.24
REG-3	$1.46	$1.88	$3.34
REG-4	$4,100.00	$4,421.25	$8,521.25

[a] Reflects the PV of 40 years of annual O&M costs discounted using the FY21 federal planning rate of 2.5%.

These cost estimates range from Class 4/Class 5 engineering estimates to "back-of-the-envelope" simplified calculations. It is generally desirable for all cost estimates to be consistent, but this was not possible for the LSCR Basin Study and the wide range of adaptation strategies considered. Class 5 engineering estimates (lowest accuracy) generally have an accuracy range of -20% to -50% on the low end and +30% to +100% on the high end, while Class 4 estimates have a range of -15% to -30% on the low end and +20% to +50% on the high end. Table 3.5 shows the 40-year total cost for each adaptation strategy assuming a -20%/+30% low-high range for total cost.

Table 3.5 – 40-Year Total Cost Estimate, Low-High Range (-20%/+30%)

Adaptation Strategy	40-Year Total Cost ($ millions)	Low Estimate (-20%) ($ millions)	High Estimate (+30%) ($ millions)
CDO-1	$102.31	$81.85	$133.00
CDO-2	$317.45	$253.96	$412.69
CDO-3	$121.91	$97.53	$158.48
SC/TV-1	$10.84	$8.67	$14.09
SC/TV-2	$11.58	$9.26	$15.05
SC/TV-3	$4.81	$3.85	$6.25
SET-1	$25.32	$20.26	$32.92
SET-2	$373.89	$299.11	$486.05
GV-1	$13.19	$10.55	$17.15
GV-2	$34.59	$27.67	$44.96
GV-3	$890.07	$712.06	$1,157.09
REG-1	$1,291.46	$1,033.17	$1,678.89
REG-2	$101.24	$80.99	$131.61
REG-3	$3.34	$2.67	$4.34
REG-4	$8,521.25	$6,817.00	$11,077.62

To compare the monetized costs and benefits for each strategy over a 40-year period, the construction cost was modeled as a lump-sum upfront cost in 2020, followed by 40 years of O&M costs and reliability benefits for the period 2021-2060. This simplified framework ensured consistency and allowed for comparisons across the strategies given that the implementation time and lifecycle was unknown for each strategy. In practice, the construction and implementation time would determine when benefits start to accrue and lead the benefits to begin at different points in time for each strategy. Table 3.6 shows the 40-year cost-benefit comparison under CAP:SAM Scenario F. To highlight the high level of uncertainty around these monetary estimates, the 40-year low-high range is presented for both the cost and benefit estimates, resulting in a low-high range for the 40-year NPV and 40-year BCR. The low-end for NPV and BCR reflects the high-end cost and low-end benefit estimates, while the high-end reflects the low-end cost and high-end benefit estimates.

Table 3.6 – 40-Year Cost-Benefit Comparison, Scenario F

Adaptation Strategy	40-Year Total Cost, Low-High ($ millions)	40-Year Benefit, MB Estimate Low-High ($ millions)	40-Year NPV, Low-High ($ millions)	40-Year BCR, Low-High
CDO-1	$81.85 - $133.00	$64.64 - $255.80[a]	$(68.36) - $173.95	0.49 - 3.13
CDO-2	$253.96 - $412.69	$119.93 - $474.09[a]	$(292.76) - $220.13	0.29 - 1.87
CDO-3	$97.53 - $158.48	$14.55 - $57.60[a]	$(143.94) - $(39.93)	0.09 - 0.59
SC/TV-1	$8.67 - $14.09	$2.57 - $10.28	$(11.52) - $1.61	0.18 - 1.19
SC/TV-2	$9.26 - $15.05	$11.54 - $46.16	$(3.51) - $36.90	0.77 - 4.98
SC/TV-3	$3.85 - $6.25	$2.79 - $11.16	$(3.46) - $7.32	0.45 - 2.90
SET-1	$20.26 - $32.92	$19.20 - $76.80	$(13.72) - $56.54	0.58 - 3.79
SET-2	$299.11 - $486.05	$47.31 - $189.23	$(438.75) - $(109.88)	0.10 - 0.63
GV-1	$10.55 - $17.15	$103.32 - $398.26[a]	$86.17 - $387.71	6.03 - 37.7
GV-2	$27.67 - $44.96	$26.65 - $103.33[a]	$(18.31) - $75.66	0.59 - 3.73
GV-3	$712.06 - $1,157.09	$116.95 - $467.78	$(1,040.14) - $(244.27)	0.10 - 0.66
REG-1	$1,033.17 - $1,678.89	$464.71 - $1,858.84	$(1,214.18) - $825.67	0.28 - 1.80
REG-2	$80.99 - $131.61	$4.50 - $17.98	$(127.11) - $(63.01)	0.03 - 0.22
REG-3	$2.67 - $4.34	$0.00[b]	NA	NA
REG-4	$6,817.00 - $11,077.62	$1,342.96 - $5,371.84	$(9,734.66) - $(1,445.16)	0.12 - 0.79

[a] Includes the 40-year groundwater pumping benefit estimate.

[b] Water volume is for environmental needs in areas where delivery is not feasible to support municipal use.

Note: All estimates reflect the PV discounted using the FY21 federal planning rate of 2.5%.

A strategy is considered economically feasible if the NPV is positive and the BCR is greater than one. This was the case for 9 of the 15 strategies under the high-end estimates for NPV and BCR. In terms of the high-end NPV, REG-1 had the highest 40-year estimate at about $826 million, followed by GV-1 at $388 million, CDO-2 at $220 million, CDO-1 at $174 million, GV-2 at $76 million, SET-1 at $57 million, SC/TV-2 at $37 million, SC/TV-3 at $7 million, and SC/TV-1 at about $2 million. In terms of the high-end BCR, GV-1 had the highest 40-year estimate at 37.7, followed by SC/TV-2 at 4.98, SET-1 at 3.79, GV-2 at 3.73, CDO-1 at 3.13, SC/TV-3 at 2.90, CDO-2 at 1.87, REG-1 at 1.80, and SC/TV-1 at 1.19. This means that, across the 9 strategies that are potentially economically feasible, REG-1 had the highest NPV, but second lowest BCR. Meanwhile, strategies

such as GV-1 and CDO-1 had a relatively large NPV and BCR. This highlights the importance of considering both measures of economic feasibility.

Under the low-end NPV and BCR, only GV-1 was estimated to be economically feasible, at least over a 40-year period. The strong performance of this strategy was likely due to a relatively low cost, which stems from much of the pipeline already being constructed and the water being delivered efficiently to a small area. The wide range of costs and benefits shown in Table 3.6 highlights the importance of more refined estimates for future economic assessments. Economic feasibility is often not the only (or even primary) objective of interest when evaluating alternative choices, and instead represents only one important consideration. This is where the trade-off analysis comes in, incorporating non-monetary considerations and impacts along environmental and social dimensions. Furthermore, the costs and benefits presented here are only preliminary estimates for a 40-year period, and several costs and benefits were excluded since they could not be easily monetized. The trade-off analysis therefore offers a more holistic view of each strategy and identifies various strengths and weaknesses that are not included in the economic analysis shown here.

4.0 Qualitative and Importance Scoring

4.1 Introduction

The economic analysis in the previous section examined 3 of the 10 evaluation criteria previously outlined in Table 1.2, particularly those quantified and monetized. For the trade-off analysis, the remaining 7 criteria were measured (scored) qualitatively for each adaptation strategy using a low to high scale. Qualitative criteria scoring was achieved by polling all partners on the LSCR Basin Study and using the average of their responses. The 7 qualitative criteria were therefore scored for the 15 strategies based on the expertise of those directly involved in the LSCR Basin Study. To capture the fact that some of the 10 criteria might be viewed as more important than others, polling was also used to ask the project partners about the importance they placed on each criterion. For the trade-off analysis, both the unweighted results (all criteria treated as of equal importance) and the weighted results (criteria weighted for importance) are presented. This section covers the results of the qualitative criteria scoring and criteria importance scoring used for the trade-off analysis.

4.2 Scoring Process

Qualitative criteria scoring and criteria importance scoring was done through a live poll conducted during a 4-hour workshop, inviting staff from all cost-share partners involved in the LSCR Basin Study. The online polling format proved to be a highly efficient process for gathering information and has been repeated for another Basin Study. During the workshop, 24 participants were given a brief summary presentation on the details of each strategy before starting the polling, and people were able to ask clarifying questions while the poll was open. All responses were kept anonymous, and participants were informed that only the average scores across all responses would be reported and used. For those unable to attend the workshop, a strategy summary document was provided along with a scoring worksheet for them to complete and return. In total, the criteria importance scores reflect the average of 24 responses and the qualitative criteria scores reflect the average across

15-20 responses. The number of responses varied for the qualitative scoring since respondents were asked to leave a score blank if they felt it was outside of their expertise (based on the criterion and/or strategy being considered).

4.3 Criteria Importance Weights

To address the fact that some criteria might be deemed more important than others, a trade-off analysis typically involves criteria weighting to assign different preferences to each criterion in the set of evaluation criteria. A weight is a measure of the relative importance of a criterion and assigning weights is a method for incorporating human judgments about the relative value of a criterion. Put differently, weighting relies on subjectively expressed preferences and judgment. Assigning weights to the criteria can be a contentious task because it is, by definition, a subjective task. To ensure transparency and highlight the sensitivity to criteria weighting, best practice is to generally report the unweighted results as well as the weighted results. In some cases, the results may be quite similar, in which case criteria weighting is less controversial. Hajkowicz et al. (2000) provide a detailed discussion on different weighting techniques used in natural resource management. The authors cover the "fixed-point," "rating," "ordinal ranking," "graphical," and "paired comparison" weighting approaches. These techniques are those most commonly used, but several others also exist.

For the LSCR Basin Study trade-off analysis, the "rating" method was used to determine criteria importance weights. The rating method used a numerical scoring scale where the low end reflected low importance, and the high end reflected high importance. The number of integers used was arbitrary, but the interval distance between the values is typically assumed to be identical. This is similar to the rating process used for rating one's satisfaction with a purchase or experience, which often involves a 1 to 5-star rating scale. This approach uses a common scale for each criterion and there is no restriction on the number of points assigned to each criterion. To determine the importance that the LSCR project partners placed on each criterion, a simple 1 to 3 (low to high) scoring scale was used. Respondents could also enter a 0 if they felt the criterion was not important at all. Table 4.1 shows the criteria importance scale used.

Table 4.1 – Criteria Importance Scoring Scale

Category	Score
Not Important	0
Low Importance	1
Moderate Importance	2
High Importance	3

Across the 24 responses, the water reliability benefit criterion and the aquifer benefit criterion received the highest importance weights. On average, the remaining criteria were considered moderately important. For the trade-off analysis, scores were normalized as a percentage of the maximum score so that the highest-scoring criterion was assigned a 100% weight and all other criteria were weighted proportionally based on their importance score. Table 4.2 shows the average importance score for the 10 evaluation criteria and the corresponding weight placed on each criterion for the trade-off analysis (weighted results).

Table 4.2 – Importance Score for Evaluation Criteria

Criterion	Average Score	Weight Applied
(1) Water Reliability Benefit	2.79	100%
(2) Capital Cost	2.25	81%
(3) O&M Cost	2.38	85%
(4) Aquifer Benefit	2.75	99%
(5) Quality of Life Benefit	2.08	75%
(6) Leverage Existing Resources	1.96	70%
(7) Barriers to Implementation	1.96	70%
(8) Riparian Impact	2.04	73%
(9) Water Quality Impact	2.25	81%
(10) Flood Risk Impact	1.96	70%

Note: Total Responses=24. Weights are based on normalizing scores as a percentage of the maximum score.

4.4 Qualitative Criteria Scores

For the 7 qualitative evaluation criteria included in the trade-off analysis, impacts were assessed based on the average score assigned by respondents. The number of responses varied from 15-20 for the qualitative scoring since respondents were asked to leave a score blank if they felt it was outside of their expertise (based on the criterion and/or strategy being considered). As done for rating criteria importance, a simple low to high scoring scale was used to keep the process straightforward. The qualitative criteria were carefully defined to have a particular directionality, either defined as a benefit scored from 1 to 3, as a cost scored from -3 to -1, or with the potential to go in either direction scored from -3 to 3. Respondents were asked to enter a score of 0 if they thought the strategy would have no impact for the criterion in question. Table 4.3 shows the scoring scale used to measure the qualitative evaluation criteria.

Table 4.3 – Qualitative Criteria Scoring Scale

Directionality	Category	Score
Benefit	High	3
	Moderate	2
	Low	1
	No Impact	0
Cost	Low	-1
	Moderate	2
	High	3

Criteria 4-6 (aquifer benefit, quality of life benefit, and leverage existing resources) were scored from 0 to 3, criterion 7 (barriers to implementation) from -3 to 0, and criteria 8-10 (riparian impact, water quality impact, and flood risk impact) from -3 to 3. Table 4.4 shows the average score for each criterion and adaptation strategy. These scores were used in the trade-off analysis, along with the monetized criteria (1-3), to identify the strengths and weaknesses of each strategy and evaluate the overall performance of strategies across all criteria.

Table 4.4 – Average Qualitative Criteria Scores

Strategy	Aquifer Benefit	Quality of Life Benefit	Leverage Existing Resources	Barriers to Implement	Riparian Impact	Water Quality Impact	Flood Risk Impact
CDO-1	2.70	1.85	1.45	1.68	1.80	0.10	0.75
CDO-2	2.58	1.84	1.11	1.94	1.58	-0.28	-0.11
CDO-3	1.68	1.42	1.21	-1.47	1.79	0.47	-0.16
SC/TV-1	1.76	1.76	2.29	-0.88	1.65	-0.12	-0.12
SC/TV-2	2.42	0.78	2.53	-1.37	1.11	0.16	-0.05
SC/TV-3	1.81	1.31	2.00	2.13	0.81	0.27	0.06
SET-1	2.42	1.42	2.16	-1.18	1.39	0.05	0.06
SET-2	1.64	0.60	1.41	-1.00	0.53	-0.20	0.13
GV-1	2.72	0.89	2.06	-0.89	0.47	-0.25	0.00
GV-2	1.72	1.06	2.06	-1.25	1.50	-0.24	0.06
GV-3	1.59	0.63	1.81	-1.00	0.27	0.07	0.20
REG-1	1.47	2.24	1.29	-1.35	1.38	0.94	0.88
REG-2	1.33	2.39	1.35	-1.00	1.89	1.06	1.11
REG-3	1.18	1.71	1.06	-0.56	2.06	0.94	0.94
REG-4	2.50	0.73	0.87	2.63	-0.38	0.53	0.19

Note: Number of responses varies from 15-20.

The scores shown in Table 4.4 do not span the entire scoring scale shown in Table 4.3 since they reflect the average scores across respondents. An alternative would be to round the average scores or use the median scores or mode scores. The median scores provided nearly identical scores as the average scores rounded, while the mode scores proved to be unreliable when there was a wide range across responses. The average scores were therefore used, and scores were kept unrounded so that the trade-off analysis included some of the response variability underlying the average scores and captured additional variability between strategies. For example, many of the strategies received an average score signifying "low" barriers to implementation, but under the "low" category the average score ranged from -0.56 to -1.47, so by keeping scores unrounded for the trade-off analysis, this additional variation across strategies was retained.

5.0 Trade-Off Analysis

5.1 Introduction

A trade-off analysis is an application of multi-criteria decision analysis (MCDA), which is a general framework for evaluating complex decision making under multiple and often conflicting objectives. MCDA is a way of looking at complex problems that are characterized by any mixture of monetary and non-monetary objectives, of breaking the problem into manageable pieces to allow data and judgements to be brought to bear on the pieces, and then of reassembling the pieces to present a coherent overall picture (UKCLG, 2009). MCDA addresses trade-offs that occur when a decision leads to a desirable change in one or more objectives while simultaneously resulting in an

undesirable change in another objective. Most multi-criteria problems have conflicting criteria and as a result there is no unique solution that can optimize all criteria simultaneously. A trade-off analysis therefore does not necessarily identify a "best" strategy, but rather, highlights the strengths and weaknesses of each strategy and trade-offs when choosing between strategies. The trade-off analysis therefore serves to identify trade-offs within strategies (between criteria) as well as across strategies.

A trade-off analysis provides a methodology for comparing different types of benefits and costs that cannot all be reliably quantified in monetary terms. Both quantified and unquantified considerations are evaluated simultaneously, which means the analysis includes a broader range of effects than a typical economic analysis which evaluates impacts only in monetary terms. The key categories of benefits and costs will differ by strategy, depending on the expected impacts of each strategy. Similar to a triple-bottom-line analysis, the set of evaluation criteria used here includes effects along economic, environmental, and social dimensions, as previously shown in Table 1.2. The trade-off analysis provided here is consistent with the PR&G, which state that an analysis of public benefits should consider all benefits and costs across economic, environmental, and social objectives, and may include monetary and non-monetary effects as well as quantified and unquantified measures.

5.2 Adaptation Strategy Trade-Offs

To evaluate trade-offs across both quantitative and qualitative criteria, all criteria must be scored on an equivalent scale, which is typically done with normalization. Normalization allows everything to be converted to an equivalent scale while ensuring the magnitude of differences (proportionality) is retained in the process. This also ensures that all criteria are treated equally prior to weighting criteria for importance. Before normalization, best practice is to set up a performance matrix (sometimes called a "decision matrix" or "consequence table") that summarizes how each strategy performs for each criterion. It is also common to convert all negative impacts to positive impacts so that the goal is a straightforward maximization problem, which can be done by changing the sign of measurement or taking the reciprocal. Both of these approaches maintain proportionality while converting negative impacts into values that can be maximized. Table 5.1 provides the performance matrix for all 15 strategies across all 10 evaluation criteria.

Table 5.1 – Performance Matrix

Adaptation Strategy	Capital Cost ($ millions)	Annual O&M Cost ($ millions)	Reliability Benefit ($ millions)	Aquifer Benefit	Quality of Life Benefit	Leverage Existing Resources	Barriers to Implement	Riparian Impact	Water Quality Impact	Flood Risk Impact
CDO-1	$97.9	$0.2	$127.4	2.70	1.85	1.45	-1.68	1.80	0.10	0.75
CDO-2	$157.0	$6.2	$236.1	2.58	1.84	1.11	-1.94	1.58	-0.28	-0.11
CDO-3	$37.0	$3.3	$28.7	1.68	1.42	1.21	-1.47	1.79	0.47	-0.16
SC/TV-1	$8.1	$0.1	$5.1	1.76	1.76	2.29	-0.88	1.65	-0.12	-0.12
SC/TV-2	$0.0	$0.5	$23.1	2.42	0.78	2.53	-1.37	1.11	0.16	-0.05
SC/TV-3	$1.0	$0.2	$5.6	1.81	1.31	2.00	-2.13	0.81	0.27	0.06
SET-1	$1.2	$0.9	$38.4	2.42	1.42	2.16	-1.18	1.39	0.05	0.06
SET-2	$96.0	$10.8	$94.6	1.64	0.60	1.41	-1.00	0.53	-0.20	0.13
GV-1	$6.5	$0.26	$196.6	2.72	0.89	2.06	-0.89	0.47	-0.25	0.00
GV-2	$25.0	$0.4	$51.1	1.72	1.06	2.06	-1.25	1.50	-0.24	0.06
GV-3	$228.8	$25.7	$233.9	1.59	0.63	1.81	-1.00	0.27	0.07	0.20
REG-1	$348.8	$23.0	$929.4	1.47	2.24	1.29	-1.35	1.38	0.94	0.88
REG-2	$77.0	$0.9	$9.0	1.33	2.39	1.35	-1.00	1.89	1.06	1.11
REG-3	$1.5	$0.1	$0.0	1.18	1.71	1.06	-0.56	2.06	0.94	0.94
REG-4	$4,100	$171.8	$2,686	2.50	0.73	0.87	-2.63	-0.38	0.53	0.19

There are a variety of normalization techniques one can use to ensure that all criteria are evaluated on an equivalent scoring scale, generally from 0 to 1. The percentage of maximum approach is used here, which involves dividing each value by the maximum value for each criterion. This is the most commonly used technique, and if there is no basis for favoring another approach, this method is generally suggested (USACE, 2002). This approach is straightforward and ensures that at least one strategy scores a one for each criterion while preserving the proportionality between strategies, and this approach ensures that all criteria are treated equally before applying criteria importance weights.

Before normalization, the reciprocal is calculated for cost categories to flip the directionality and make the goal a maximization problem with the normalized scores. For the qualitative criteria that go into the negative domain, the scoring scale is already defined with a directionality for scores to be maximized. That said, normalization as a percentage of the maximum score requires converting values to the positive domain, so this is achieved by subtracting the minimum strategy score from each score, which retains the proportionality between scores. Table 5.2 shows the performance matrix with normalized scores to be maximized.

Table 5.2 – Normalized Performance Matrix

Adaptation Strategy	Capital Cost ($ millions)	Annual O&M Cost ($ millions)	Reliability Benefit ($ millions)	Aquifer Benefit	Quality of Life Benefit	Leverage Existing Resources	Barriers to Implement	Riparian Impact	Water Quality Impact	Flood Risk Impact
CDO-1	0.01	0.42	0.14	0.99	0.77	0.57	0.46	0.89	0.28	0.72
CDO-2	0.01	0.01	0.25	0.95	0.77	0.44	0.33	0.80	0.00	0.04
CDO-3	0.03	0.02	0.03	0.62	0.59	0.48	0.56	0.89	0.56	0.00
SC/TV-1	0.12	0.69	0.01	0.65	0.74	0.91	0.85	0.83	0.12	0.03
SC/TV-2	1.00[a]	0.16	0.02	0.89	0.33	1.00	0.61	0.61	0.33	0.08
SC/TV-3	1.00	0.49	0.01	0.67	0.55	0.79	0.24	0.49	0.41	0.17
SET-1	0.79	0.08	0.04	0.89	0.59	0.85	0.70	0.72	0.25	0.17
SET-2	0.01	0.01	0.10	0.60	0.25	0.56	0.79	0.37	0.06	0.22
GV-1	0.15	0.28	0.21	1.00	0.37	0.81	0.84	0.35	0.02	0.12
GV-2	0.04	0.20	0.06	0.63	0.44	0.81	0.67	0.77	0.03	0.17
GV-3	0.00	0.00	0.25	0.58	0.26	0.72	0.79	0.26	0.26	0.28
REG-1	0.00	0.00	1.00	0.54	0.94	0.51	0.62	0.72	0.91	0.82
REG-2	0.01	0.08	0.01	0.49	1.00	0.54	0.79	0.93	1.00	1.00
REG-3	0.65	1.00	0.00	0.43	0.71	0.42	1.00	1.00	0.91	0.87
REG-4	0.00	0.00	1.00[a]	0.92	0.31	0.34	0.00	0.00	0.61	0.27

[a] Score is assigned.

These normalized scores retain the magnitude of differences between strategies, with the top-performing strategy for each criterion receiving a score of 1 and other strategies scored on a relative basis.[8] This means that the normalized scores only have meaning with respect to the set of strategies being considered. If any strategy was added or removed, the normalized values would be affected. To better understand the normalized scores shown in Table 5.2, it is common to use a chart or diagram to visualize how strategies perform across the evaluation criteria. With a large number of criteria, radar diagrams offer a quick way to identify the trade-offs within each strategy. Figure 5.1 shows a radar diagram for each of the 15 strategies considered for the LSCR Basin Study. These show the performance of strategies along each of the 10 criteria, prior to any weighting for criteria importance. The normalized 0-1 scale is shown from 0-100% where 100% indicates that a strategy was the top-performing strategy for that criterion. As shown, at least one strategy scored 100% for each criterion, but no strategy scored well across all criteria, highlighting the fact that several trade-offs exist. These diagrams quickly show the strengths and weaknesses of each adaptation strategy.

[8] A score of 1 was assigned to SC/TV-2 for capital cost since the value is $0 which cannot be used with normalization. This means the second lowest capital cost strategy (SC/TV-3) was scored a 1, reflecting the lowest non-zero capital cost, and the other strategies were then scored in relation. A score of 1 was also assigned to REG-4 for the reliability benefit since the strategy offers such a large volume of water and thus a large reliability benefit. If this was not done, the strategy would mask the variation across other strategies, and many would score a 0 in relation to REG-4 as the maximum value. Assigning a score of 1 to REG-4 means the second highest volume strategy (REG-1) was scored a 1, and the other strategies were then scored in relation. A score of 1 for REG-1 and REG-4 makes sense since both fully meet the shortage gap in the LSCR study area, with both potentially offering spillover benefits for the larger 3-county area.

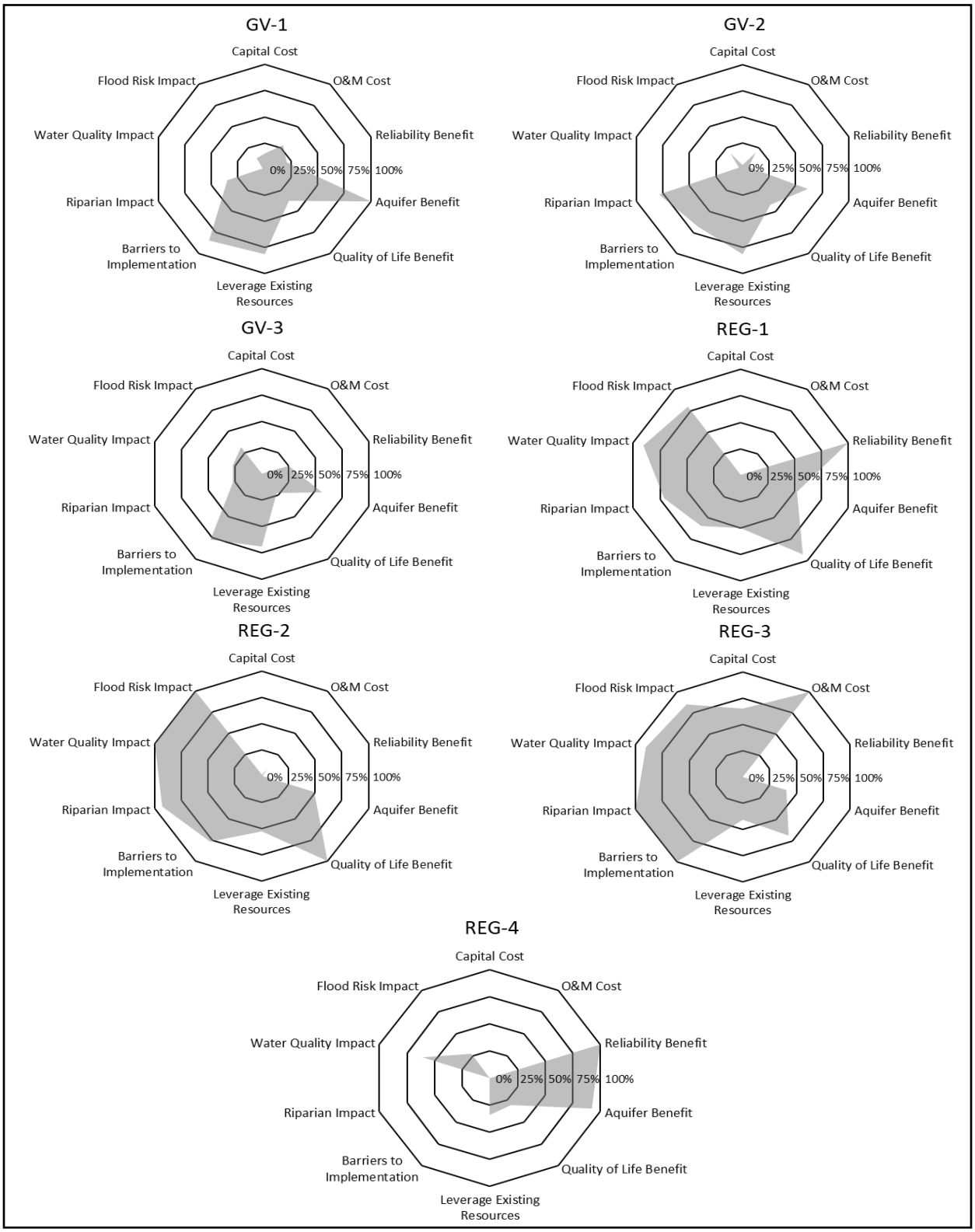

Figure 5.1 – Adaptation Strategy Performance

Note: Scale is from 0-100% where 100% indicates that a strategy is the top-performing for that criterion

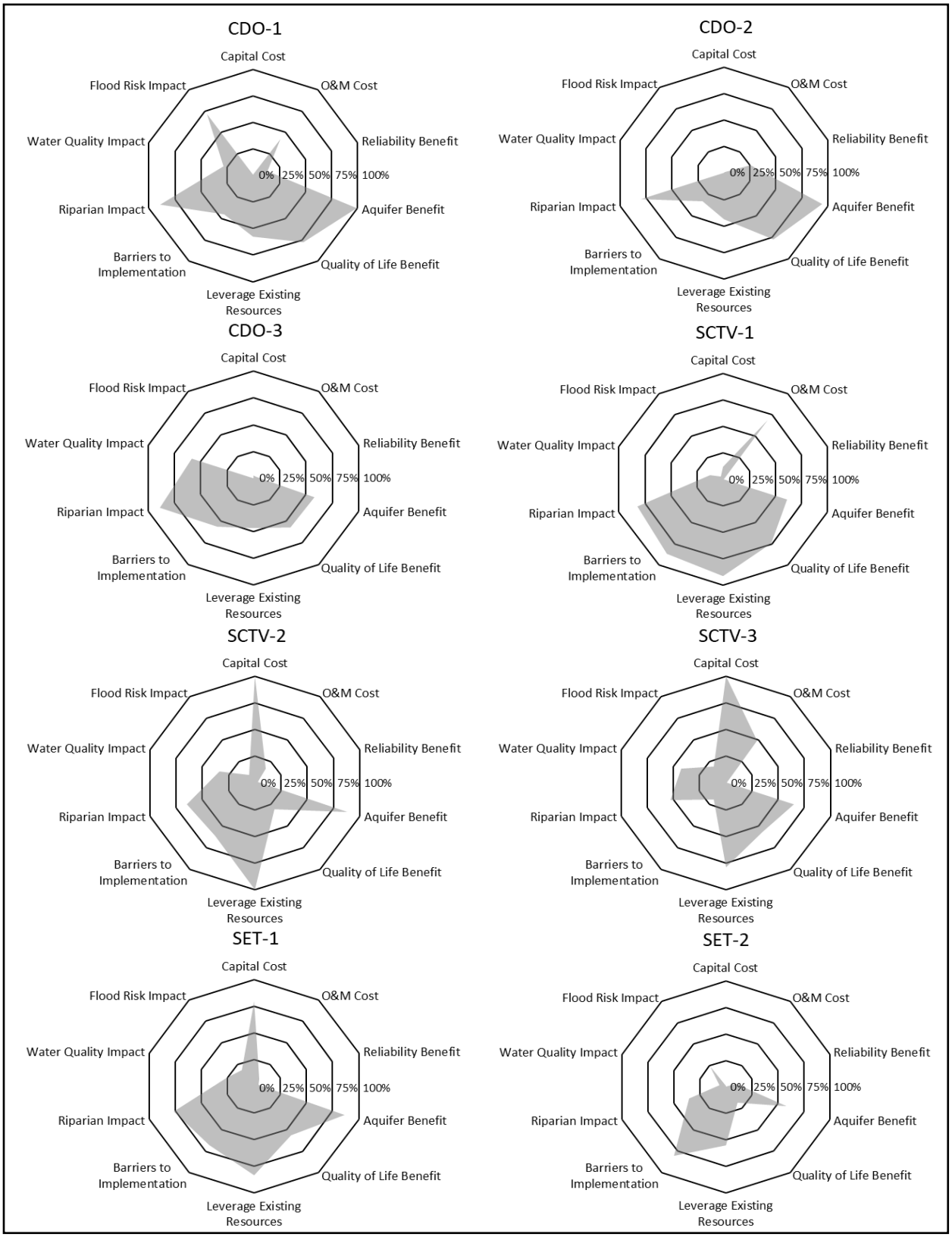

Figure 5.1 – Adaptation Strategy Performance (continued)

Looking at the radar diagrams in Figure 5.1, no two diagrams look alike, meaning each strategy comes with a unique set of costs and benefits and trade-offs. Those diagrams with the most shaded area reflect strategies that performed well across several criteria and well for the unweighted overall score. That said, accounting for criteria importance weights will influence the overall score for each strategy, which is not reflected in these diagrams.

Looking across the 15 strategies, the greatest reliability benefit came from REG-1 and REG-4, which are the strategies that provided the largest volume of water. In terms of capital cost, SC/TV-2 and SC/TV-3 had the lowest costs, but several other strategies also had relatively low upfront cost. For O&M cost, SC/TV-1 and REG-3 had the lowest cost compared to other strategies. For aquifer benefit, several strategies performed well, with at least one strategy scoring high in each area of concern. In particular, CDO-1, CDO-2, SC/TV-2, SET-1, GV-1, and REG-4 all appeared to provide large aquifer benefits. In terms of quality-of-life benefits, the top-performing strategies were REG-1 and REG-2, with several other strategies also providing a notable benefit. In terms of leveraging existing resources, SC/TV-2 and SC/TV-1 performed the best, while SC/TV-3, SET-1, GV-1, GV-2, and GV-3 also all performed well. Looking at barriers to implementation, REG-3 had the fewest barriers, with SC/TV-1, SET-2, GV-1, GV-3, and REG-2 not far behind.

For riparian impact, REG-3 and REG-2 performed the best, with CDO-1, CDO-2, CDO-3, SC/TV-1, SET-1, GV-2, and REG-1 also performing well. Looking at water quality impact, REG-1, REG-2, and REG-3 performed the best, with other strategies offering notably less benefit. Finally, for flood risk impact, REG-1, REG-2, and REG-3 again performed the best, with CDO-1 also offering a notable reduction in flood risk. This outcome highlighted which strategies performed well for each particular evaluation criterion. To evaluate how strategies perform across all criteria together, one can look at the overall scores. The next section examines the overall score and performance for each strategy, with both the unweighted score and weighted score based on criteria importance. This was then used to rank strategies based on the area of interest.

5.3 Adaptation Strategy Overall Performance and Ranking

The tables and diagrams from the prior section highlight the performance and trade-offs for each strategy, but it is not shown how strategies compare in relation to one another. To examine how strategies perform overall and rank relative to one another, and to incorporate criteria importance weights into the analysis, this section evaluates the overall scores for each strategy. Summing the normalized scores in Table 5.1 across all 10 criteria provided the overall unweighted score for each strategy. Incorporating the importance weights based on project partner preferences previously shown in Table 4.2 provided the overall weighted score for each strategy.

The maximum unweighted total score a strategy could receive was 10, scoring a 1 for all criteria. This is only possible if a strategy dominates all other strategies along every criteria considered, which would then imply no trade-offs exist between strategies and the best strategy is clear. For the strategies and criteria considered here, there was no dominant strategy, meaning no strategy performed the best across every criterion and trade-offs exist between strategies. For the weighted scores, the maximum overall score a strategy could receive is 8.03.

Comparing overall scores and ranking the performance of strategies depends on the set of strategies being considered. Since the LSCR Basin Study identified four areas of concern, it made sense to compare strategies within each area of concern, as well as across areas of concern and across all strategies considered. As such, a "location rank," "areas of concern rank," and "overall rank" were provided for each strategy. The "location rank" focused on the strategies in each area of concern. The "areas of concern" rank looked at all strategies that target one of the four areas of concern. This excluded the regional strategies which are generally much larger in scale and were not developed and tailored to the LSCR study and areas of concern in the same fashion as the other strategies. Finally, the "overall rank" compared all 15 strategies identified for the LSCR Basin Study, which included the regional strategies and those strategies targeting the areas of concern. Table 5.3 shows the overall unweighted score and rankings for each strategy.

Table 5.3 – Adaptation Strategy Overall Score and Ranking, Unweighted

Adaptation Strategy	Total Score	Normalized Score	Location Rank	Areas of Concern Rank	Overall Rank
CDO-1	5.26	0.75	1st	1st	4th
CDO-2	3.60	0.51	3rd	9th	12th
CDO-3	3.78	0.54	2nd	8th	11th
SC/TV-1	4.94	0.71	2nd	4th	7th
SC/TV-2	5.03	0.72	1st	3rd	6th
SC/TV-3	4.81	0.69	3rd	5th	8th
SET-1	5.09	0.73	1st	2nd	5th
SET-2	2.97	0.43	2nd	11th	15th
GV-1	4.16	0.59	1st	6th	9th
GV-2	3.82	0.55	2nd	7th	10th
GV-3	3.41	0.49	3rd	10th	14th
REG-1	6.06	0.87	2nd	-	2nd
REG-2	5.84	0.84	3rd	-	3rd
REG-3	6.99	1.00	1st	-	1st
REG-4	3.45	0.49	4th	-	13th

Note: Unweighted scores treat all criteria equally (max score possible=10).

Looking at the location rankings for each area of concern, CDO-1, SC/TV-2, SET-1, and GV-1 each ranked 1st for their specific area of concern. Looking across all strategies targeting one of the four areas of concern, CDO-1 ranked 1st, followed by SET-1 and then SC/TV-2. This means that the top three strategies spanned three different areas of concern, suggesting that implementing these strategies could be preferable from both a local and regional perspective. The top six strategies spanned all four areas of concern, further suggesting that implementing multiple strategies across the areas of concern is likely preferable to multiple strategies in any single location. Looking at the overall rankings, the regional strategies stand out, with REG-3 ranking 1st, followed by REG-1 and then REG-3, with CDO-1 ranking 4th overall. It is not too surprising that the regional strategies performed well overall in the trade-off analysis, since the scale of impact is in general much larger for these strategies than those targeting the areas of concern. This means that the preferred strategy will depend on whether one is focusing on a particular area of concern, looking across the four areas of concern, or looking at strategies for the overall region.

Table 5.4 shows the overall weighted score and rankings for each strategy. With weighting for importance, the rankings remained the same for the location rankings, suggesting that the importance weighting has minimal effect on the comparison of strategies within each area of concern. For the area of concern rankings, 1st and 3rd (CDO-1 and SC/TV-2) switched places, 4th and 5th (SC/TV-1 and SC/TV-3) switched, and 7th and 8th (GV-2 and CDO-3) switched. For the overall rankings, these same strategies switched places, as well as the 12th and 13th ranking strategies (CDO-2 and REG-4). Switching rankings is most likely to occur when total scores are similar prior to weighting since small differences increase the chance that weighting certain criteria as more important might flip the ordering of strategies. In general, the weighted scores are most appropriate to focus on since they incorporated the preferences of stakeholders and partners involved in the Basin Study.

Table 5.4 – Adaptation Strategy Overall Score and Ranking, Weighted

Adaptation Strategy	Total Score	Normalized Score	Location Rank	Areas of Concern Rank	Overall Rank
CDO-1	4.13	0.75	1st	3rd	6th
CDO-2	2.89	0.53	3rd	9th	13th
CDO-3	2.96	0.54	2nd	7th	10th
SC/TV-1	3.83	0.70	3rd	5th	8th
SC/TV-2	4.17	0.76	1st	1st	4th
SC/TV-3	3.99	0.73	2nd	4th	7th
SET-1	4.15	0.76	1st	2nd	5th
SET-2	2.30	0.42	2nd	11th	15th
GV-1	3.33	0.61	1st	6th	9th
GV-2	2.95	0.54	2nd	8th	11th
GV-3	2.64	0.48	3rd	10th	14th
REG-1	4.71	0.86	2nd	-	2nd
REG-2	4.43	0.81	3rd	-	3rd
REG-3	5.48	1.00	1st	-	1st
REG-4	2.91	0.53	4th	-	12th

Note: Weighted scores treat criteria differently based on the criteria importance weights (max score possible=8.03).

As shown by the overall rankings, both unweighted and weighted, REG-3 performed the best across the set of evaluation criteria used here. Recall that this strategy was not fully evaluated in the economic analysis since it is assumed that this strategy does not provide any reliability benefit for municipal users. This highlights how fundamentally different the economic analysis and trade-off analysis are. By accommodating a range of measurement scales and including both quantitative and qualitative measures, the trade-off analysis accommodates a wide range of information to assist decision making. That said, the trade-off analysis does not actually consider whether a strategy is economically justifiable and thus welfare enhancing from a national stance, which requires comparing monetized costs and benefits (note that economic feasibility could be one of the criteria considered for the trade-off analysis, but that was not the approach used here, which instead treated monetized costs and benefits as separate and individual criteria). In general, those strategies that perform well in both the economic analysis and trade-off analysis are most likely to be preferable strategies. Of course, the analysis provided here is only preliminary, so further work is warranted to

get a more accurate picture of economic feasibility and the trade-offs associated with particular strategies of interest.

6.0 Conclusion and Opportunities

The economic and trade-off analysis provided here assesses the adaptation strategies considered for the LSCR Basin Study. The economic analysis included monetary considerations such as the cost of construction, the cost of operation and maintenance (O&M), and the water reliability benefit associated with each strategy. For select strategies, a groundwater pumping benefit was also calculated. All monetary estimates were at a preliminary level and only for a 40-year period of analysis, and the analysis excluded several costs and benefits that could not be monetized for the LSCR Basin Study. To address some of these unmonetized costs and benefits, the trade-off analysis included both quantified and unquantified effects together in a single assessment, considering a diverse range of impacts along economic, environmental, and social dimensions. A trade-off analysis is a mandatory component of the Basin Study and served to identify the strengths and weaknesses of each adaptation strategy. The trade-off analysis provided here serves as a screening tool to help identify which adaptation strategies warrant further consideration and assessment.

6.1 Limitations

This analysis relied on existing data and the outputs identified in parts of Appendix F, Adaptation Strategies Technical Memorandum. As a result, several areas of measurement and evaluation were limited, and several uncertainties and limitations exist. The economic analysis is considered preliminary since it relied on several simplifying assumptions and excluded several costs and benefits that could not easily be monetized. The trade-off analysis included a broader range of effects, but including criteria measured qualitatively using a simple low-high scale offered limited insight. In general, quantitative measurement is more objective and informative than qualitative measurement, which was largely reflective of the input and expertise provided by the study partners. A different set of criteria and/or study partners might generate different results for the trade-off analysis, especially the weighted performance which incorporated subjective preferences of the study partners. Here, several impacts are evaluated qualitatively, which offers a first look at strategy strengths and weaknesses. In future studies, quantifying (and possibly monetizing) more effects would offer a more objective and concrete evaluation.

In addition to the limitations of using qualitative measurement, the trade-off analysis compared strategies on a relative basis and was therefore influenced by the set of strategies considered and the set of evaluation criteria used. Adding or removing strategies and/or criteria would likely affect the analysis and comparisons made. That said, the criteria list was tailored to the LSCR Basin Study and based on the most likely effects from strategies, and the relative ordering of strategies is unlikely to be affected by adding or removing strategies. This means that the strengths and weaknesses identified here are expected to be robust, differing only in magnitude if qualitative impacts were quantified, and to remain valid regardless of the set of strategies or set of evaluation criteria used.

Another limitation of this assessment is that strategies were evaluated independently. This misses any potential synergies or dissonance associated with implementing strategies together. Since it is

unlikely that any one strategy alone will be able to fully address future water shortages and groundwater imbalances, it is important to understand which combination of strategies might be preferable. There is therefore an opportunity for future work to assess potential synergies and trade-offs with combined strategy implementation, and the results from this analysis can help inform which strategies might be worth further consideration. It is also important to note that not all strategies were developed by the Project Team to address the specific water supply imbalances identified for the LSCR Basis Study. Future analyses would benefit from ensuring that strategies are developed in a consistent manner to meet the same purpose and need.

Additional limitations stem from the simplifying assumptions used at various steps in the analysis. For example, the CAP:SAM projections of future water supply and demand rely on several assumptions for key model parameters, and this analysis relies on simplifying assumptions for estimating reliability benefits. The Project Team also relied on several assumptions when determining the water volume provided by each strategy, and the link to offsetting future shortages varies across strategies. The length of the study period was also an important factor, and the life-cycle impacts of a strategy could prove to be different than the impact across 40 years. These assumptions were central to the economic analysis but have less influence on the trade-off analysis due to the framework used. That said, the trade-off analysis does not actually consider whether a strategy is economically justifiable and thus welfare enhancing from a national stance. Although not required for Basin Studies, this is the reason a preliminary economic analysis is provided separately from the trade-off analysis. Ultimately, the economic analysis and trade-off analysis provided here both serve to help screen strategies and identify key strengths and weaknesses, but there are several opportunities for further evaluation.

6.2 Future Opportunities

This study utilized readily available data and information generated for the LSCR Basin Study to evaluate adaptation strategies and highlight the strengths and weaknesses of each strategy considered. Due to the wide range of strategies considered, several simplifications were required to evaluate the strategies in a consistent manner. Future work is warranted to take a closer look at strategies in more detail and using more consistent assumptions. For the economic analysis, more refined monetary estimates would reduce the uncertainty range around the estimates and monetizing additional costs and benefits would improve the analysis and offer a more holistic cost-benefit comparison. Accounting for the construction/implementation time and the life-cycle of each strategy would also improve the economic analysis, rather than looking only at a 40-year snapshot.

For the trade-off analysis, future work would benefit from quantifying some of the impacts measured qualitatively in this assessment. The set of evaluation criteria could also be refined for a higher level of detail (e.g., separating some of the components under the broad quality of life criterion) or tweaked to combine or include additional criteria. Additional criteria weighting schemes could also be explored, beyond the weights generated based on the preferences of study partners. It could also be worthwhile to examine strategies in combination with one another to identify potential synergies. This analysis offers only a first pass at evaluating and screening the strategies considered for the LSCR Basin Study, without going to the extent of identifying any preferred strategies. There are several opportunities to improve upon this analysis and evaluate strategies further.

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