MEMORANDUM

DATE: March 20, 2019

TO: Honorable Mayor and Council Members

FROM: Tim Thomure, P.E.
Director
Tucson Water Department

SUBJECT: **FY 2018 Water Conservation Annual Report**

In May 2008, the Mayor and Council directed that Tucson Water implement conservation projects recommended by the Community Conservation Task Force. By providing financial incentives to specific sectors of the community to upgrade fixtures and equipment, these projects supplemented Tucson Water's existing water Conservation Program. To date, over 2.1 billion gallons of water has been saved as a result of Tucson Water's customer rebate and incentive programs.

Attached is the Water Conservation Program FY 2017-2018 Annual Report. Prepared by Tucson Water's Conservation Office and reviewed by the Citizens' Water Advisory Committee's (CWAC) Conservation and Education Subcommittee. The report details the activity of the efficiency programs, educational partnerships, outreach events and conservation research that comprise the Conservation Program.

Tucson Water's educational partners are providing programs for diverse audiences throughout the community, now reaching 50,000 students and 5,000 adults annually, and over 40,000 students, 50,000 adults and 10,000 teachers in the last decade. A significant accomplishment this fiscal year was the scale-up of the limited-income rainwater harvesting loan and grant program, resulting in about 25% of all rebates benefiting these qualifying customers.

I would like to acknowledge CWAC's Conservation and Education Subcommittee for their commitment to providing ongoing guidance and suggestions for improving Tucson Water's conservation programs.

If you have any questions about these programs, please contact James MacAdam, Public Information & Conservation Superintendent, or Candice Rupprecht, Conservation Program Manager, at 791-4331.

Attachment A: Letter from Conservation and Education Subcommittee Chair Catlow Shipek
Attachment B: Water Conservation FY 2017 Annual Report

cc: Michael Ortega, City Manager
Roger Randolph, City Clerk
Mike Rankin, City Attorney
Jeff Biggs, Tucson Water, Strategic Initiatives

cwac

Citizens' Water Advisory Committee
City of Tucson
P.O.Box 27210
Tucson, AZ 85726-7210

DATE: February 11, 2019

TO: Honorable Mayor and Council Members

FROM: Catlow Shipek
Chair of the CWAC Conservation and Education Subcommittee

SUBJECT: Tucson Water Conservation Program FY 2017-2018 Annual Report

On behalf of the Conservation and Education Subcommittee of CWAC, I am pleased to share the Water Conservation Program Annual Report for FY 2017-2018. This annual report has been reviewed by the Conservation and Education Subcommittee members. The programs described in this report are funded from the Conservation Fee, which was set at $0.09 per Ccf (FY 2018) of monthly billed potable water sales.

This annual report provides a detailed and insightful review of conservation program outcomes paired with historical context, programmatic metrics, and expenditure data. With the ongoing threat of declining Colorado River water, it is imperative that locally we strive to conserve potable resources, develop alternative supplies, and foster an evolving desert water ethic. Tucson Water's conservation programs are critical to ensure a resilient and thriving Tucson community. We are confident that this Tucson Water Conservation & Education annual report will provide a helpful resource to you, our community, and to regional and national interests. Highlights of the report include:

- Thorough accounting of numerical and geographical reach into the community. In just this past year, 50,000 students and over 5,000 adults were engaged in educational programming;
- Highlight of limited income-based program success as Tucson Water improves access and equity for program participation;
- Addition of a life cycle accounting analysis for a better understanding of efficiency and rainwater harvesting incentive program expenditures and water savings;
- Zanjero program integration to improve customer service in saving water;
- And, research results of the behavior and motivations of rainwater harvesting incentive program participants.

Tucson Water Conservation and Education staff will soon embark upon a strategic planning process. As an advisory subcommittee with oversight of the the Conservation Fee we encourage both subcommittee and stakeholder participation at this critical point as we consider how conservation can be instrumental to achieve a secure water future, improve the health of the community, and enable restoration across the basin of our desert river heritage.

If you have any questions about these programs, please contact James MacAdam, Public Information and Conservation Supertintendent, or Candice Rupprecht, Water Conservation Program Manager, at 791-4331.

Attachment - Water Conservation Program FY2017-2018 Annual Report
CS

WATER CONSERVATION PROGRAM FY 2017-18 ANNUAL REPORT

Water Conservation Program FY 2017-18 Annual Report

November 2018

City of Tucson

Jonathan Rothschild, Mayor

Michael Ortega, City Manager

City Councilors

Regina Romero, Ward One

Paul Cunningham, Ward Two

Paul Durham, Ward Three

Shirley Scott, Ward Four

Richard Fimbres, Ward Five

Steve Kozachik, Ward Six

Prepared by

Candice Rupprecht (Water Conservation Program Manager)

Acknowledgments

Tom Arnold (Management Analyst)

Michael Liberti (GIS Project Manager)

James MacAdam (Public Information & Conservation Superintendent)

Tucson Water Public Information & Conservation Staff

TUCSON WATER

A proud part of the City of Tucson

CITY OF TUCSON FOUNDED 1775

Table of Contents

Abbreviations v
Conservation Snapshot of Fiscal Year 2017-2018 6
Conservation Program Budget 7
Water Conservation Program Expenditures 7
Water Conservation Policies 8
Mayor and Council Policy for Water Conservation 8
ADWR Municipal Conservation Program 8
Conservation Ordinances 8
Plan Tucson 9
Conservation Program Planning 9
Demand-Side Management and Efficiency Programs 9
Community Conservation Task Force 10
National Water Use Studies 10
Updated Water Conservation Planning 11
GPCD - Gallons per Capita per Day 11
Conservation Research 12
Rainwater Harvesting Research 12
Ongoing: Cistern Monitoring Study 12
Completed: Participant Behavior Study 12
Water Efficiency Programs 13
Programmatic Updates 13
Rebate Administration 13
National Updates 13
Income Tax Parity Issue 13
EPA WaterSense Program 13
Service Area Distribution of Program 13
Distribution of Programs by Customer Class 13
Distribution of Programs by Ward 14
Program Activity 14
Rebates by Year 14
Water Savings 14
Single-Family HET Rebate 19

Low-Income HET Direct Install 20
Multi-Family HET Rebate 25
Commercial HET Rebate 27
High-Efficiency Urinal Rebate 29
Clothes Washer Rebate (Pilot) 32
Gray Water Rebate 36
Irrigation Efficiency Incentive Program 39
Customized Commercial Efficiency Program (Pilot) 40
Rainwater/Stormwater Programs 43
Rainwater Harvesting Rebate Program 44
Low-Income Rainwater Harvesting Grant & Loan Program 45
Neighborhood-Scale Stormwater Program 45
Water Harvesting Demonstration Sites 48
Community Education Programs 54
Arizona Project WET (APW) 56
Environmental Education Exchange 57
Smartscape 58
Other Conservation Activities 59
National Mayor's Challenge for Water Conservation 59
Regional & National Collaboration 59
Retail Outreach and Promotion 59
Community Garden Pilot Program 59
Zanjeros 60
Water Waste Enforcement 60
Appendix A – Plan Tucson Policies Addressed with Water Conservation Fee Programs 61

Abbreviations

ADWR – Arizona Department of Water Resources

AMI – Area Median Income

BCRs – Benefit-Cost Ratios

CAP – Central Arizona Project

Ccf – hundred cubic feet (1 Ccf = 748 gallons)

CCTF – Community Conservation Task Force

CEE – Consortium for Energy Efficiency

CHRPA – Community Home Repair Projects of Arizona

CWAC – Citizens' Water Advisory Committee

FY – Fiscal Year

Gpcd – gallons per capita per day

Gpf – gallons-per-flush

HET – high-efficiency toilet

HEU – high-efficiency urinal

HUD – The U.S. Department of Housing and Urban Development

IA – Irrigation Association

MaP – Maximum Performance Testing

REU2016 – Residential End Use Study, 2016 Update

REUWS – Residential End Uses of Water Study (1999)

SERI – Sonoran Environmental Research Institute

TAP – Tucson Audit Program

TRC – Total Resource Cost

ULFT – Ultra-low-flush toilet (1.6 gpf)

Conservation Snapshot of Fiscal Year 2017-2018

In 2017, total potable water use was 122 gallons per capita per day (gpcd) with a residential gpcd of 82, just slightly up from 2016. The conservation fee, now in its tenth year, has allowed Tucson Water to offer our customers high-quality conservation and education programs and robust efficiency incentives.

In FY 2017-2018, programs funded by the conservation fee have resulted in:

- 46.5 million gallons conserved
- $1.19 million invested in rebates and incentives
- 4,548 high-efficiency toilet (HET) and urinal installations
- 365 rainwater harvesting and gray water installations

To date, programs funded by the conservation fee have resulted in:

- More than 2.1 billion gallons (6,446 acre-feet) conserved
- More than 10 million dollars invested in rebates and incentives
- Over 53,000 HET and urinal installations
- Over 2,000 rainwater harvesting, and gray water installations

In FY 2017-2018 our partner education programs reached nearly 50,000 students and over 5,000 adults:

- Arizona Project WET programs reached 618 teachers, 36,365 students, and 6,042 adults
- Environmental Education Exchange reached 17,201 students
- Smartscape reached 963 adults (homeowners & professionals) with 105 workshops
- 746 adults attended water harvesting workshops offered by program partners

Together, our education partners have engaged 255,000 students, over 10,000 teachers who have taught nearly 147,000 students, and over 50,000 adults in our community over the last 10 years.

Milestones for FY 2017-18 include:

- Expanded Spanish-language outreach and training with materials written in Spanish, targeted community events and landscape classes taught in Spanish
- Ramped up the Low-Income Rainwater Harvesting program to provide grants and loans for eligible customers, engaging over 100 customers to date
- Established a Neighborhood-scale Stormwater Harvesting program to increase green stormwater infrastructure in neighborhoods, with three completed projects and several more underway
- The Zanjeros – Tucson Water's residential audit team – moved to PICO

Upcoming focus areas for FY 2018-19 include:

- Increase the participation of low-income families in Tucson Water's rainwater harvesting rebate program through the low-income grant and loan program with additional community partners
- Initiate a conservation planning process in conjunction with One Water 2100 – the utility-wide planning process that will be launched in 2019 to update and reframe long range water plan
- Pursue technology solutions to improve adiminstration of rebate programs and enhance customer support and data acquistion
- Fully staff Conservation team
- Fully integrate Zanjeros team into Conservation program

Conservation Program Budget

This operating report describes the expenditures and activities of the Tucson Water Conservation Program for July 1, 2017 through June 30, 2018, referred to as Fiscal Year (FY) 2017-18. Funding for the Conservation Program is collected by a conservation charge assessed on all potable water sales and operates out of a separate fund within the Tucson Water Department. Beginning July 1, 2017, the conservation fee increased to nine cents per ccf (hundred cubic feet or 748 gallons) for FY2017-18 and in FY 2019-20, the fee is will increase to ten cents per ccf. Table 1 illustrates funds raised and the expenditures since the inception of the Water Conservation Fund in FY 2008-09. The fund was established by the Mayor & Council through adoption of ordinance 10555 on May 20, 2008. Reserve funds are budgeted to maintain the current budget until the end of FY 2020-21 as established in the five-year Financial Plan *(see below)*.

The Conservation and Education Subcommittee of the Citizens' Water Advisory Committee (CWAC) reviews and advises the Mayor and Council on the budget and programs funded by the Water Conservation Fee. The Subcommittee meets monthly with staff and makes recommendations to the main CWAC body. and works with staff to develop and evaluate programs.

Water Conservation Program Expenditures

The Conservation Fund expenditures listed below and shown in Table 1 reflect a financial summary of the fiscal year beginning July 1, 2017 and ending June 30, 2018 prepared by the Business Services division of Tucson Water. This report also features rebate program summaries of the quantity, cost and estimated savings of rebates processed during the fiscal year. The program numbers provided in the following sections are for operating purposes and not intended to reconcile with financial reports.

The water conservation fund can be separated into eight main categories as shown in Figure 1 with a total fund expenditure of $3,108,333 in FY 2017-18.

1. Operating ($253,393)
   Salaries and wages for permanent employees:
   a. 1 Supervisor
   b. 1 Water Conservation Specialist
   c. 1 Lead Planner (vacant)
   d. 1 Water Conservation Inspector
   e. 2 Administrative Assistant and Secretary (portion of time spent processing invoices and rebates)
2. Professional Services ($1,342,799)
   Contractors that support the conservation program through research and in implementation of education, commercial water audits, and low-income toilet and rainwater harvesting programs:
3. Rebate Programs ($1,153,657)
   Incentive and rebate programs designed offset customer expense of implementing to water efficiency retrofits. Rainwater Harvesting Programs account for $391,191 of total category expenditures.
4. Outreach & Marketing ($28,815)
   Public relations and advertising to promote conservation programs.
5. Fixtures & Devices ($114,683)
   Materials to support programs (Low-income HET materials, irrigation training materials and conservation devices) and promotional materials including store displays and conservation giveaway items.
6. Miscellaneous ($65,118)
   Travel, training, memberships, printing, subscriptions, uniforms, computers, etc.
7. Administration Fee ($149,868)
   Paid to the City of Tucson for business and administrative services.

	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY 13/14	FY 14/15	FY15/16	FY 16/17	FY 17/18
Cons. Fee	$0.03	$0.04	$0.05	$0.07	$0.07	$0.07	$0.07	$0.08	$0.08	$0.09
Budget	$997,000	$997,000	$1,086,690	$2,902,630	$3,356,820	$2,950,000	$3,050,000	$3,540,250	$3,540,250	$3,540,250
Revenue	$1,217,280	$1,716,880	$2,124,838	$2,816,241	$2,830,967	$2,832,950	$2,726,208	$3,000,905	$3,035,932	$3,524,361
Expenditure	$794,462	$831,883	$1,720,075	$1,795,082	$2,727,541	$2,725,288	$2,771,450	$2,785,621	$3,445,812	$3,108,333

Table 1: Water Conservation Program Budget Historic Overview

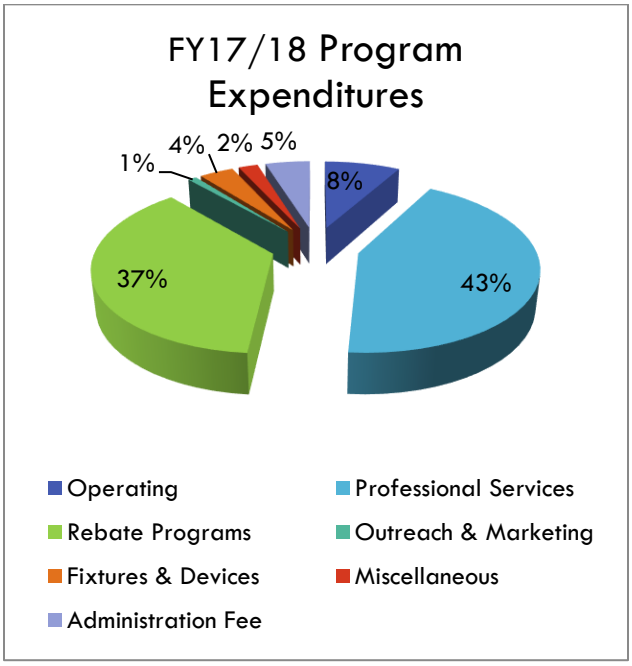


Figure 1: Water Conservation Program Expenditures by Percentage

Water Conservation Policies

Mayor and Council Policy for Water Conservation

Mayor and Council established water conservation policies January 26, 1998. Since then, Tucson Water has worked to expand education and conservation offerings to achieve established policies, while recognizing that Tucson has achieved state-mandated goals for several years since community demand has trended down since 2000.

The original policy states:

- The City of Tucson is required to meet conservation targets as established by the Arizona Department of Water Resources. Conservation program elements, such as public information and education, incentives and ordinances, will be developed and implemented to achieve conservation targets.
- The City of Tucson will "Lead by Example" by promoting water conservation and environmental aesthetics by applying the principles of Xeriscape to public projects and following adopted regulations.

While Xeriscape remains a core landscape aesthetic in Tucson, our community has moved beyond Xeriscape to incorporate more holistic views of water use into vocabulary and behavior. Today "water efficiency" has replaced "water conservation" in our lexicon. This is a result of previous success in reducing water demand, especially peak demand, and the recognition that water is integral to our community's quality of life and that all water use should be beneficial and appropriate.

ADWR Municipal Conservation Program

As a groundwater user within the Tucson AMA, Tucson Water is required participate in a mandatory conservation program for large municipal providers with a designation of Assured Water Supply. Tucson Water currently participates in the Gallons Per Capita Per Day (GPCD) program under the Fourth Management Plan for the Tucson AMA, which annually sets a GPCD target for Tucson Water. Tucson Water's GPCD requirement is currently set at 160. The Total GPCD program does not specify which conservation actions or programs to implement in the service area.

Conservation Ordinances

Current water use policies are implemented across the City and are codified into building requirements and landscape ordinances. New development requirements for multifamily, commercial and industrial construction include the City of Tucson Plumbing Code (§§ 6-121—6-126), the Xeriscape Landscaping Ordinance (7522) and the International Plumbing Code, 2012 Edition, which sets maximum uses for indoor fixtures. The Xeriscape ordinance requires the use of drought-tolerant plants from a published list and minimizes oasis

areas, including turf and water features to 2.5% of a commercial site. The Commercial Rainwater Harvesting Ordinance (10597) encourages greater use of alternative, non-potable water supplies by requiring new construction to include a rainwater harvesting system and/or practices to provide 50% of the estimated annual landscape water budget with onsite rainfall.

The Water Waste Ordinance (27-15) is enforced by a Water Conservation Inspector who addresses water waste reports and works with commercial customers to eliminate water wastes and solve high water use concerns. This ordinance applies throughout Tucson Water's service area and targets the waste of or unreasonable use of the city's water supply. Water waste violations include:

(1) Allowing water to escape from any premises onto public property, such as alleys or streets, or upon any other person's property.

(2) Allowing water to pond in any street or parking lot to a depth greater than one-quarter (1/4) inch or to permit water to pond over a cumulative surface area greater than one hundred fifty (150) square feet on any street or parking lot.

(3) Washing driveways, sidewalks, parking areas, or other impervious surface areas with an open hose, or with a spray nozzle attached to an open hose, or under regular or system pressure, except when required to eliminate conditions that threaten the public health, safety, or welfare. This restriction does not apply to residential customers.

(4) Operating a misting system in unoccupied non-residential areas.

(5) Operating a permanently installed irrigation system with a broken head or emitter, or with a head that is spraying more than ten (10) percent of the spray on a street, parking lot, or sidewalk; this prohibition does not apply unless the head or emitter was designed to deliver more than one (1) gallon of water per hour during normal use.

(6) Failing to repair a controllable leak, including a broken sprinkler head, a leaking valve, or a leaking faucet.

(7) Failure to meet the fifty (50) percent rainwater harvesting requirement for landscape irrigation set forth in Chapter 6, Article VIII of the Tucson Code.

Plan Tucson

Plan Tucson is the City of Tucson General & Sustainability Plan ratified by voters November 5, 2013. A key emphasis of this Plan is the integrative nature of the elements addressed. Goals and policies identified in the Plan have been aligned to Tucson Water's conservation program. For a complete list of Plan Tucson policies addressed through work under the Conservation Fund, see Appendix A.

Conservation Program Planning

To determine whether the Water Conservation Program is meeting the defined policies and objectives stated in the previous section, a variety of program evaluation tools are employed to assess program activity and success. This section describes the various tools and how they are used to analyze data and gather information.

Demand-Side Management and Efficiency Programs

The role of water conservation requires balancing the development of adequate water supplies with the needs of the utility's customers. The focus of any supply strategy is to satisfy customer water needs in the most cost-effective and efficient manner, minimizing any adverse environmental impact and preserving the quality of life. Additionally, there should be a focus on demand-side management and to plan and prepare for future water supply fluctuations.

Since July 2008, the water conservation program has offered customers financial incentives in the form of rebates to encourage adoption of water-saving devices and practices. New incentive programs are introduced as pilot projects to ensure that they meet goals, policies, and objectives. New programs are evaluated after a three-year period for water efficiency impacts and cost-effectiveness before being adopted as part of the permanent conservation program. Low participation rates can be examined through surveys and marketing studies to aid efforts to promote greater participation.

Those still under evaluation are identified as pilot projects.

It is a priority of Tucson Water to create incentives that equitably serve all water customers. To that end, the department is working to modify existing programs and create new programs that achieve greater equity. In the future it also makes sense for Tucson Water to promote incentives that are most efficient in terms of cost per unit of water saved.

While water savings will continue to be monitored and reported, additional evaluation criteria are being developed to reflect the broader goals of the rainwater and stormwater programs.

Community Conservation Task Force

The model used to calculate Tucson Water's avoided supply costs for the original implementation the Community Conservation Task Force report of the expanded water conservation program (infrastructure and supply acquisition costs the utility will not have to incur because conservation has decreased future supply needs) was developed for the California Urban Water Conservation Council and the American Water Works Association Research Foundation. It is a generalized Excel-based tool which is designed to be applied to any utility configuration. Based on user inputs regarding present and future demands, supplies, and facilities, as well as basic economic assumptions, the model computes seasonal short-run and long-run avoided costs over a user-designated planning period.

To ensure that the water conservation strategies selected for implementation were both effective and broadly supported by the community, the CCTF was established by Tucson Water in the summer of 2005. Members of the CCTF represented a wide range of community stakeholders.

The mission of the CCTF was to "*Ensure community involvement in the development of a water conservation program strategy that will provide measurable water savings, consistent with the Long Range Water Plan.*"

To that end, in 2006, the CCTF prepared a recommendations report that included a benefit-cost analysis of 48 different conservation measures. For each program, benefit-cost ratios (BCRs) were calculated from three perspectives (Utility, Participant, and Total Resource Cost). In each case, the BCR is calculated as the present value of the program benefits divided by the present value of the program costs.

Utility perspective benefits are the reductions in utility revenue requirements that result from the program. Participant perspective benefits are the reductions in a participating customer's utility bill due to reduced consumption. Total Resource Cost (TRC) perspective benefits reflect the total economic resources which are expended for the program, whether they are borne by utility or not.

Furthermore, unlike traditional water conservation incentives that target demand reductions, Mayor and Council directed Tucson Water to offer rebate programs like rainwater harvesting that provide an alternate water supply and help to attain broader community goals outlined in Plan Tucson. Tucson Water is working to holistically evaluate these non-traditional programs with various partners.

National Water Use Studies

National water use studies such as the Residential End Uses of Water Study (REUWS) published in 1999 and in 2016 provide conservation professionals with valuable information on indoor end use opportunities and trends. These two studies provide metered daily water use for indoor fixtures, referred to as "end uses." This data is valuable in understanding water use patterns and trends, establishing efficiency levels, and developing predictive models of future demand. The 2016 study update also included analysis of future projections for homes equipped with the most water-efficient technology. Figures 2 and 3 offer a comparison of how these end uses are shifting and decreasing overall. This information helps with conservation program planning to identify the biggest areas of potential household savings that can be targeted with education and incentive programs. Our residential rebates address the largest two indoor uses and our education partners address behavior patterns, including the third biggest use, showers.

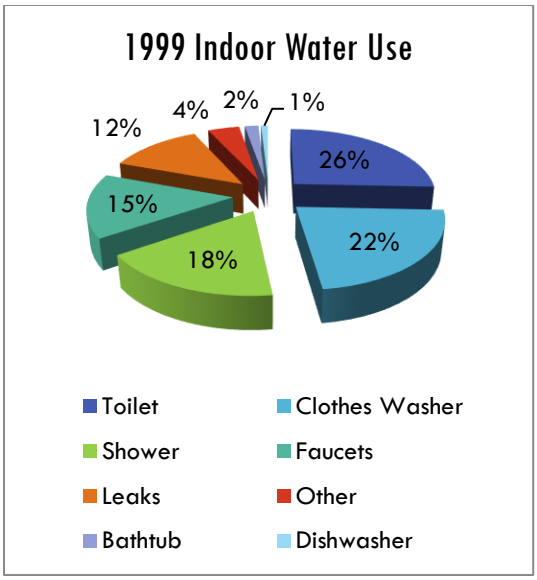


Figure 2: Average indoor residential water use from 1999 REUWS

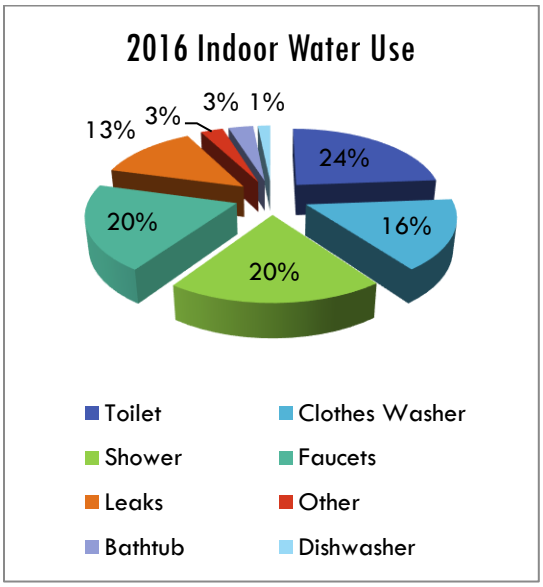


Figure 3: Average indoor residential water use from REU2016

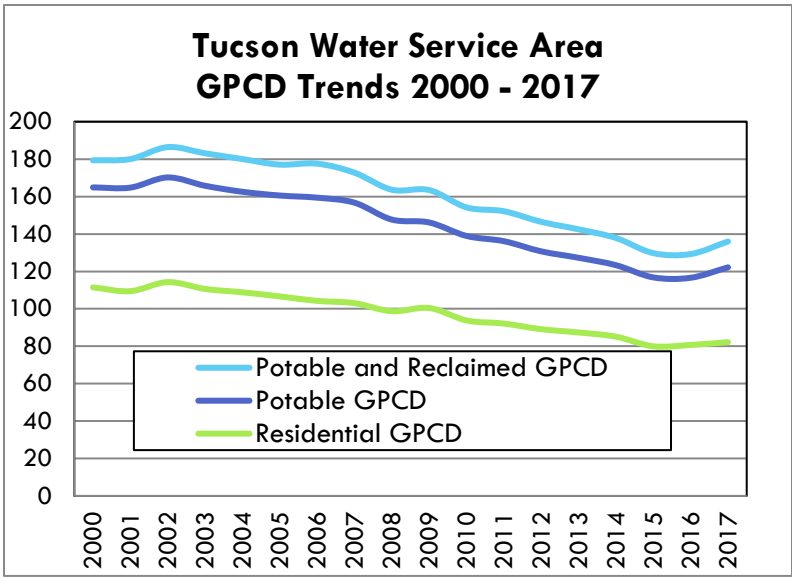


Figure 4: Total and Residential GPCD from 2000 to 2017

Updated Water Conservation Planning

Tucson Water recognizes the need to update the CCTF based on current technology and demand projections. The utility began a planning process in FY16-17 to develop a new water conservation plan for the City of Tucson and staff had multiple brainstorm sessions with CWAC C&E members to elicit research and program ideas. Currently, a more robust planning process has been put on hold and will resume once additional staff are added. The conservation planning process will begin inconjuction with a utility-wide water plan update to the long range plan.

GPCD - Gallons per Capita per Day

Tucson Water has a long history of planning and developing water supplies for today and the future. This has been accomplished by increasing the use of renewable Colorado River water, using recycled water (known as reclaimed water) for irrigation purposes, and supporting one of the longest running conservation programs in the nation. As a result, Tucsonans are now using water at the same level of use as in 1985, while population has increased by more than 200,000 and service connections have increased by more than 75,000. This fact alone is a strong indicator that water is being used more efficiently than ever.

	Total GPCD	Residential GPCD[1]	Population
2010	139	94	705,817
2011	136	92	706,118
2012	131	89	708,863
2013	127	88	712,698
2014	124	85	715,260
2015	117	80	717,875
2016	117	81	721,205
2017	122	82	725,461

Table 2: Annual GPCD and Tucson Water service area population from 2010 to 2017.

A common metric for comparing annual water use and water conservation effectiveness is gpcd, which is derived by dividing the number of people served by the amount of water produced. Table 4 illustrates the reduction in gpcd compared to a rise in population for the last five years; Figure 4 illustrates total and residential gpcd trends since 2000.

Conservation Research

Research into conservation and efficiency programs and methodologies, as well as ongoing analysis of programs are important components of developing innovative programs that meet community needs.

Rainwater Harvesting Research

Tucson Water is prioritizing the evaluation of the rainwater harvesting rebate program by leading and partnering on several research projects to expand the knowledge about program participation and impacts. Currently, several research projects about different aspects of our rainwater harvesting program are ongoing.

Ongoing: Cistern Monitoring Study

A study of a limited group of rainwater harvesting rebate participants launched in January 2017 and will run until 2020. The 15 participants have pressure transducers attached to their rainwater harvesting cisterns and wireless rain gauges nearby to collect data on the relationship between roof drainage area, tank size and inflow during precipitation events. This study will inform system sizing based on precipitation, overflow events and use of tank water. A summer intern with the Pima County Regional Flood Control District analyzed the data collected to date to build runoff coefficients. Findings indicate that roof runoff coefficients, although variable, may need to be adjusted down, which would ultimately estimate a lower total of water available for capture.

Completed: Participant Behavior Study

A one-year study to understand the motivation and unique behaviors of rainwater harvesting rebate participants will concluded in early 2018. The researchers conducted initial interviews with 25 participants, did monthly email surveys and then conducted final interviews after a one-year time period. The interviews, conducted at participants' homes, explored the decision-making process around rainwater harvesting, the participants' expectations of their systems and how users are interacting with their systems.

Findings include two models for participant perception of rainwater; as an additional or supplementary water source that can be utilizied to increase landscape area and as a replacement or alterative water source to potable water. For both models, having a lush landscape was the most common desirable benefit of rainwater harvesting; 75% of participants planted new vegetation after installing systems, about a third removed high-water-use plants and 31% installed rainwater harvesting systems as part of a larger landscape redesign project. The study also identifies additional education needed including better understanding of plant water needs and irrigation practices and offers suggestions for Tucson Water to consider in thinking about how to enhance the existing program. The full report is included as Appendix B.

[1] The residential gpcd does not include Multi-Family water use.

Water Efficiency Programs

Programmatic Updates

Rebate Administration

No administrative or policy changes were made to the rebate programs during this fiscal year. Most rebates continue to be issued as bill credits since the bulk of rebates processed are for toilets and clothes washers.

National Updates

Income Tax Parity Issue

Despite the introduction of federal bills that would remove the consideration of water conservation rebates as taxable income, none of the bills were passed into law and the revised tax plan also failed to remove this requirement. It remains that rebates $600 or more are subject to income tax and applicants must submit a W-9 form with their application before Tucson Water can process their rebate. The W-9 form requires submitting a social security or tax identification number. The applicant will be issued a 1099-MISC for miscellaneous income to be filed with their tax return. Tucson Water continues to support legislative action to change the tax code to remove the taxable income requirement and create parity between water and energy conservation programs.

EPA WaterSense Program

Tucson Water, along with over 1,900 organizations across the county, is a proud partner of the EPA's WaterSense program, which turned a decade old in 2016 and has helped American consumers save over 2.7 trillion gallons of water and more than $63.8 billion in water and energy bills. Additionally, because of the close connection between energy and water, WaterSense-labeled products have saved 367 billion kilowatt hours, enough to supply a year's worth of power to more than 34.1 million homes.

Like many water providers across the county, Tucson Water depends on the WaterSense program's product labeling criteria to identify rebate-eligible products. WaterSense has ensured national consistency in rebate programs and product quality that meets rigorous standards; high-quality products and a common language, similar to EnergyStar, have elevated the conversation about water efficiency and conservation to a national platform.

WaterSense is a necessary partner in effectively administering water conservation incentive programs and finally received federal authorization with the passing of America's Water Infrastructure Act of 2018. Although the Act does not set a budget for WaterSense, it ensures that the program remains in the EPA budget annually.

Service Area Distribution of Program

Distribution of Programs by Customer Class

A stated policy of the conservation program is to "*provide an equitable distribution of conservation benefits throughout customer classes and the community.*" Potable water consumption by customer class reveals that in FY17-18 residential customers used 54%, multi-family used 19% and 27% for non-residential uses, primarily by commercial and industrial customers. Water savings achieved through conservation rebates and the expenditures for these rebates are broken out by customer class in Figures 5 and 6.

Programs for single-family customers include: high-efficiency toilet, high-efficiency clothes washer, gray water, and rainwater harvesting rebates. Programs for multi-family customers include: high-efficiency toilet and custom commercial rebates. Programs for commercial customers include: high-efficiency toilet, high-efficiency urinal and custom commercial rebates.

Figure 5 illustrates FY 2017-18 water savings by customer class; Figure 6 illustrates FY 2017-18 estimated expenditures by customer class.

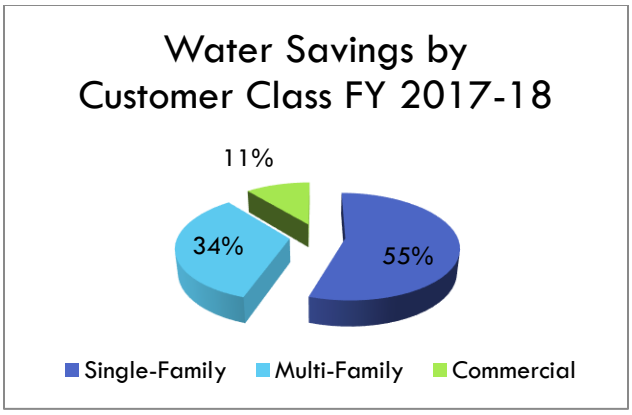


Figure 5: FY 2017-18 Water Savings by Customer Class

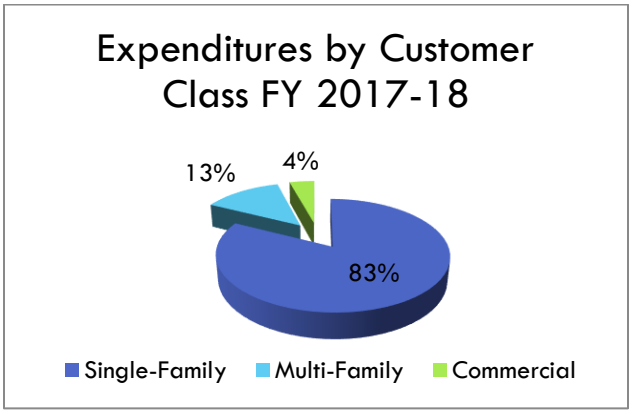


Figure 6: FY 2017-18 Expenditures by Customer Class

Distribution of Programs by Ward

The graphical distribution of residential rebate programs by Ward compared to the percent of customers by Ward has been added to the report to illustrate more accurately each rebate program's geographic distribution. This data, paired with a service area map showing all rebate recipients for a given program, provides a clear picture of rebate program participation.

Furthermore, Ward demographics are important considerations when developing and improving a program, as well as the age of homes and businesses. For example, the single-family HET program will not show a large percentage of installations where a majority of the homes were built after 1991; Ward Four is a good example of this pattern.

Additionally, combining the impacts of regular income and limited-income incentive programs provides a more holistic understanding how program uptake in specific parts of our community. For example, the single-family HET rebate program and the low-income HET direct install program have unequal concentrations of installations in the different jurisdictions. However, combined, the two programs illustrate a more uniform distribution throughout the service area as shown in Figure 17.

This type of information helps with conservation program planning to identify areas of potential savings that can be targeted with increased or modified outreach and new or modified programs that will reach underserved communities.

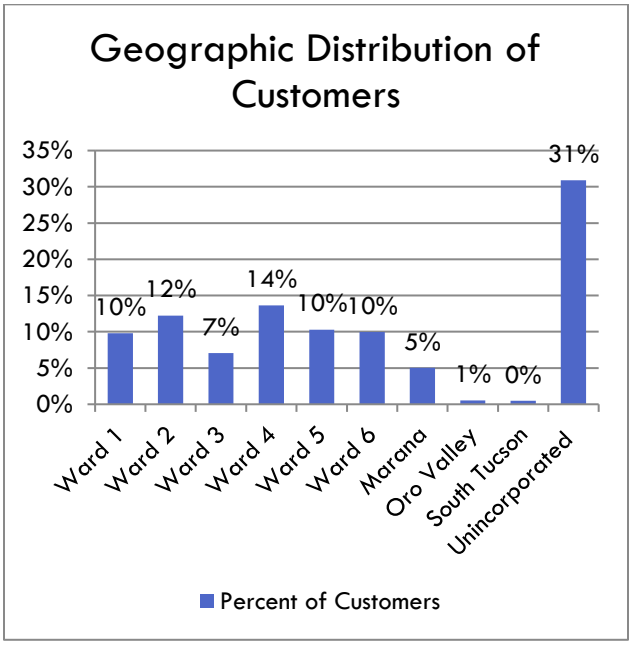


Figure 7: Percent of Customers by Jurisdiction, broken out by Ward within city limits and outside of the city limits.

Program Activity

Rebates by Year

Table 4 reports the rebates processed for each efficiency program and rainwater harvesting by fiscal year and Table 5 reports the expenditures for each incentive program.

Water Savings

Tucson Water calculates water savings for each incentive program using a mix of field research and customer consumption analysis. Savings for each program are calculated with the known information

about fixture usage and behavior patterns. Specific program savings numbers are described in the following sections that discuss rebate programs in greater detail.

Annual water savings are calculated for each program by multiplying the number of fixtures replaced with an average annual savings number. These numbers reflect the savings expected in a given program year based on the number of installations that were completed, so this savings number fluctuates annually. Additionally, cumulative savings are calculated for each program by summing the annual savings calculated for each year a given program has been running because these savings are assumed to persist well past their year of installation. This calculation is done for the expected lifetime of the fixtures, which is based on industry research for fixture devices and has been adopted by conservation organizations such as the Alliance for Water Efficiency.

	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	Total
Single-Family HET[6]	353	2,959	2,629	1,716	1,916	2,493	2,171	2,305	1,891	1,527	**19,959**
Low-Income HET[9]	0	484	808	288	840	871	1,041	734	719	503	**6,289**
Multi-Family HET[6]	11	378	284	1,237	3,638	4,906	6,579	1,413	3,024	2,109	**23,578**
Commercial HET[6]	3	428	382	345	136	361	416	482	219	409	**3,181**
High-Efficiency Urinal[6]	0	0	10	6	3	108	423	205	14	25	**794**
Clothes Washer[6]	0	0	0	0	0	0	0	1,325	1,948	1,417	**4,695**
Gray Water[7]	0	0	2	9	11	10	34	38	23	21	**148**
Irrigation Upgrade[8]	0	1	10	3	7	10	0	0	1	0	**32**
Commercial Upgrade	0	0	0	0	0	0	0	22	9	5	**40**
Rainwater Harvesting[8]	0	0	0	0	296	272	269	325	438	365	**2,074**

Table 3: Total Rebates by Fiscal Year

	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY 13/14	FY 14/15	FY 15/16	FY 16/17	FY 17/18	Total
Single-Family HET	$30,036	$254,688	$213,543	$142,812	$155,473	$202,160	$177,552	$174,208	$139,980	$113,475	**$1,603,928**
Low-Income HET*	$367	$213,720	$301,684	$110,379	$301,034	$313,116	$335,643	$240,922	$247,170	$179,728	**$2,243,763**
Multi-Family HET	$705	$29,033	$21,329	$119,347	$358,485	$490,506	$645,690	$106,125	$226,780	$158,175	**$2,156,175**
Commercial HET	$299	$37,985	$36,688	$25,086	$12,948	$28,886	$33,554	$45,600	$18,225	$42,150	**$281,421**
High-Efficiency Urinal	$0	$0	$2,000	$1,200	$900	$52,400	$156,300	$41,000	$2,800	$5,200	**$261,800**
Clothes Washer	$0	$0	$0	$0	$0	$0	$0	$265,800	$389,400	$283,200	**$938,400**
Gray Water	$0	$0	$265	$1,566	$4,144	$4,678	$14,224	$17,398	$12,742	$14,670	**$69,689**
Irrigation Upgrade	$0	$31,089	$52,770	$29,792	$48,964	$83,676	$600	$0	$664	$0	**$247,554**
TAP Commercial Upgrade	$0	$0	$0	$0	$0	$0	$0	$8,766	$24,518	$3,050	**$36,334**
Rainwater Harvesting*	$0	$0	$0	$0	$349,360	$353,858	$357,145	$426,100	$500,555	$593,183	**$2,580,201**
Total	**$31,407**	**$566,514**	**$628,279**	**$430,182**	**$1,231,309**	**$1,529,280**	**$1,720,708**	**$1,325,919**	**$1,562,835**	**$1,392,831**	**$10,419,263**

Table 4: Total Incentive Program Expenditures by Fiscal Year

*Includes contracted services to execute limited-income program.

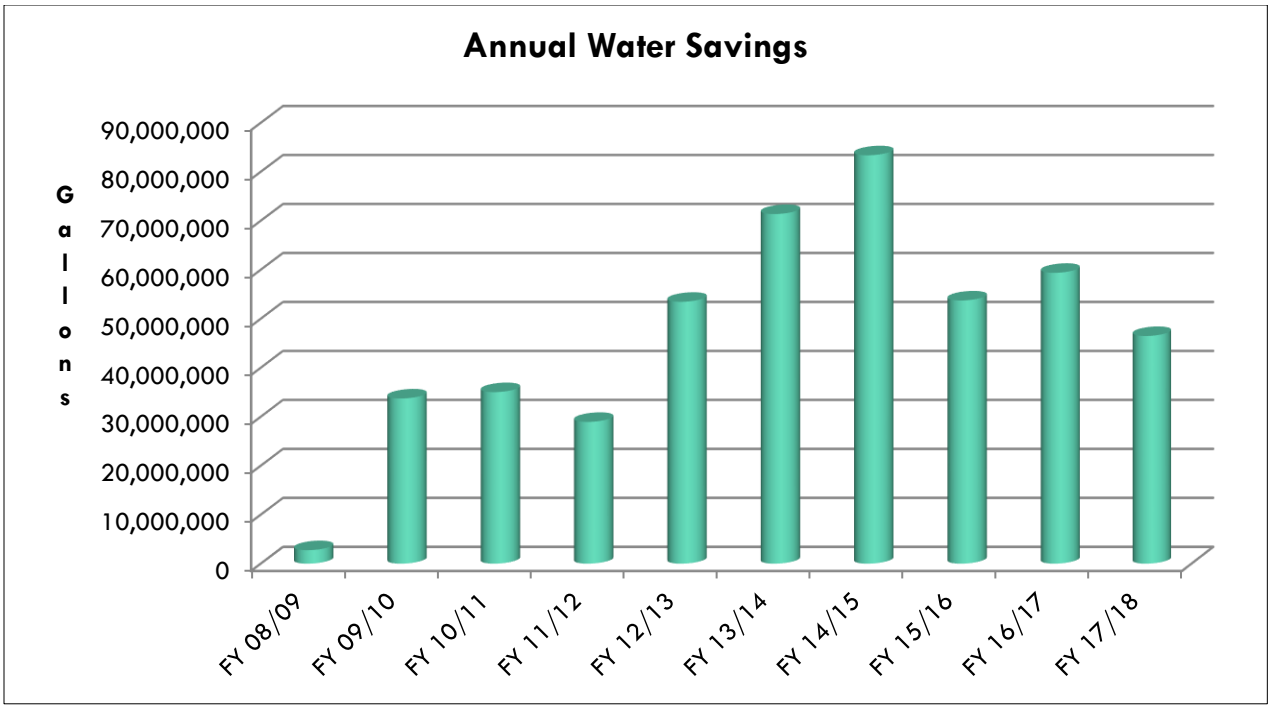


Figure 8: Annual Water Savings from Tucson Water's Incentive Programs

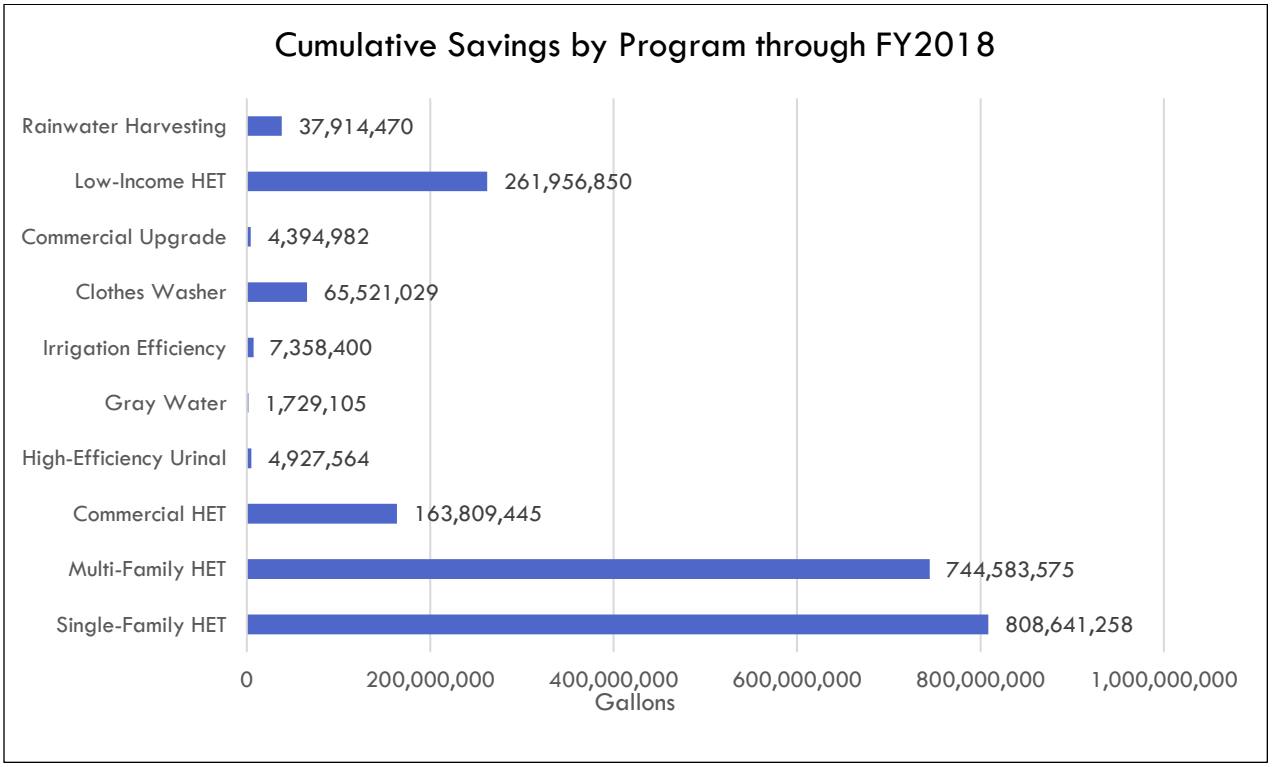


Figure 9: Cumulative Water Savings from Tucson Water's Incentive Programs

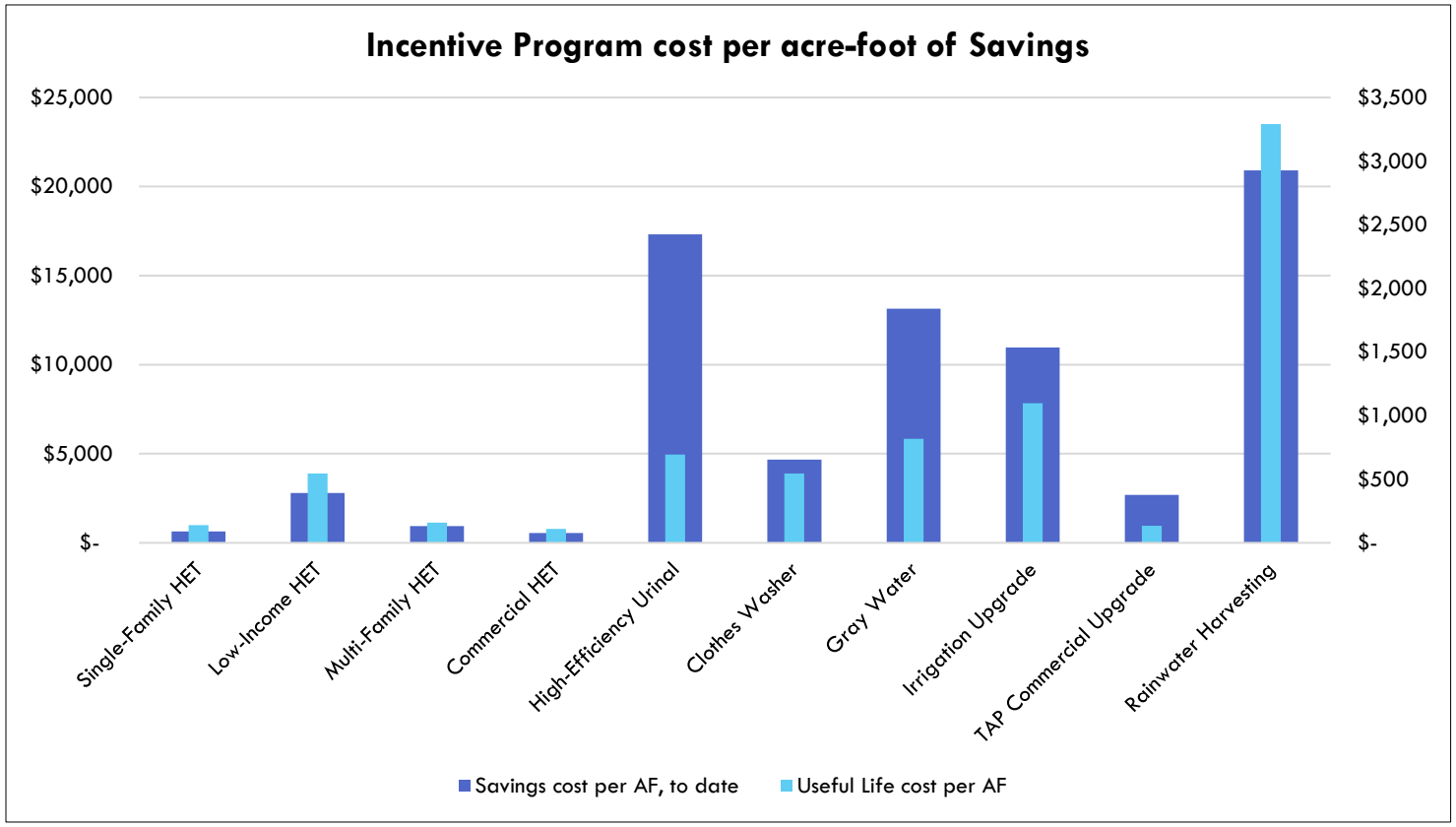


Table 5: Cost per acre-foot of savings per program, to-date and for projected fixture life.

Incentive Program	Useful Life (years)
Single-Family HET	25
Low-Income HET	25
Multi-Family HET	25
Commercial HET	25
High-Efficiency Urinal	25
Clothes Washer	15
Gray Water	15
Irrigation Upgrade	10
TAP Commercial Upgrade	20
Rainwater Harvesting	20

Table 6: Useful life of fixtures used to calculate cost per savings; all numbers taken from the Alliance for Water Efficieny except for Rainwater Harvesting, which was taken from Batchelor, C., Fonseca, C. and Smits, S., 2011. *Life-cycle costs of rainwater harvesting systems.* <http://www.irc.nl/op46>.

r

Single-Family HET Rebate

Implementation date: July 7, 2008

Modified March 1, 2015; July 1, 2016

This rebate program is designed to encourage single-family residential customers to retrofit older 3.5 or more gallons-per-flush (gpf) toilets with high-efficiency models. Only WaterSense-certified, high-efficiency toilets qualify for the rebate, which uses 1.28 gpf or less.

FY 2017-18 Activity:		Cumulative:
Number of HETs Retrofit:	1,527	19,959
Expenditure:	$113,475	$1,603,928
Estimated Gallons Saved:	11.4 million	809 million
Estimated Acre-Feet Saved:	35	2,482

Program Participation Rate[2]: The assumed participation rate recommended in the CCTF report for a targeted ultra-low-flush toilet (ULFT) rebate program was approximately 45,000 toilet replacements through 2015. The participation estimate assumes an aggressive program with participation decreasing over time. However, Mayor and Council elected to start the program at a slower pace with a low conservation fee, which would increase over time so customers would not experience a large rate increase on their water bill.

According to the residential baseline study, the total number of non-ULFTs in the Tucson water service area was approximately 225,000. The total retrofits for single-family to date is over 25,000. This leaves approximately 200,000 non-ULFTs for retrofit.

Effective March 1, 2015, the rebate was changed to $75 per retrofit limited to two HETs per household, in an effort to streamline the application process, create a more equitable rebate, and eliminate confusion for participants.

Effective July 1, 2016, single-family HET rebates are credited to the customer's account. In most instances, checks are no longer processed and mailed to the customer. This allows that customers with delinquent accounts do not receive a check, and streamlines the process with customers receiving their rebate faster.

Outreach and Promotion: Point-of-sale displays are provided to any stores that want them; currently 26 retailers are promoting the HET rebate programs. Tucson Water works with each retailer to provide display options that work with their merchandizing. Displays are stocked with brochures and rebate applications. Providing information at the time of sale ensures the customer knows about Tucson Water's rebate and purchases a qualifying fixture. Public Service Announcements using print and broadcast media are also used to promote the program.

Toilet water use is the highest of all indoor water use in most single-family homes illustrated in Figure 12 and contributes to 20 percent of all use. Retrofitting toilets saves on both the water and sewer bills.

[2] The CCTF report needs to be updated as identified in the water conservation planning process, Page 8.

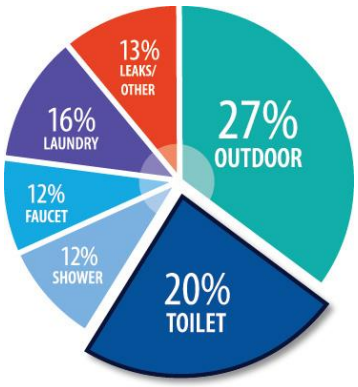


Figure 10: Typical Single-Family Water Use

Single-Family HET Retrofit Savings:

From Tom Arnold, Tucson Water, Management Analyst – 10.28.14

The single-family HET savings of 20.5 gallons per day (gpd) per unit (7,482.5 gallons per annum) originates from an analysis of program participants completed in 2011. This analysis compared water use between 2008 and 2011 of single-family households that had participated in the HET rebate program in 2008.

Customer Payback: The average cost of HETs purchased by participants was $183.99. The cost of qualifying toilets typically starts at $85. Total annual water and sewer savings per retrofit is $61.86 with, on average, a payback period of less than two years (1.8) after $75 rebate for an average water-use customer[3].

Rebates by Ward: The single-family HET rebate program, illustrated in Figure 15 (p. 27), has unequal concentrations of installations in the different jurisdictions. When combined with the low-income HET direct install program, illustrated in Figure 17, a more uniform distribution throughout the service area is achieved.

Low-Income HET Direct Install

Implementation date: October 2009

This efficiency program offers free high-efficiency toilet replacements for qualifying low-income homeowners who are Tucson Water customers. The program replaces older toilets that use 3.5 gallons or more per flush. Since many of these older toilets have other functional problems that cause chronic leaking or water flow, the effectiveness of the program is compounded by resolving these issues.

FY 2017-18 Activity:		Cumulative:
Number of HETs Retrofit:	503	6,289
Expenditure:	$179,728	$2,243,763
Estimated Gallons Saved:	4.3 million	262 million
Estimated Acre-Feet Saved:	13	804

Income Eligibility: The U.S. Department of Housing and Urban Development (HUD) State Income Limits are used for the low-income HET replacement program. The HUD median family income for Arizona is established each year, and 80 percent of that value is the maximum allowed to be considered low-income. The HET Replacement program is available to all owner-occupied households that report an annual income of 80 percent area median income (AMI) or less.

Low-Income Customers: A City of Tucson and Pima County HUD report[4] published in 2015 reports that 66% of homes in Pima County are owner-occupied and 34% are renter-occupied. Tucson Water has approximately 203,000 single-family customer accounts and based on the report findings, about 134,000 (66%) of these single-family accounts are owner-occupied. Approximately 27% of owner-

[3] Approximately 72% of single-family customers use, on average, nine Ccf per month or less, and the average customer uses approximately eight Ccf.

[4] DRAFT City of Tucson and Pima County Consortium 02/19/15 Federal Fiscal Years 2015-2019 HUD Consolidated Plan: http;//www.tucsonaz.gov/files/hcd/3-25-2015_CityofTucsonandPimaCounty5-yearHUDConsolidatedPlanPublicDommentDraft.pdf

occupied, single-family customers would have an income threshold of 80 percent AMI or less, which is currently the cutoff for Low-Income HET replacement (Table 9). Given these assumptions, 36,180 owner-occupied, single-family customers would be eligible for HET replacement.

Participation Rate[5]: Of the 2,610 HET retrofits in owner-occupied, single-family homes for FY 2017-18, 28% (719) were in low-income homes. This amount indicates the program is on target with HET retrofits within Tucson Water customer accounts.

AMI Threshold	<30% AMI	30-50% AMI	50-80% AMI	80-100% AMI	>100 % AMI
# Owner-Occupied Homes	8,040	10,720	17,420	12,060	85,760
% of Owner-Occupied Homes	6%	8%	13%	9%	64%

Table 7: Estimated Owner-Occupied Tucson Water Customer Accounts, Projected from 2015 HUD Consolidated Plan

Tucson Water purchases the HETs and the non-profit Community Home Repair Projects of Arizona (CHRPA) verifies participants and does the installation. Tucson Water provides financial assistance for the reimbursement of HETs installed. The cost to Tucson Water is $200 for one HET replacement and $100 for the second HET, or $300 for two HETs.

Additionally, in fiscal 2012-13, Tucson Water expanded the scope of the program to include supplying materials for repairing water supply leaks in the homes. CHRPA uses the materials to repair leaks including faucets, tub/shower valves, main or secondary water lines. They have also repaired many toilets that did not qualify for replacement. For these water supply repairs, Tucson Water has provided materials, and has not paid for the installation or labor.

Outreach and Promotion: Tucson Water uses a mix of approaches to promote this limited-income program including one-on-one interactions between our contractors and customers (CHRPA and SERI), as well as a variety of general outreach. Outreach includes:

- Flyer distribution at eligible mobile home parks and townhouse developments
- Television commercials
- Promotional materials at service fairs
- Tucson Water promotion at public outreach events and in the "message" area on water bills
- NewsNet for City Employees
- Ward Office newsletters
- On-hold recording for Tucson Water customer service
- Water Matters, monthly bill insert

Low-Income HET Retrofit Savings:

From Tom Arnold, Tucson Water, Management Analyst – 10.28.14

The low-income HET savings of 23.5 gpd per unit (8,577.5 gallons per annum) comes from an analysis of program participants completed in 2014. This analysis compared water use between 2011 and 2014 of low-income households that had participated in the HET rebate program in 2011.

Customer Payback: The payback is immediate because the HET and installation are free to the customer. Therefore, the participant will experience, on average, an annual savings of $70.91.

Discussed previously in Distribution of Programs by Ward on page 18, the low-income HET direct install program, illustrated in Figure 16, has unequal concentrations of installations in the different sectors with Wards One and Five receiving the largest percent of HET installations. Conversely, combined with the single-family HET rebate program, illustrated in Figure 15, a more uniform distribution throughout the service area is achieved.

[5] The CCTF report needs to be updated as identified in the water conservation planning process, Page 13.

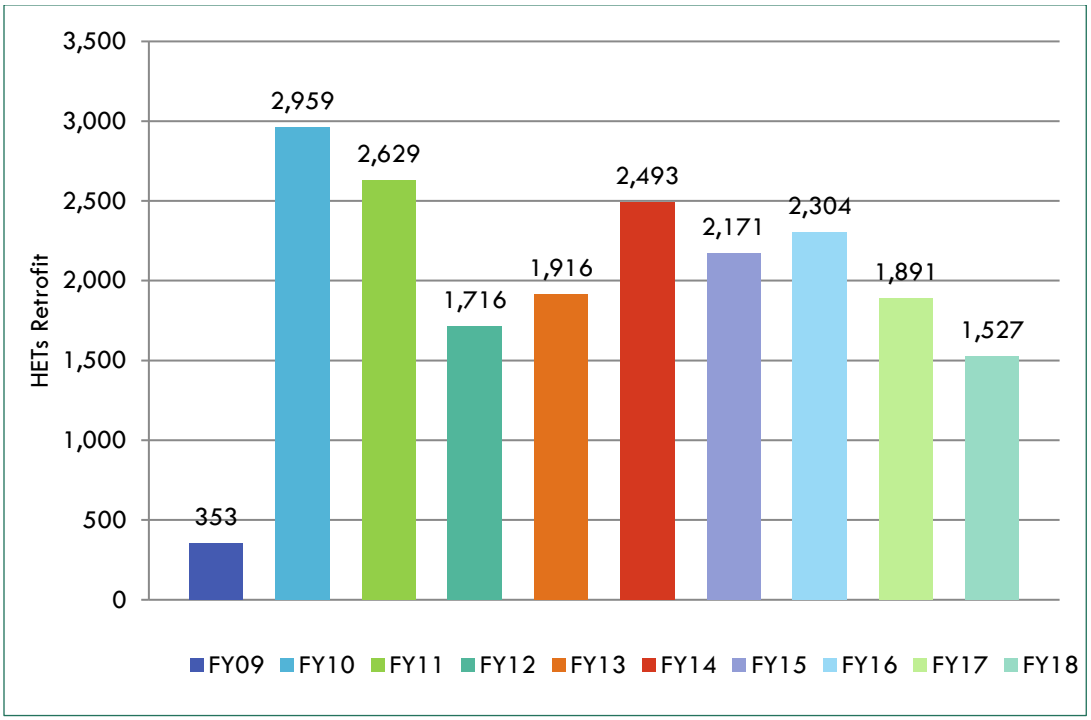


Figure 11: Single-Family HET Rebates by Fiscal Year

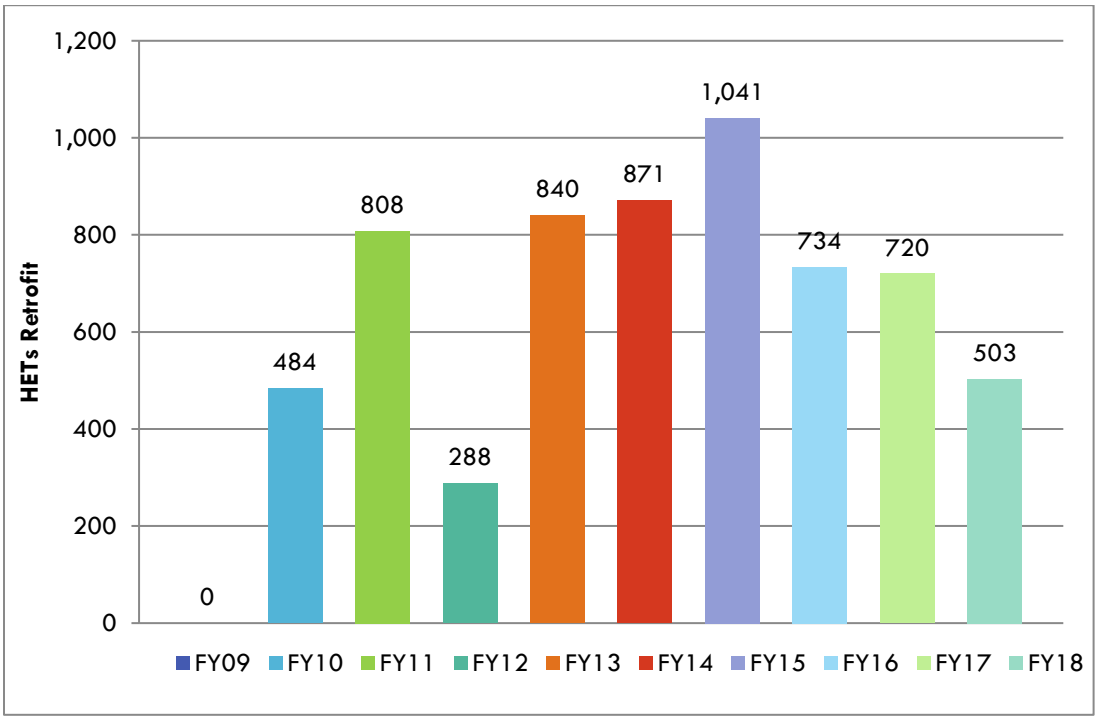


Figure 12: Low-Income HET Direct Installs by Fiscal Year

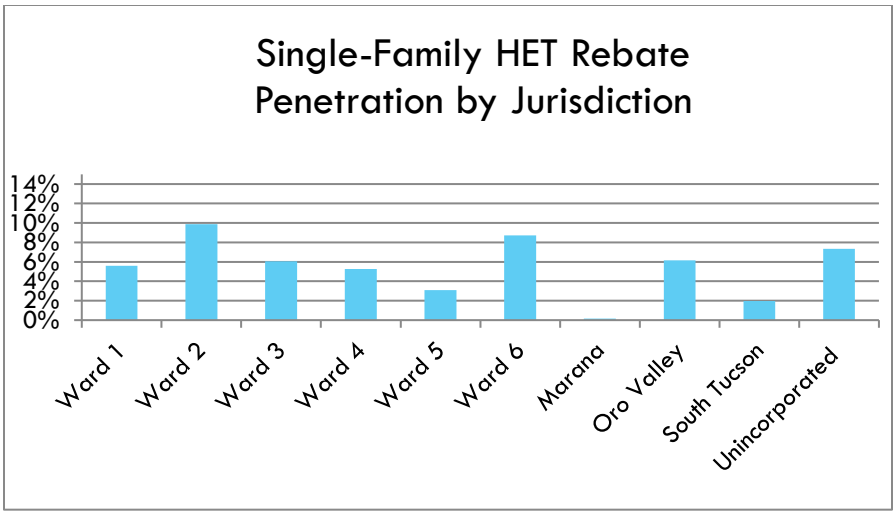


Figure 13: Single-Family HET Rebates by Jurisdiction

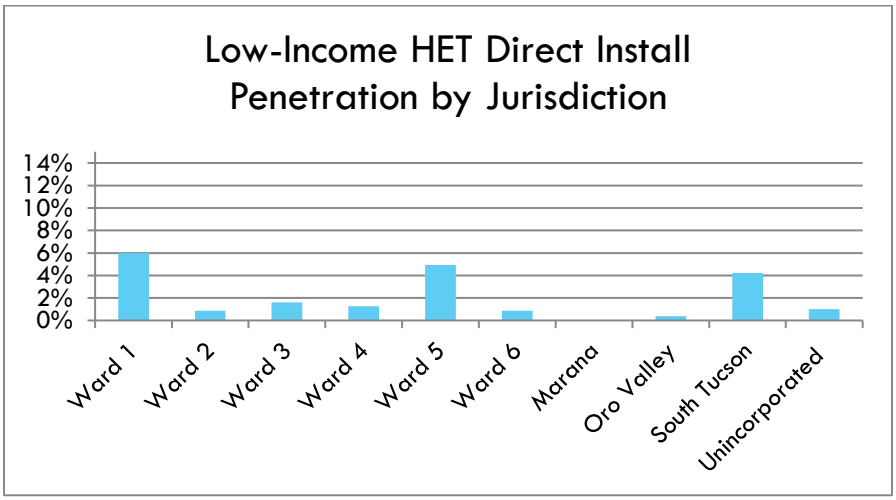


Figure 14: Low-Income HET Direct Install Retrofits by Jurisdiction

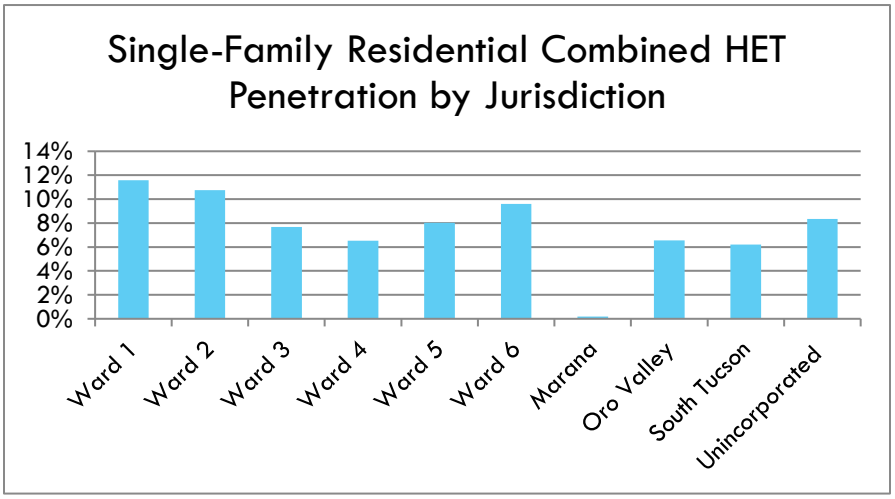


Figure 15: Combined HET participation by Jurisdiction

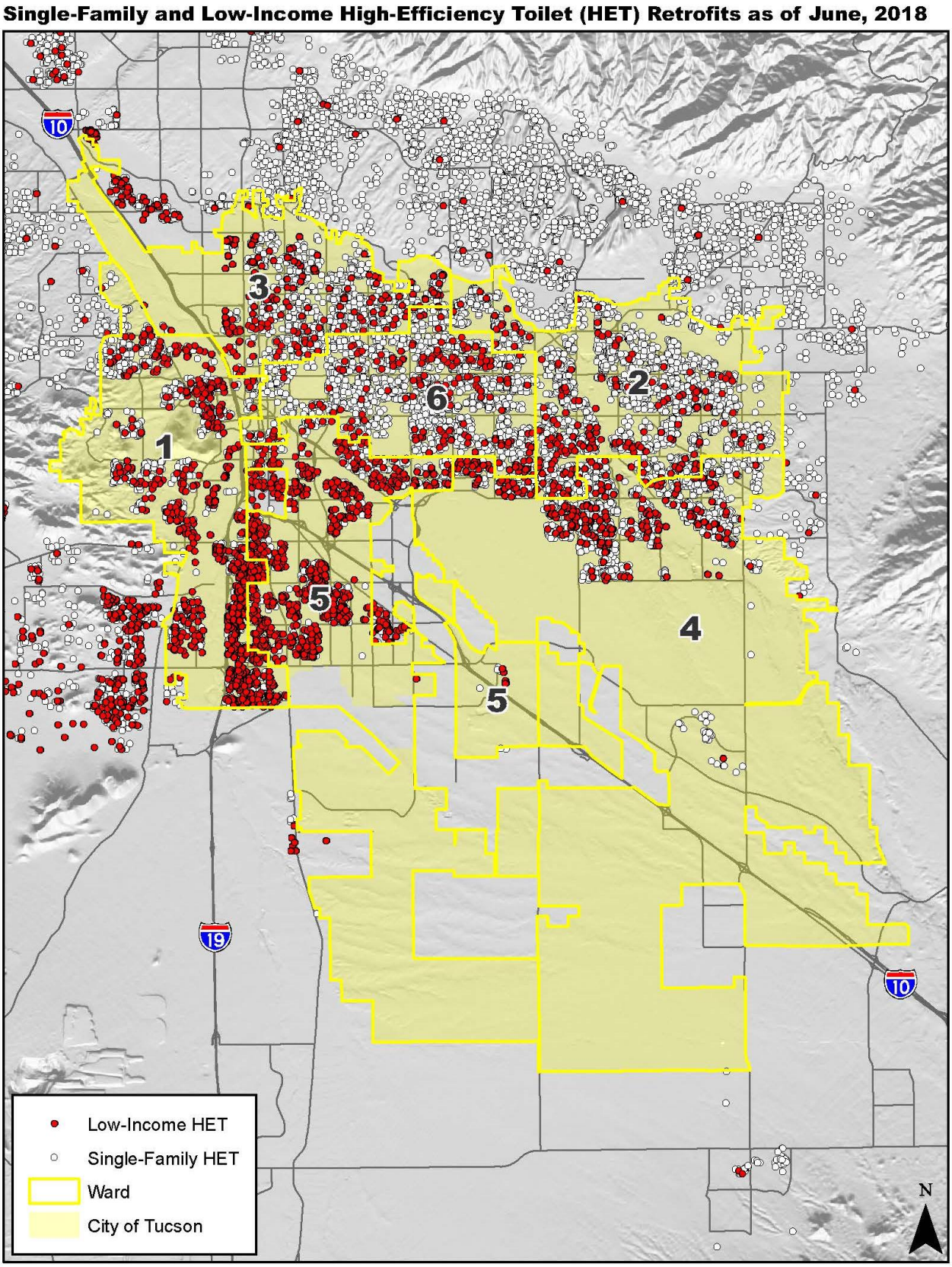


Figure 16: Map of all single-family high-efficiency toilet installations since program inception.

Multi-Family HET Rebate

Implementation date: July 7, 2008; modified March 1, 2015

This rebate program is designed to encourage multi-family customers to retrofit older 3.5 or more gallons-per-flush toilets with high-efficiency models. Only WaterSense-certified, high-efficiency toilets qualify for the rebate, which use 1.28 gallons per flush or less.

FY 2017-18 Activity:		Cumulative:
Number of HETs Retrofit:	2,109	23,578
Expenditure:	$158,175	$2,156,175
Estimated Gallons Saved:	15.7 million	745 million
Estimated Acre-Feet Saved:	48	2,285

Program Participation Rate[6]: The assumed participation rate identified in the CCTF report for a high-efficiency toilet rebate program was two percent annually of the approximately 99,000 non-ULFTs with an aggressive start up. The actual participation rate, on average, for the program is between two and three percent with a slow start up the first three years. This leaves approximately 80,000 non-ULFTs for retrofit.

Effective March 1, 2015, the rebate was changed to $75 per retrofit to match the single-family rebate in an effort to streamline the application process and create a more equitable rebate between classes.

Outreach and Promotion: Promotion of this program is largely done at a staff level by providing a customized analysis to customers interested in this rebate program. The analysis considers current water usage, a fixture count and behavior assumptions to provide each customer with return-on-investment calculations to help customers make informed decisions. Information is also provided at point-of-sale displays, similar to our residential HET rebate.

Multi-Family HET Retrofit Savings:

From Tom Arnold, Tucson Water, Management Analyst – 10.28.14

The single-family savings number of 20.5 gpd (7,482.5 gallons per annum) is used to calculate multi-family savings estimates.

Customer Payback: The average cost of multi-family HETs purchased by participants was $106.86. The cost of qualifying toilets typically starts at $75. Total annual water and sewer savings per retrofit is $72.55 with, on average, a payback period of less than half a year after the $75 rebate.

Figure 22 provides a map showing locations of multi-family and commercial HET retrofits combined with HEU retrofits.

[6] The CCTF report needs to be updated as identified in the water conservation planning process, Page 13.

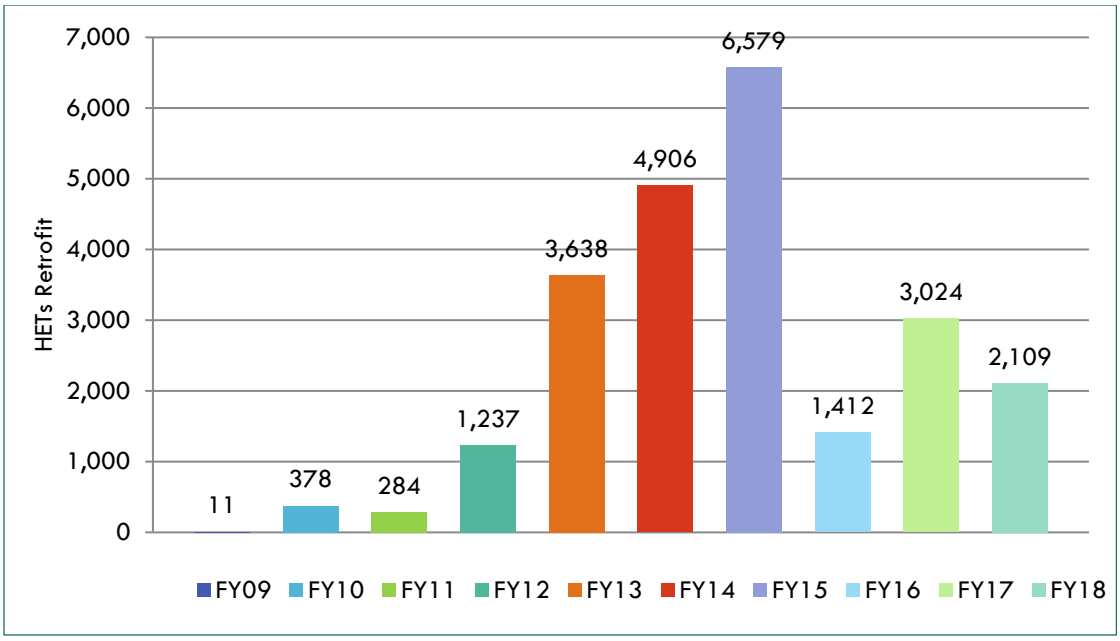


Figure 17: Multi-Family HET Rebates by Fiscal Year

Commercial HET Rebate

Implementation date: July 7, 2008; modified March 1, 2015

This rebate program is designed to encourage commercial/industrial customers to retrofit older 3.5 or more gallons-per-flush toilets with high-efficiency models. Only WaterSense-certified, high-efficiency tank-type toilets or flushometer valve/bowl combinations rated by Maximum Performance (MaP) Testing at 800 grams or more qualify for the rebate, which use 1.28 gallons per flush or less.

FY 2017-18 Activity:		Cumulative:
Number of HETs Retrofit:	409	3,181
Expenditure:	$42,150	$281,421
Estimated Gallons Saved:	2.1 million	154 million
Estimated Acre-Feet Saved:	7	472

Program Participation Rate[7]: The commercial-industrial baseline study estimated a total of approximately 33,000 non-ULFTs in the service area. About 7,500 of which the expected daily savings would be at least 25 gallons. The cumulative participation of the targeted establishments would be 6,750 by 2015 with an aggressive program.

Effective March 1, 2015, the rebate was changed to $75 per retrofit per gravity-tank type and pressure assist-tank type toilets and $150 for flushometer-valve type toilets in an effort to streamline the application process and create a more equitable rebate between classes.

Estimated water savings in nonresidential market segments is not the same. Typically, the greatest water savings can be achieved in restaurants, bars, and retail establishments with the least savings achieved in health-care facilities, offices, and hotel/motels. Furthermore, commercial applications include more types of toilets: the less expensive gravity-tank type and the pressure assist-tank type toilets and the flushometer-valve type toilets that cost more to retrofit. The flushometer-valve type toilets typically save more water because they are found most often in public restrooms that receive more use.

Updated Commercial HET Retrofit Savings for FY 2015-16:
Differentiated water savings were calculated for flushometer-type and gravity-tank or pressure assist-tank types based on the CII estimated toilet savings in the CCTF 2006 report. These estimates were based on ULFTs (1.6 gpf), so a 20% additional savings is added for HETs (1.28 gpf) resulting in 50 gpd for flushometer-type toilets and 23 gpd for gravity-type and pressure-assist tank toilets. The new calculations for determining water savings for flushometer-valve type toilet retrofit are 50 gpd or 16,425 per annum and 23 gpd or 8,030 gallons per annum for each gravity-tank and pressure assist-tank type toilet.

Outreach and Promotion: Tucson Water promotes this program through the same point-of-sale displays used to promote the other high-efficiency toilet rebate programs and using direct staff and contractor outreach. Similar to the multi-family HET program, a customized analysis is provided to the customer. If the customer is participating in TAP, a comprehensive

[7] The CCTF report needs to be updated as identified in the water conservation planning process, Page 8.

recommendations report will be provided to the customer and if the customer is just interested in the toilet rebate, staff provides a customized analysis that considers current water usage, a fixture count and behavior assumptions to provide each customer with return-on-investment calculation.

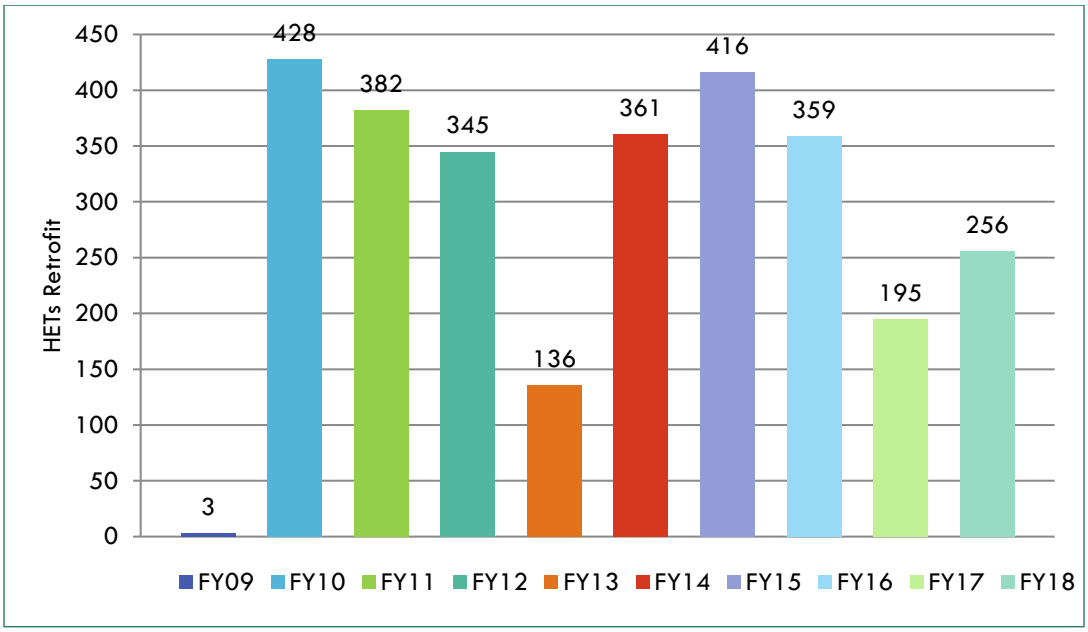


Figure 18: Commercial HET Rebates by Fiscal Year

Toilet Count by Sector	# Toilets	GPD savings per ULFT	Daily savings by Sector
Industrial	1,915	23	44,045
Retail	10,008	40	400,320
Restaurants	3,073	47	144,431
Office	12,311	20	246,220
Health care	6,198	21	130,158
Church	1,176	28	32,928
Government	1,620	25	40,500
Other	6,936	18	124,848
Hotels	6,384	16	102,144
Schools: 9-12	933	18	16,794
Schools: K-8	19,871	18	357,678
	70,425	Weighted avg. savings (gpd)	23.29

Table 8: CII Toilet Savings table reproduced from CCTF Planning Report, 2006 (p. 48)

High-Efficiency Urinal Rebate

Implementation date: January 1, 2011; modified January 1, 2013; modified March 1, 2015

This rebate program is designed to encourage commercial customers to retrofit high water-use urinals with high-efficiency models.

Program Participation Rate[8]: The commercial-industrial baseline study estimated a total of approximately 4,400 urinals in the service area. The participation rate assumes that slightly more than half of these will be retrofit by 2015 with an aggressive program.

FY 2017-18 Activity:		Cumulative:
Number of HEUs Retrofit:	25	794
Expenditure:	$5,200	$261,800
Estimated Gallons Saved:	155,150	18.9 million
Estimated Acre-Feet Saved:	0	58

Effective January 1, 2013, the rebate was increased from $200 to $500 and the range of options expanded to include all WaterSense-certified as well as waterless models.

Effective March 1, 2015 the rebate was changed back to $200, which is more in line with the commercial HET rebate.

Promotion and Outreach: Brochures are provided to specialty plumbing stores and large retailer stores that supply commercial accounts. This program has seen a tremendous decrease in participation since the rebate was decreased in 2015. Similar to the multi-family and commercial HET program, staff assistance is provided in providing a return-on-investment analysis to interested customers.

High-Efficiency Urinal Retrofit Savings:

The calculation for determining water savings for each retrofit is 17 gpd or 6,206 gallons per annum. This number has been adjusted from the previous number of 49 gpd to reflect updated savings estimates provided in the AWE Conservation Tracking Tool 2.0. This number compares closely with a study completed in California that looked at potential savings from large-scale urinal retrofits.

[8] The CCTF report needs to be updated as identified in the water conservation planning process, Page 8.

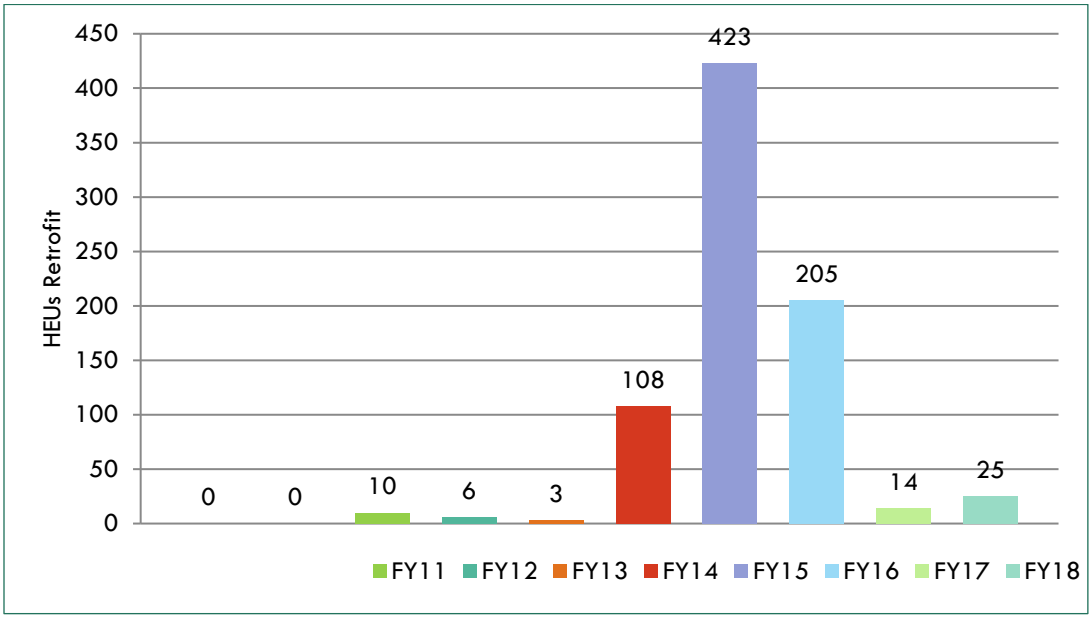


Figure 19: High-Efficiency Urinal Rebates by Fiscal Year

Multi-Family and Commercial High-Efficiency Toilet (HET) and Commercial High-Efficiency Urinal (HEU) Retrofits as of June, 2018

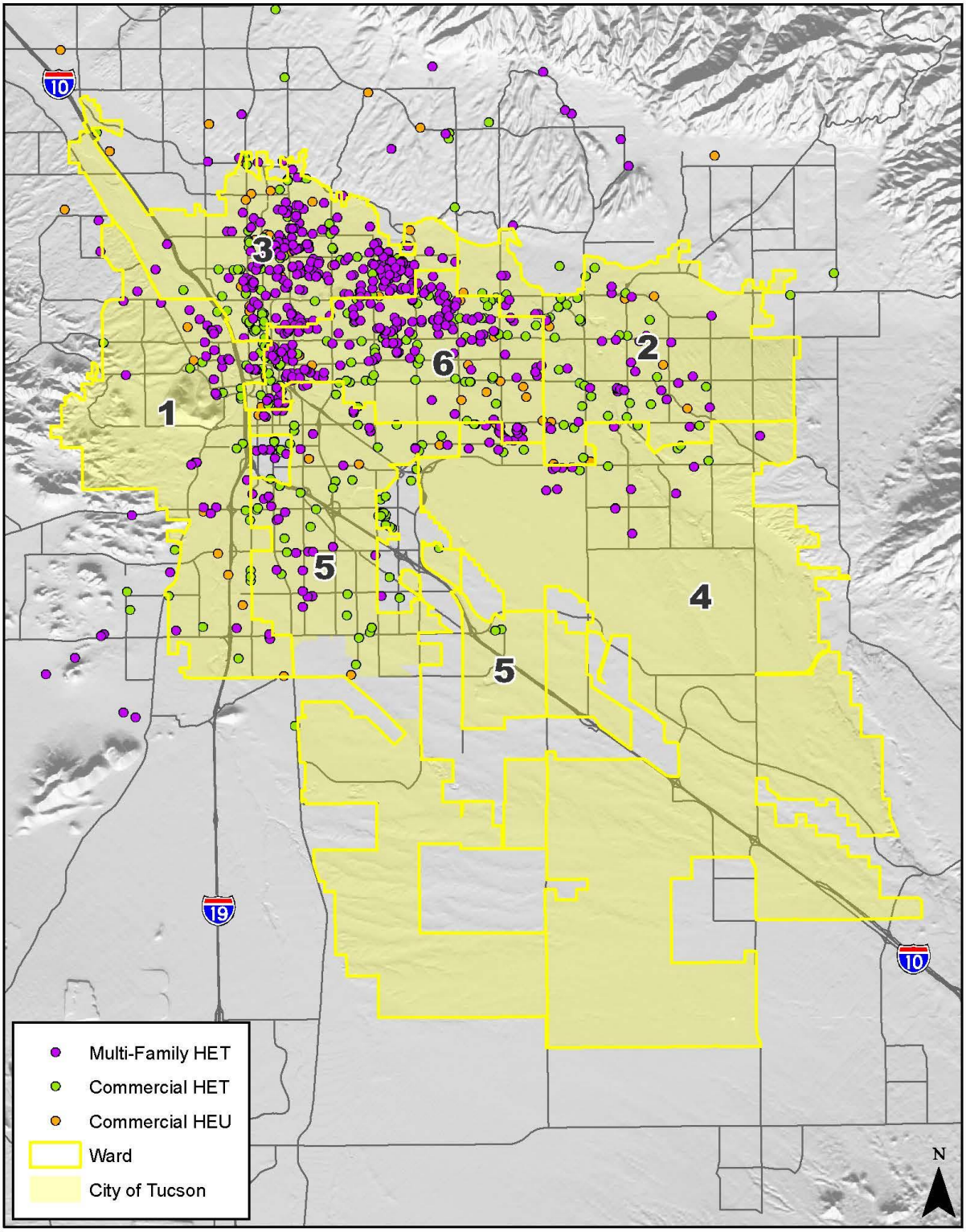


Figure 20: Map of all commercial and multi-family high-efficiency toilets and urinals since program inception.

Clothes Washer Rebate (Pilot)

Implementation date: August 1, 2015

This rebate is designed to offset the difference between purchasing conventional clothes washers and high-efficiency models.

FY 2017-18 Activity:		Cumulative:
Number of Clothes Washers:	1,417	4,695
Expenditure:	$283,200	$938,400
Estimated Gallons Saved:	9.9 million	66 million
Estimated Acre-Feet Saved:	31	201

Effective August 1, 2015, Tucson Water began offering residential customers a $200 rebate for purchasing a qualifying high-efficiency clothes washer.

Effective July 1, 2016, clothes washer rebates are credited to the customer's account. In most instances, checks are no longer processed and mailed to the customer. This allows that customers with delinquent accounts do not receive a check, and streamlines the process with customers receiving their rebate faster.

The Consortium for Energy Efficiency (CEE) specifies tiers of efficiency based on both water and energy use so that rebate programs and manufacturers can work together to offer efficient products. Clothes washer efficiency is based on an integrated Modified Energy Factor and an Integrated Water Factor. For more information, visit www.cee1.org. When the program launched in August 2015, the qualifying list was the CEE Tier 2 and 3 clothes washers. To ease customer confusion about the CEE list, Tucson Water began publishing its own qualifying product list in December 2015, available on the website and at all local retailers.

Laundry is the second-largest indoor water user for most single-family households, illustrated in Figure 23, with an estimated seven loads per week, or 350 loads per year for a family of four. On average, 16 percent of residential water used goes to laundry. Using a high-efficiency washing machine equates to saving more than 7,000 gallons of water and 352 kWh of energy per year.

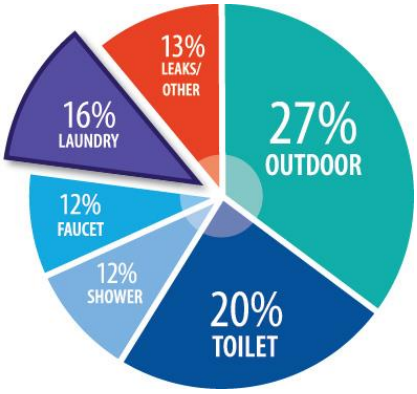


Figure 21: Typical Single-Family Water Use

Outreach and Promotion: Point-of-sale displays are provided to any retail stores that request materials. Currently, 25 retailers are promoting the rebate program. Monthly e-mail updates are sent including the most recent qualifying product list and displays are stocked with brochures and rebate applications.

Clothes Washer Savings:

The calculation for determining water savings for each purchase is 19.3 gpd or 7,043 gallons per annum. This assumption is from the Alliance for Water Efficiency that has used this value in their Conservation Tracking Tool 2.0. This value is a mid-range estimate, as published literature has indicated both higher and lower potential savings.

Customer Payback: The average cost of clothes washers purchased by participants was $707.74. The cost of qualifying clothes washers typically starts at $450. Total annual water, sewer, and energy savings per clothes washer is $93.43 with, on average, a payback period of less than six years (5.7) after rebate.

Program Evaluation: In conjunction with work being done by Montgomery & Associates to update the Tucson Active Management Area water demand model (funded by CAP and ADWR), the clothes washer rebate program was analyzed to determine better coefficients for the demand model.

A pooled time series-cross sectional analysis, which produces a monthly comparison of rebate customers before and after clothes washer installation. Results indicate that a substantial amount of rebates are given to customers with existing top-load washing machines (Figure 24).

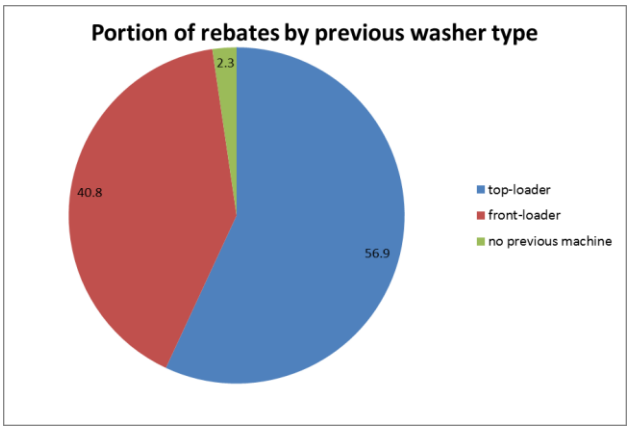


Figure 22: Clothes washer rebate recipients as a function of previous washer type.

The analysis also determined that the average water use reduction for a customer that previously had a top-load washer is 0.81 ccf/month, but only 0.07 ccf/month for customers with a previous front-load machine and 0.17 ccf/month for customers who did not previously have a washing machine at their residence. The savings number of 7,043 gallons per year used in program development aligns closely with 0.81 ccf/month (7,270 gallons), but the high incidence of front-loaders replacing front-loaders is a concern when considering the cost of incentive-driven water savings. Staff will begin reviewing policies and market trends to determine whether changes are necessary.

Rebate by Ward: The distribution of clothes washers by Ward is illustrated in Figure 26. This information helps with conservation planning to determine where improvements can be made with outreach efforts and program modifications to improve participation. Furthermore, an assistance program, similar to the low-income HET direct install program and the low-income rainwater harvesting grant and loan program should be considered.

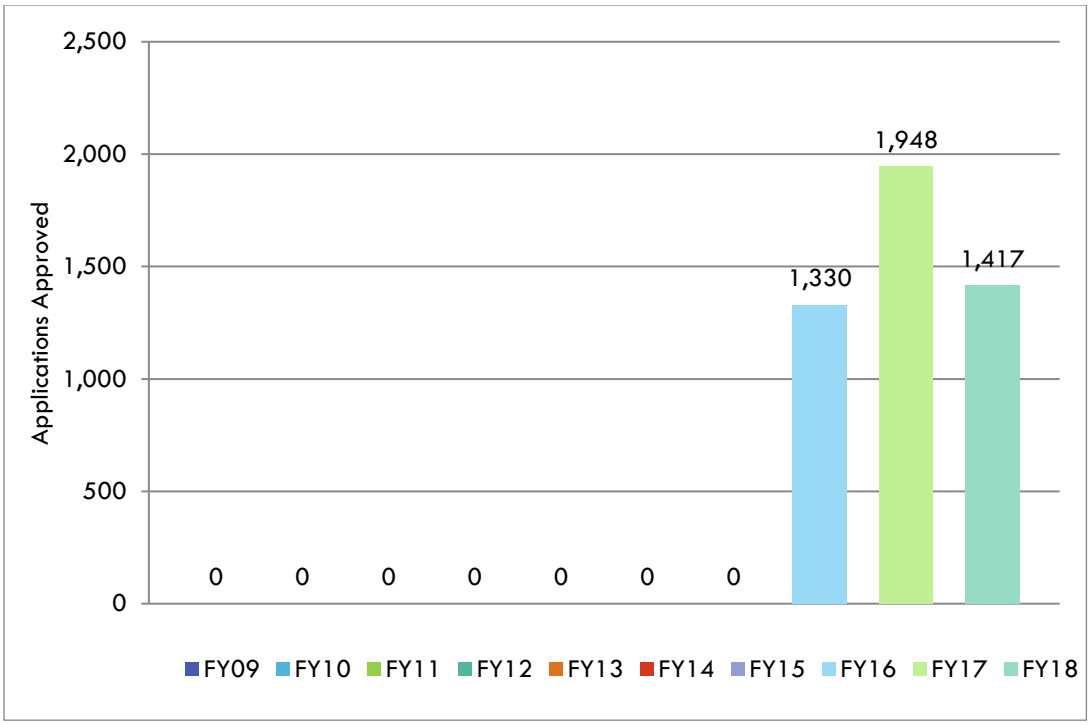


Figure 23: Clothes Washer Rebates by Fiscal Year

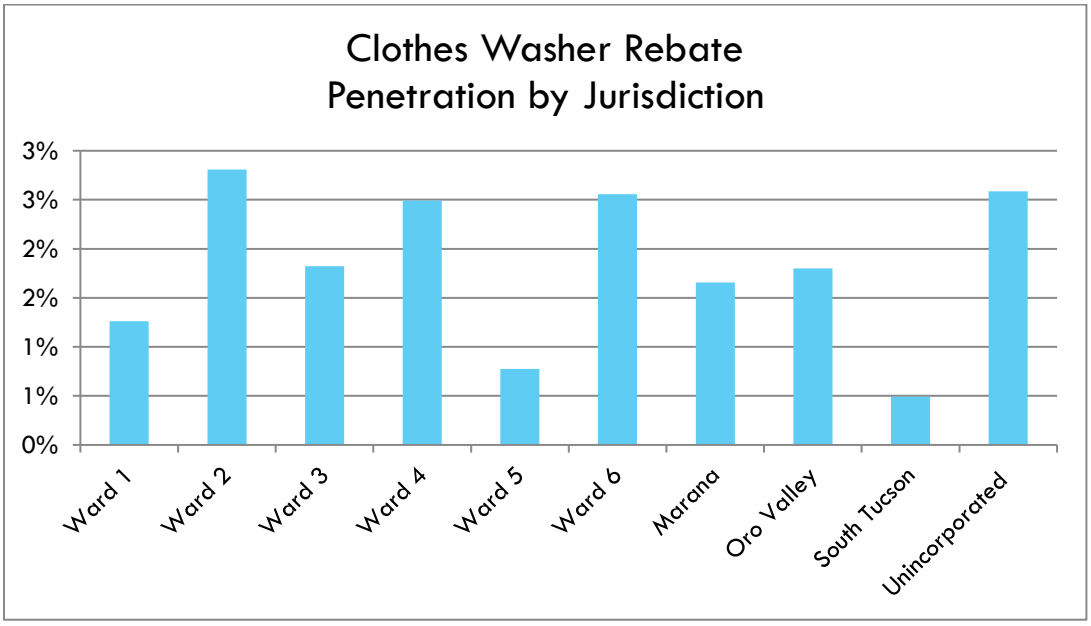


Figure 24: Clothes Washer Rebates by Jurisdiction

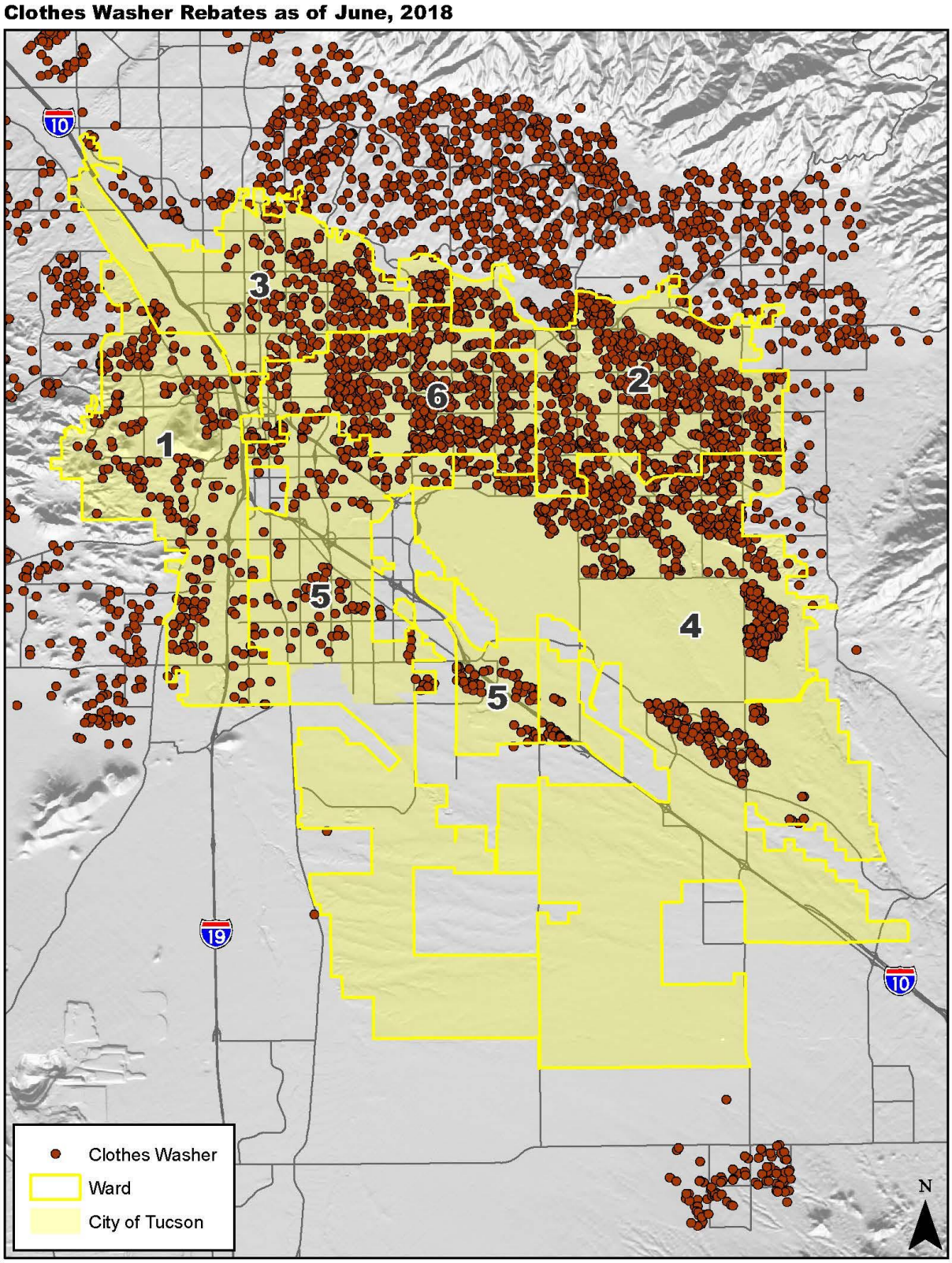


Figure 25: Map of all high-efficiency clothes washer rebates since program inception.

Gray Water Rebate

Implementation date: January 1, 2011; modified January 1, 2013

This rebate program is designed to encourage homeowners to install gray water systems for landscape irrigation. Beginning January 2013, the rebate amount increased from one-third of the cost up to $200 to one-half the cost up to $1,000. Participation in the program has remained low.

Program Participation Rate[9]: Given the relatively high up-front participant cost and the long payback period, the assumed participation rate identified in the CCTF report for a gray water incentive would be low.

FY 2017-18 Activity:		Cumulative:
Approved Applications:	21	148
Expenditure:	$14,670	$69,689
Estimated Gallons Saved:	285,915	6.7 milion
Estimated Acre-Feet Saved:	1	21
Workshops:	8	
Workshop Attendees:	98	

To be eligible for the gray water incentive rebate program, applicants must attend a two-hour workshop. Qualifying workshops were offered through Smartscape and Watershed Management Group.

Of the total amount of waste water generated in a typical home, clothes washers, showers, and hand-washing sinks illustrated in Figure 28, approximately 34 percent can be re-used as gray water for landscape plants. Most applicants are installing laundry-to-landscape systems, which can recycle 12-16 percent of household use directly from clothes washers.

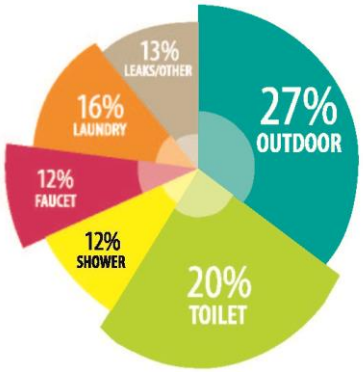


Figure 26: Typical Single-Family Water Use

Gray Water Savings:

The calculation for determining water savings for each rebate is 37.2 gpd or 13, 615 gallons per annum.

Most gray water systems approved for rebate are installing laundry-to-landscape systems that divert clothes washer water to the landscape instead of the sewer system. This savings number is calculated by multiplying the percent end use of clothes washers (16%) and Tucson's gpcd, to get 13.5 gpcd. This number is multiplied by the average persons per single-family household (2.76).

[9] The CCTF report needs to be updated as identified in the water conservation planning process, Page 8.

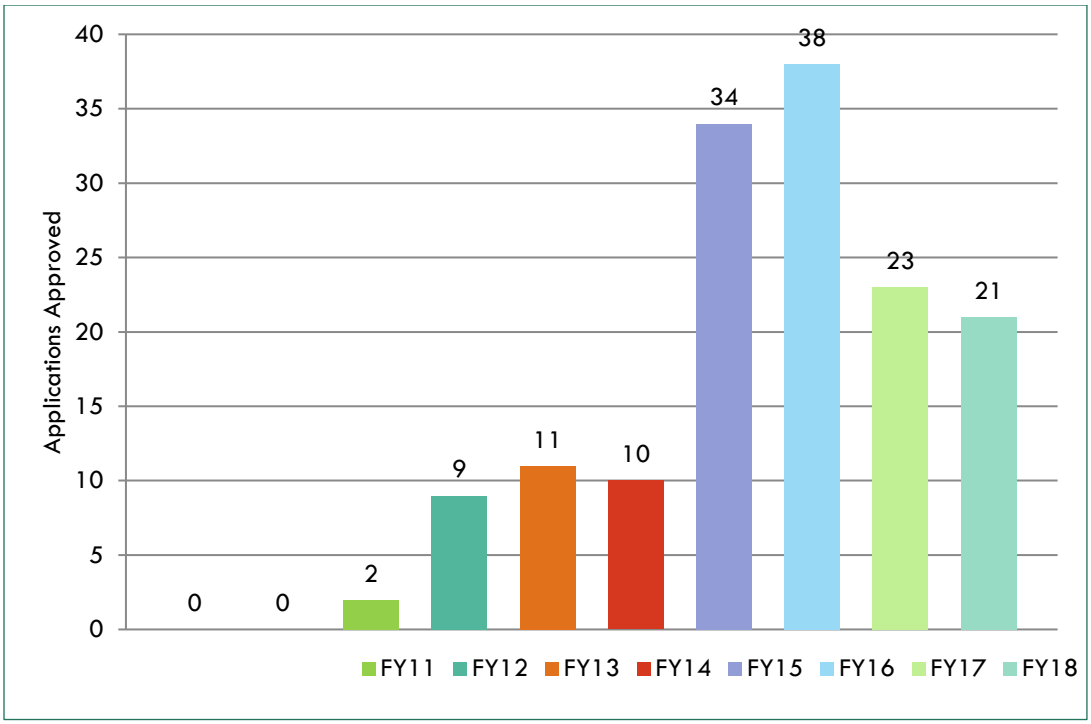


Figure 27: Gray Water Rebates by Fiscal Year

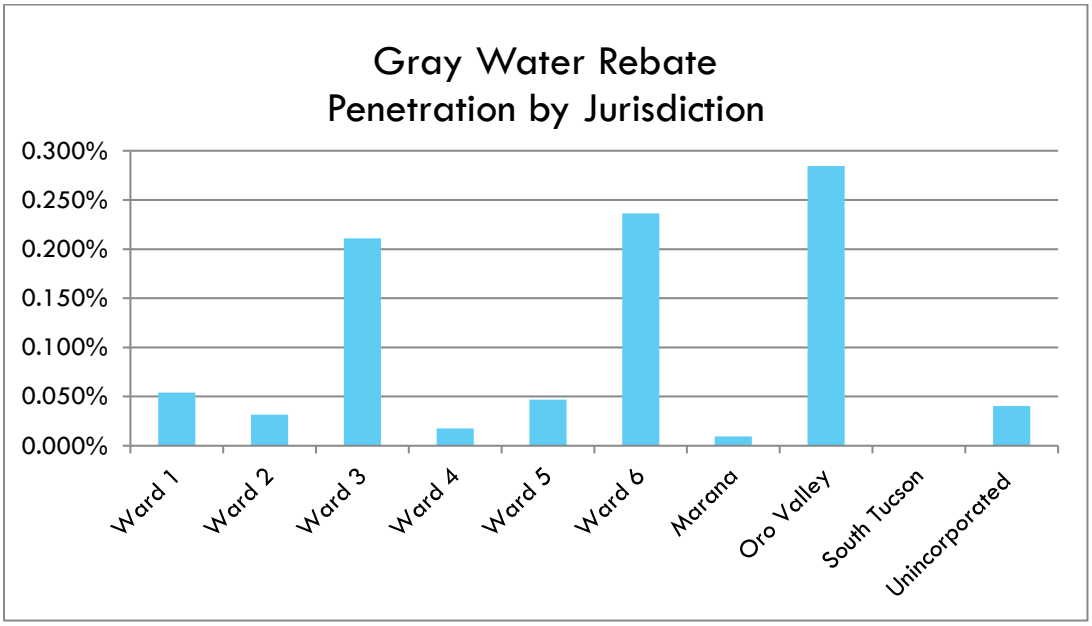


Figure 28: Gray Water Rebate by Jurisdiction

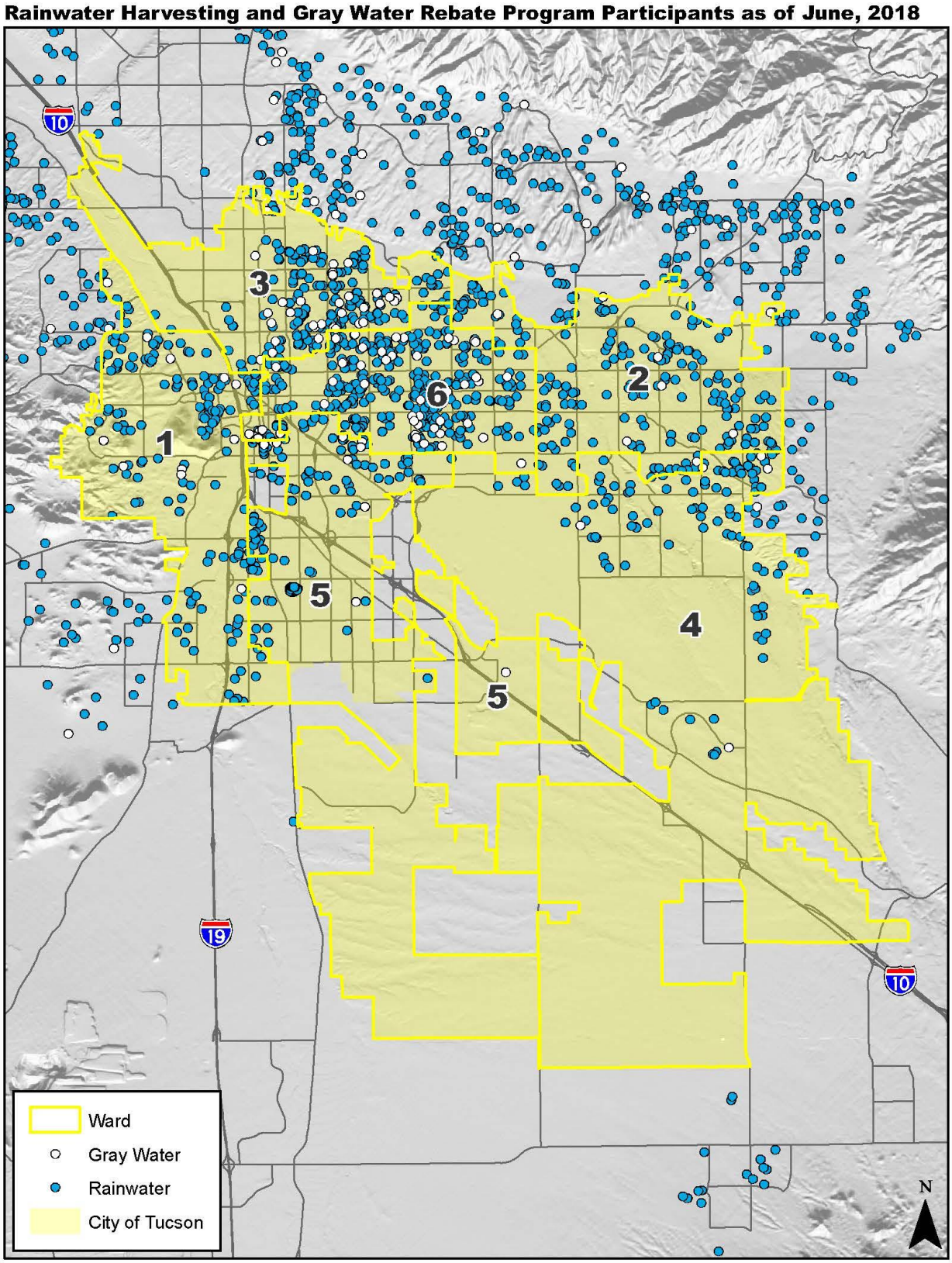


Figure 29: Map of all rainwater harvesting and graywater rebate locations since program inceptions.

Irrigation Efficiency Incentive Program

Implementation date: July 7, 2008; modified fall 2014; put on hold for FY17-18

The Irrigation Efficiency Incentives Program, formerly Irrigation Upgrade Rebate Program, introduces multi-family and commercial water customers to the concepts of irrigation efficiency and uniformity. Water customers can fine tune, upgrade, and maintain their in-ground irrigation system to be more efficient resulting in healthier plants and save water. Participants will qualify for irrigation system upgrade rebates up to $10,000.

Program Update: During several pre-upgrade inspections for applicants, it became apparent that some irrigation systems were in such disarray that we have had to re-examine the type of assistance best suited to achieve a more stringent landscape irrigation design standard. Concerns about investing in retrofitting existing systems that were either poorly designed from the start and/or have been improperly maintained throughout the years have become prominent. Tools need to be developed to help staff and customers evaluate landscapes and compare retrofitting an existing system to redesigning a brand new system. The challenge has been to identify ways of effectively inventoring existing flaws in established landscape irrigation systems (moving and/or adding sprinkler heads and emitters versus retrenching and installing brand new systems) and calculating potential savings opportunities.

There is also a need for landscape professionals with the proper credentials in efficient irrigation design, installation, and maintenance to help our customers. Pima Smartscape has added Irrigation Association (IA) classes to its roster of professional classes to expand the certification of local contractors to perform upgrades. This work will continue toward the goal of having more IA-certified individuals in the community who can be resources for customers seeking to upgrade and retrofit their landscapes and irrigation systems.

To evaluate technology options to support landscape investigations, staff has worked with Cascadia Consulting Group, the contractor for commercial water audits, to conduct a thorough review of existing auditing tools. This review will provide staff with additional information on the types and functions of auditing tools available that can be customized to represent local climate conditions as well as integrated into a platform that multiple staff and potentially contractors can use to serve clients.

Customized Commercial Efficiency Program (Pilot)

Implementation date: January 1, 2016

Tucson Water's customized commercial rebate encourages businesses and industries to use water efficiently. Rebates help offset the initial costs of installing water-saving hardware, equipment, and systems. Rebate amounts are calculated based on estimated water savings to ensure program cost-effectiveness.

FY 2017-18 Activity:		Cumulative:
TAP Customers:	5	40
Expenditure:	$3,050	$326,334
Estimated Gallons Saved:	225,000	9.6 million
Estimated Acre-Feet Saved:	1	30

The Customized Commercial Efficiency Program is being branded as the Tucson Audit Program (TAP) and replaces the WaterSmart Business Program and offers free water-savings audits and customized incentive packages to business customers. Tucson Water has contracted with Cascadia Consulting Group and their subcontractor Montgomery & Associates to provide technical services for this program. TAP audits identify water and money-saving opportunities for organizations that are presented in a Water Efficiency Recommendations Report, prepared by Cascadia Consulting Group, and reviewed by Tucson Water staff. The audits also provide valuable data on the current state of water use in commercial and industrial customers that can be used in future conservation program planning efforts.

The City of Tucson Water Department's 2012 Drought Preparedness and Response Plan includes four drought response levels beginning with Stage 1 and increasing in severity to Stage 4. The Drought Plan states that if Stage 2 drought is declared, all commercial and industrial customers using, on average, over 325 ccf per month (2.5 million gallons per year) need to conduct a self–audit of water use at the facility and develop a conservation plan. Tucson Water is currently in Stage 1 drought and has been for several years. Declaration of Stage 2 drought is dependent on Colorado River conditions, and is made by the Tucson City Manager, on advice from the Director of Tucson Water. For more information the Drought Plan: tucsonaz.gov/files/water/docs/drought_plan_update_spring_2012_p_31-49.pdf

Tucson Water is offering these TAP audits free of charge to our customers now, to help get ahead of these requirements. This program is targeting our largest commercial and industrial users, but is available to any commercial or industrial customer.

To qualify for a customized commercial rebate, business customers will have Tucson Water staff or a professional auditor under contract with Tucson Water conduct an audit of the property. The results of the audit are provided in a Water Efficiency Recommendations Report, which projects the water-savings potential of each measure, and the incentive package is calculated based on these unique measures.

All technologies and retrofits that can prove real water savings will be considered for a rebate excluding the HET, urinal, and clothes washer rebates already in place. Additional information about the program is provided in the annual report prepared by Cascadia Consulting Group, available online at tucsonaz.gov/water/conservation.

The uptake of rebates based on efficiency recommendations has been slow; it has become apparent that staff needs to invest more time in engaging customers that have already received audits to drive them to action. Staff anticipates doing fewer audits next fiscal year and focusing on engagement of customers that have already received audits through TAP.

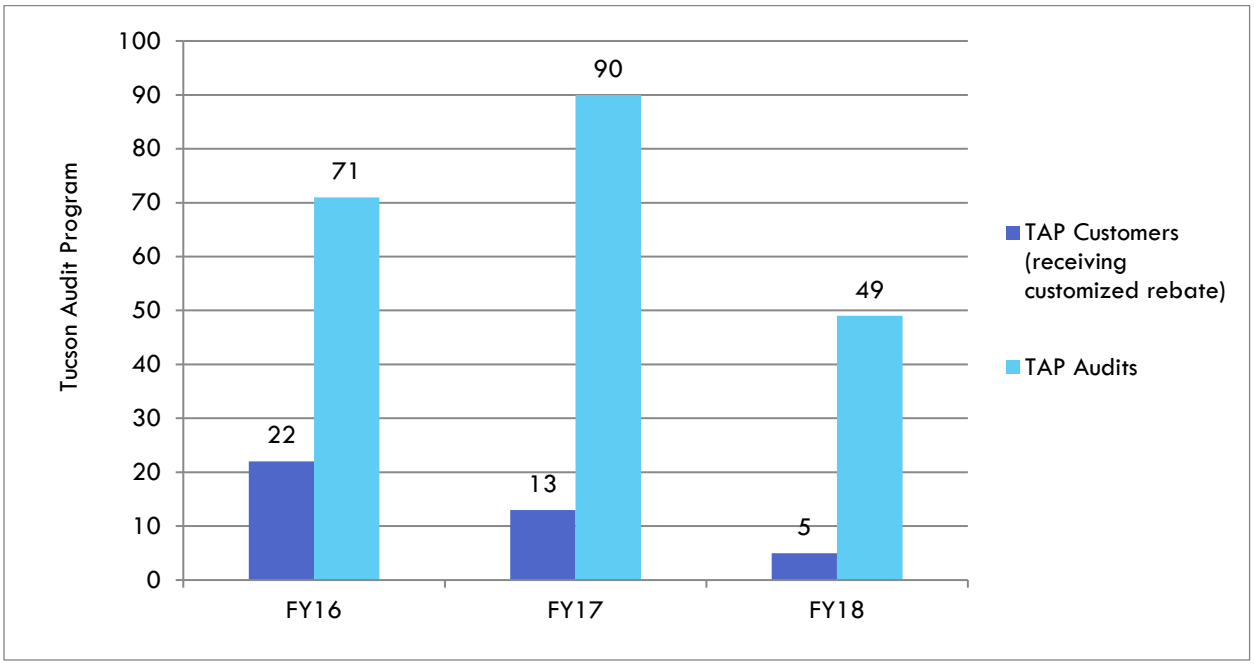


Figure 30: Custom Commercial Rebate by Fiscal Year

2017-2018 Fiscal Year Statistics

Total savings potential (calculated): 97,016,769 gallons

Proposed Measure	Units	Calculated Savings (gpy)	Estimated Annual Savings ($)
Standard Measures			
Cooling Tower	24	14,583,589	$95,417
Irrigation	25	26,656,694	$161,669
Toilets	2,354	18,799,475	$154,096
Kitchen	6	1,683,035	$14,940
Showerheads	1,518	4,145,613	$34,581
Urinals	332	2,175,555	$17,417
Handwash Sinks	930	141,210	$1,172
Pool	0	0	$0
Swamp Coolers	2	29,200	$251
Laundry	24	919,000	$9,703
Leaks/Unknown	361	24,800,717	$153,961
Subtotal	**5,576**	**93,934,087**	**$643,208**
Other Measures			
Investigate high water use and take steps to minimize.	1	844,068	$5,710
Reduce high usage between 10:30 PM and 6:30 AM	1	unknown	unknown
Switch from potable to reclaimed water for irrigation	1	2,238,614	$6,847
SUBTOTAL	**3**	**3,082,682**	**$12,558**
TOTAL	**5,579**	**97,016,769**	**$655,765**

Table 9: Estimated savings of fixtures/measures if implemented by businesses after TAP audits.

Rainwater/Stormwater Programs

Rainwater and Stormwater programs represent a shift in philosophy in water management strategies for Tucson Water. Both rainwater and stormwater harvesting are considered additional or alternative water supplies when captured and put to beneficial use. These alternative water supplies, when considered as part of a larger water supply portfolio and regional water planning, become part of an integrated water management approach. Quite recently, "One Water" has become the new term to describe this integrated approach to water management.

One Water works to:

Integrate and optimize urban water systems within the larger context of a city.

One Water is defined as an approach "that considers the urban water cycle as a single integrated system, in which all urban water flows are recognized as potential resources, and the interconnectedness of water supply, groundwater, stormwater, and wastewater is optimized, and their combined impact on flooding, water quality, wetlands, watercourses, estuaries, and coastal waters is recognized." – *Water Environment & Reuse Foundation*

There are two general categories of rainwater harvesting; active rainwater harvesting refers to a cistern storing rainwater collected from roofs, which provides a means to store the rainwater for later use; passive rainwater harvesting refers to directing and retaining water in the landscape using site appropriate practices such as basins, berms terraces, swales, and infiltration trenches.

Stormwater harvesting refers to rainwater collected from non-roof surfaces, such as streets, parking lots, hardscapes, and landscapes. Strategies to capture and utilize this water include, landscaping designs to retain water in soil, semi-porous hardscape material, curb cuts, and detention/retention basins. Reducing stormwater flows is often a main impetus of rainwater collection in urban settings and both play a role in an integrated approach to water management.

The Rainwater Harvesting rebate program is reported separately from the other efficiency programs because it addresses broader goals and objectives than demand management program goals aimed at strictly conserving water. Rainwater and stormwater programs are designed to integrate this alternate water resource into a long-term planning framework that incorporates the One Water approach. Policy and guidance for this effort is provided through Plan Tucson.

Rainwater and stormwater projects being developed by Tucson Water will be designed to assist with long-term planning in mind. Data collected from projects will help to assess the costs and long-term impacts of green infrastructure elements and additional community benefits. New evaluation strategies will be developed to address the evaluation for rainwater and stormwater management programs, which are also funded through the conservation fee.

In FY 2016-17 Tucson Water, at the behest of Mayor and Council, initiated a pilot program for neighborhood-scale stormwater projects and expanded work on the low-income grant and loan rainwater harvesting program. Together, these programs significantly increase the funding capacity for stormwater and rainwater harvesting programs. Collectively, these programs are addressing the policies identified in Appendix A regarding Plan Tucson goals.

Rainwater Harvesting Rebate Program

Implementation date: September 27, 2011; modified June 1, 2013; modified July 1, 2015

The residential rainwater harvesting rebate program was introduced in June 2012, retroactive to September 27, 2011. The program was expanded July 1, 2015, to include curb cuts/core drilling and small commercial customers. As shown in Table 4, this program has the highest expenditures of Conservation Fund projects. While preliminary tracking of water use for systems installed are not showing an overall reduction in water use at the water meter, it is understood that the benefits that accrue are broader in scope than demand management programs.

FY 2017-18 Activity:		**Cumulative:**
Approved Applications:	365	2,074
Expenditure Level 1:	$13,981	$100,899
Expenditure Level 2:	$377,210	$2,174,412
Expenditure L-I Level 1:	$2,294	$23,420
Expenditure L-I Level 2:	$106,118	$125,688
Limited-Income Grants	$16,429	$20,609
Estimated Gallons Saved:	2,900,135	38,014,970
Estimated AF Saved:	9	117
Gallons of Storage:	580,027	2,412,851

Tucson Water will rebate qualifying residential rainwater harvesting system costs under two levels of funding:

- Level 1 –Simple/Passive will rebate 50 percent of the cost of eligible material and labor up to $500
- Level 2 – Complex/Active System will rebate system costs up to $2,000 based on gallon capacity:
- $0.25 per gallon capacity of 50-799 gallon rain tank
- $1 per gallon capacity of 800 gallon and larger rain tank

Applicants may apply for both a passive and active rebate not exceeding $2,000 for the combination. Applicants must attend an approved three-hour workshop to qualify for the rebate program. Fifty-seven workshops were held this fiscal year and 907 people attended. Qualifying workshops were offered in English through Smartscape and Watershed Management Group, and 20 of the 57 workshops were offered in Spanish through by Sonoran Environmental Research Institute (SERI).

Almost 40 percent of applicants are attending the workshop after the system has been installed. This number is important because these applicants are not receiving the full benefit from the workshop and most likely are attending just to receive the rebate.

Rainwater Harvesting Savings:

The basic evaluation method used by Tucson Water is to compare the usage of a control group to the participants in a conservation program before and after participants have taken some action to reduce their water usage. Preliminary tracking of water use for systems installed did not show a net reduction in water use compared to two control groups (all single-family and high use).

A new statistical analysis was done in 2017 and determined that savings are 10-12 ccf/year for participants who installed tanks and have not moved since their installation.

The current estimated water savings is calcuated from the assumption that tanks will fill, on average, five times per year, based on historic weather and assumed tank usage patterns. This "engineering estimate" provides a total savings number, which when divided by the number of rebate participants to-date, yields 7.4 ccf/year of savings per customer – significantly less than the new statistical findings for the group analyzed.

Low-Income Rainwater Harvesting Grant & Loan Program

In FY 2014-15, Tucson Water partnered with Sonoran Environmental Research Institute (SERI) to implement a pilot program to work with low-income families to install rainwater harvesting systems. To participate in the program, families were required to have trees from Trees for Tucson, attend rainwater harvesting/tree care workshops, and agree to maintain the system after installation. Thirty-one systems were installed in the pilot program.

In FY 2017-18 $300,000 was allocated to fund an expanded program; SERI and Watershed Management Group were contracted to begin expanding this program to limited-income communities throughout the service area. These contract partners qualify customers based on low-income status and offer design consultation services for interested families. Both contractors submit the applications to Tucson Water on behalf of their clients and manage all of the grant and loan tracking. During FY2017-18, our contractors provided 32 workshops in English, 20 workshops in Spanish and provided information about the program at 63 community events.

To expand the pool of local practioners able to do rainwater harvesting design and installation, Tucson Water also executed a contract with the Community Food Bank (CFB) to build a business incubation and green jobs/workforce development program. CFB is offering rainwater harvesting training programs in economically-challenged areas of the community and is working to identify individuals committed to launching or expanding their landscape services into rainwater harvesting installations, especially for low-income customers.

Low-Income Pilot Savings:

Preliminary tracking of water use for the thirty-one participants compared to the class average usage was about 0.8 Ccf more per month than the class average. Overall, the passive water harvesting installations have not shown a decrease in usage since installing the systems.

Neighborhood-Scale Stormwater Program

In March 2015, Mayor and Council directed Tucson Water staff to allocate $350,000 to fund neighborhood scale stormwater harvesting pilot projects. In discussions with Ward offices, the decision was to allocate $45,000 per Ward, including the Mayor's office. Tucson Water worked with Tucson Clean and Beautiful (TCB) in FY16-17 to develop a Financial Participation Agreement (FPA) to administer this neighborhood-scale program. It was officially initiated in July 2017. TCB was selected due to their Adopt-A-Place program; the maintenance piece of the Stormwater Harvesting projects was to require groups to “Adopt-the-project” and maintain for a minimum of three years, along with data collection to provide citizen-science regarding functionality of the basins. As a pilot project, the program was limited to public properties within the City of Tucson. Reaching out to each of the Ward offices, neighborhood meetings were held, soliciting applications from groups to submit projects within their neighborhoods. Project applications were accepted until end of October 2017. For the first round of submittals, a total of 20 projects were received, with 18 from Wards 3 and 6. Three projects in each of those two Wards were selected for implementation by a review committee comprised of city staff and professionals familiar with stormwater harvesting elements. Proactive searches within the other Wards lead to identifying projects in a small neighborhood park in Ward 4, a request by Ward 1 to convert concreted traffic circles to vegetative circles, and two traffic medians in Ward 2. Implementation of these projects began in FY17-18 and three projects were completed by the end of the fiscal year (two in Ward 3 and one in Ward 6).

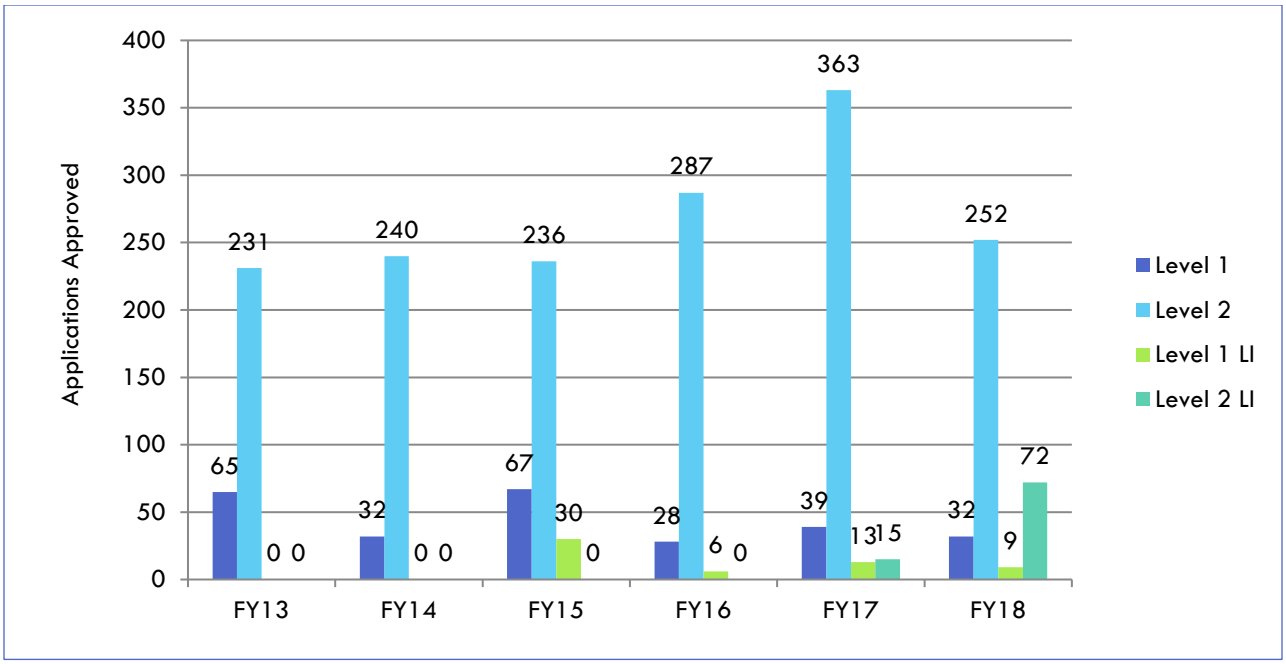


Figure 31: Rainwater Harvesting Rebates by Fiscal Year

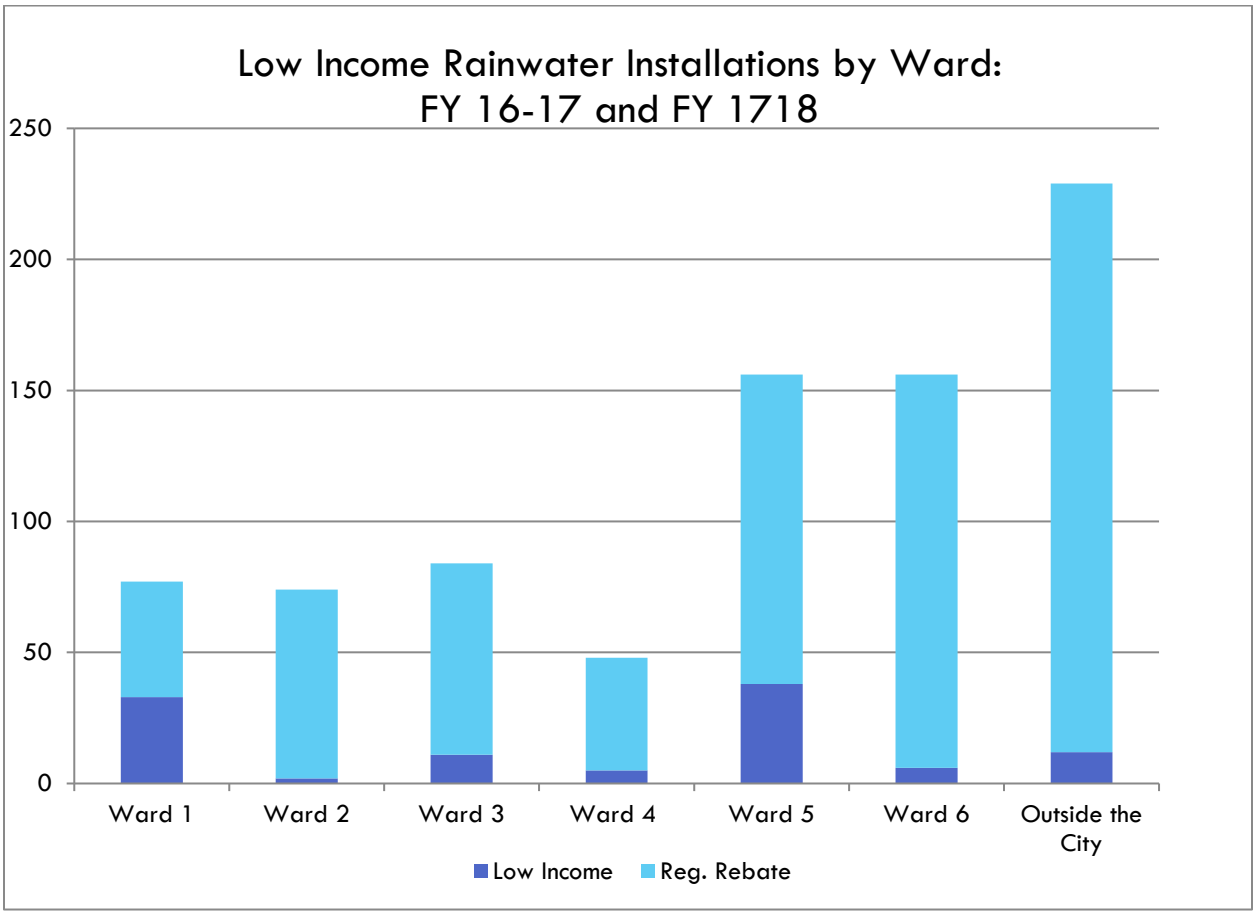


Figure 32: Rainwater Harvesting rebates by Jurisdiction

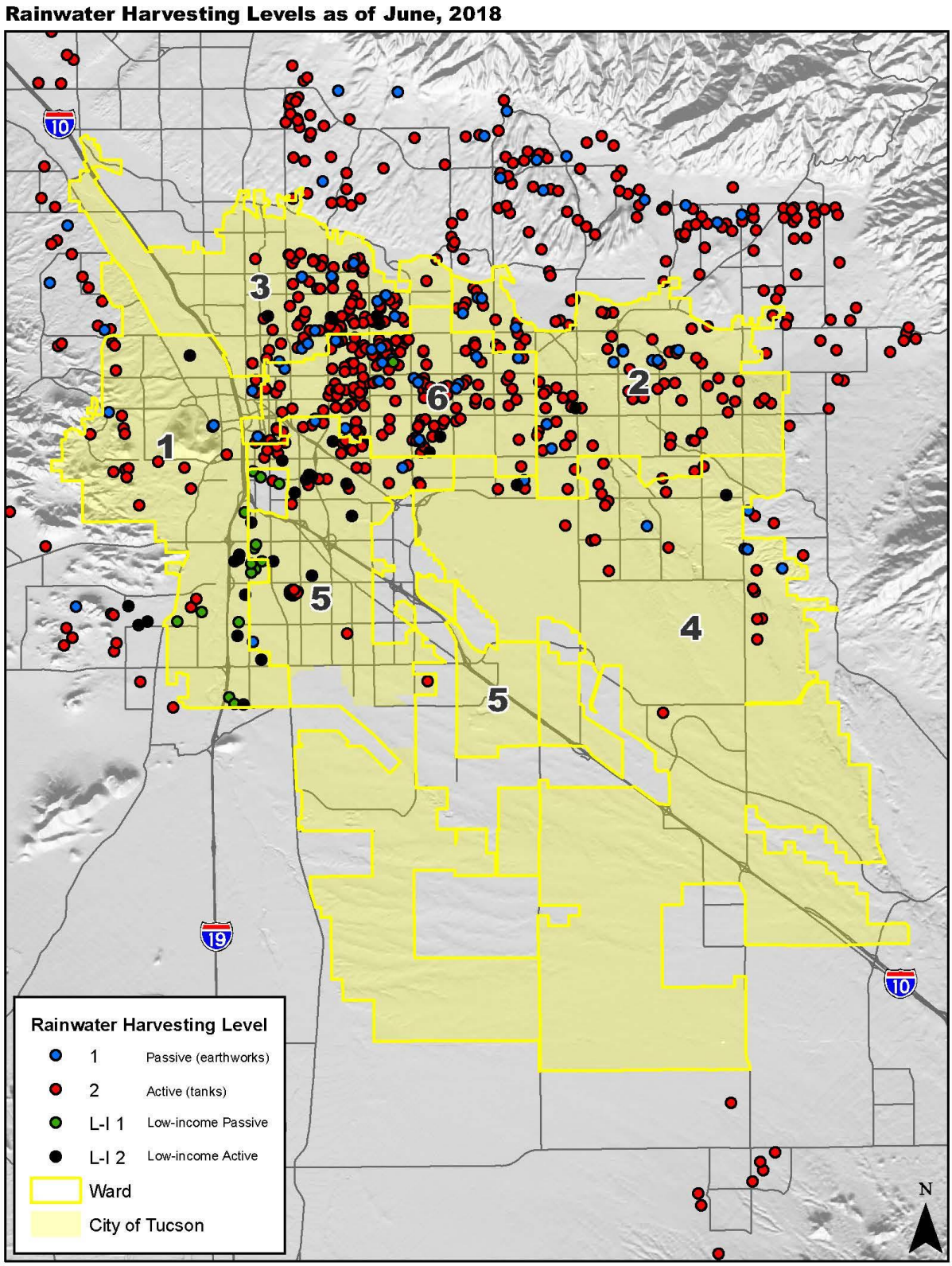


Figure 33: Map showing type of rainwater harvesting rebate by location. Types include Level 1 (passive), Level 2 (active), L-I 1 (low-income passive) and L-I 2 (low-income active).

Water Harvesting Demonstration Sites

Stakeholder groups involved in the creation of the Residential Gray Water Ordinance and the Commercial Water Harvesting Ordinance (and Development Standard) identified a need for Demonstration Projects to aid in education of the public affected by these ordinances. In addition, establishment of Pilot Projects to analyze various techniques and technologies related to gray water and rainwater harvesting systems was also identified as necessary to ensure successful implementation of the ordinances.

Demonstration Projects are designed to educate the public on the various methods, techniques, and technologies that are available for harvesting of rainwater. Priority was given to sites that offer public access; provide educational opportunities, including signage, printed materials, and tours; and emphasize meeting requirements established in rainwater harvesting ordinances.

There are currently 17 demonstration sites throughout Tucson that familiarize residents with a variety of rainwater harvesting and usage techniques and designs.

Blue Moon Community Garden

1501 N Oracle Road

$19,000

Description: This repurposed parking lot hosts both active and passive rainwater harvesting systems. The garden collects nearly 45,000 gallons of rainwater a year from the adjacent 17-story Tucson House apartment complex roof and an additional 2,200 gallons of rainwater from the garden ramada roof. The rainwater irrigates fruit trees and landscapes plants. Notable features include a layout completely accessible to people with disabilities, green space for recreation, and fresh food supply in an area designated as a "food desert."

The irrigation design incorporates flow sensors, soil moisture sensors, and a smart controller.

Figure 34: Blue Moon Community Garden

Christopher Franklin Carroll Centennial Park

NW Corner of Main and Paseo Redondo

$9,934

Description: Centennial Park is a collaborative public private partnership to create a pedestrian oasis for citizens and visitors, featuring a curving walkway, benches, and panels to interpret Tucson's rich history, and low-impact development and green infrastructure techniques. This "pocket park" and rainwater harvesting demonstration site, highlights the 4,000 years of continuous agricultural history in Tucson. Design features include historic markers and signage, gabion retention walls to make the site more usable, curb cuts to direct water off the street into the park, and a xeriscape garden with native and desert adapted plants.

Figure 35: Christopher Franklin Carroll Centennial Park

The Nuestra Tierra Garden at the Community Food Bank

3003 S Country Club Road

$9,736

Description: No matter the budget, or space available, the rainwater harvesting demonstration gardens at the Community Food Bank have techniques to illustrate how everyone can effectively harvest and use water for urban agriculture and landscaping.

There are two main demonstrations on-site, one for commercial customers and the other for residential customers; however, the design principles of each are interchangeable. The more commercially-designed demonstration includes a 14,000-gallon cistern which catches rainwater from the food bank and is used to water native and desert adapted plants. This area also includes a passive terrace catchment system. The more residentially-designed demonstration illustrates various ways to capture rainwater for agricultural purposes, including cost-effective "rain jars" (approximately $50 to make and install yourself), water efficient planters, and a number of rainwater and gray water irrigation systems to water native and agricultural plants farmed in a passive rainwater terrace system.

Figure 36: Community Food Bank

The Nuestra Tierra garden is a public site where community members learn desert organic gardening methods by getting their hands dirty. This garden includes sunken veggie beds with drip irrigation, a hen house, olive, fig, and pomegranate trees, worm bins, and a composting station. The overflow from the cistern flows into a series of mulched basins with native plants.

Ewing Irrigation

4250 S Station Master Drive

$0

Description: This commercially designed demonstration site features a large cistern for rainwater captured from the roof. The water captured is used to support native and desert adapted landscaping. Other prominent features include large swales at various locations around the site that provide additional opportunities to capture rainwater for landscaping purposes.

Food Conspiracy Co-op Garden

725 E Seventh Street (Administration Building)

$10,029

Description: This rainwater harvesting demonstration site hosts a 2,500 gallon cistern for rainwater captured from the administration building of the Co-op. The rainwater is used to support a vegetable garden, fruit trees, and native shade trees. The vegetable garden is planted in a sunken bed to take advantage of passive rainwater harvesting techniques.

The Food Conspiracy Co-op offers monthly orientation tours for new co-op owners. They also offer tours to visiting school children of all ages. Finally, the site is featured on an annual tour of backyard chicken coops, which highlight backyard sustainability projects like solar ovens, composting systems, and rainwater harvesting.

4th Avenue Bicycle Boulevard

(Grant to Fort Lowell Road –4th turns into Fontana north of Grant)

$11,903

Description: This rainwater harvesting demonstration site highlights the benefits of using rainwater to create a more comfortable and esthetic corridor for cyclists and pedestrians. Design features include traffic calming circles with curb cuts to capture rainwater that would otherwise flow off site. The rainwater captured is used to support the planting of large native shade trees. Additionally, artwork has been woven into the cyclist route creating a unique sense of place.

Native Seeds/SEARCH

3584 E River Road

$10,239

Description: The use of passive and active rainwater harvesting systems is used to transform a once bare dirt courtyard to support the planting of a native vegetable garden, fruit trees, and a variety of native and desert-adapted plants. Design features include meandering swales and basins that capture rainwater from the roof and hardscape, cisterns fed from the gutters off the seed bank rooftop, and basins stocked with a variety of plants. Additionally, this project includes the installation of two cisterns to collect roof runoff from the Seed Bank building. One 1,000 gallon cistern on the south side of the building demonstrates a gravity fed system to water the vegetable demonstration garden. A second 2,000 gallon cistern built on the north side of the building is linked into the existing irrigation system to water fruit trees and demonstration gardens. The tanks will have the capacity to store water from 2 to 3 inches of rain.

The site is open to the public twice daily, once a month. During this time both self and guided tours are available.

Reid Park Zoo

1100 S Randolph Way

$3,825

Description: The Zoo's rainwater harvesting demonstration illustrates that by saving rainwater more water can be used for wildlife habitats. By collecting rainwater from building rooftops and storing it in cisterns, the Zoo is able to enhance its exhibits and save water. Look for the large cistern, several smaller "rain jars," and lots of educational signage about the importance of conserving water for people and the environment.

REPP Design and Construction Offices

2502 N First Avenue

$10,000

Description: This site is a laboratory for innovative architectural features and a demonstration of environmental techniques in the desert. This site utilizes passive solar principles, environmentally-appropriate materials, a photovoltaic system, and a rainwater harvesting system. The active rainwater harvesting system collects water from the roof which is funneled into a cistern that holds the water until it is used to support a palette of desert appropriate drought tolerate plants. The passive rainwater harvesting system includes basins planted with desert plants that line the streets and offer pedestrians a more aesthetic experience.

The site can be accessed during business hours Monday through Friday 8:00 - 4:00 for tours and demonstration purposes. Brochures and information are available in the office.

Tri-Sports.com

4495 S Coach Drive

$10,000

Description: This rainwater harvesting demonstration site highlights how commercial uses can beautify their site using rainwater. It utilizes two 18,000 gallon storage

tanks, which catches rainwater from the 22,000 square foot roof and stores the water for use to support the plantings of native shade trees and a palette of appropriate desert-adapted plants that add intrigue into the landscape.

Figure 37: Tri-Sports

Tucson Botanical Gardens

2150 N Alvernon Way

$10,000

Description: Hosting both active and passive features, the Tucson Botanical Gardens offers gardeners techniques that can be learned and applied to their own homes and businesses. Active rainwater harvesting features include: french drains, two underground cisterns (which can capture up to 11,000 gallons of rainwater), and two above ground cisterns that harvest rainwater from a pavilion. The features are placed in areas to mimic appropriate usage on a residential scale.

Passive rainwater harvesting is showcased throughout 17 demonstration gardens. Berms and swales are present in nearly every section of the garden to assure maximum water absorption and direct runoff to the plantings that require the most water. Contouring of the gardens has been completed in an aesthetic manner to demonstrate that water harvesting methods can be visually pleasing as well as economical for the home gardener. The new water harvesting education project emphasizes the gardens' recently redesigned native crops gardens where the horticultural practices of traditional desert peoples, including tiered, canal-fed garden plots are demonstrated.

Tucson Botanical Gardens provides structured opportunities for learning about the world of plants and gardening. Self-guided activities are available seven days a week, 8:30 – 4:30. Community Education Programs include guided tours, classes, workshops and field trips, and community lectures on botanical and horticultural topics. Workshops and classes address responsible gardening and landscape design, plant selection, irrigation, composting, water harvesting, and other aspects of desert gardening.

Ward 1 Council Office

940 W Alameda Street

$16,169

Description: The Ward 1 office underwent an "asphalt-diet," shrank the size of the parking lot, added in curb cuts, and created earthwork basins to passively capture rainwater. Additionally, an active system catches rainwater from the roof with a 5' x 8' (1,176 gallon) steel culvert. The water caught from both the passive and the active systems is used to support a native plant palette.

Figure 38: Ward 1 passive water harvesting

Ward 2 Council Office

7575 E Speedway Boulevard

$9,175

Description: The Ward 2 office utilizes both active and passive harvesting systems in their rainwater harvesting demonstration. A large cistern stores rainwater captured from the roof. Basins that passively capture rainwater are planted with a variety of native plants. Benches are available to sit and enjoy the native plant life and sculptures.

Ward 3 Council Office

1510 E Grant Road

$9,430

Description: The Ward 3 office utilizes both active and passive harvesting systems in its rainwater harvesting demonstration. A 5' x 6' (882 gallon) steel culvert style cistern stores rainwater captured from the roof. The former non-native, higher water-using plant selection was replaced with a variety of appropriate native plants. Removing asphalt created space for a series of earthwork basins that capture rainwater and are planted with an appropriate selection of native plants. Benches are available to sit and enjoy the native plant life and sculptures.

Ward 5 Council Office

4300 S Park Ave

$12,965

Description: The Ward 5 office utilizes active water harvesting by collecting water into a 2,825-gallon cistern and passive water harvesting will be integrated in the fall of 2017 to complete the system. In addition to being a demonstration site, the ward office will also be used a training location for water harvesting workshops.

Ward 6 Council Office

3202 E 1st Street

$9,850

Description: This rainwater demonstration site utilizes passive basins to capture rainwater which is used to support a native plant palette

Additionally, remaining funds were used in neighborhood rights-of-way, which are highly visible and residents have the chance to learn about water harvesting and maintenance techniques through project participation.

Figure 39: Ward 6 passive water harvesting

Watershed Management Group

1137 N Dodge Road

$15,350

Description: This demonstration site uses both active and passive systems to capture an astonishing 77,500 gallons of rainwater. The rainwater captured supports native trees, fruit trees, a vegetable garden, and there is even some water left over that is filtered for drinking. This unique one-acre site once belonged to a devoted conservationist, and was willed to the Watershed Management Group, who now operates the site as an education center.

Above ground rainwater catchment is demonstrated with plastic tanks, and below ground rainwater catchment is demonstrated through a 10,000-gallon

concrete tank. All the tank systems demonstrate use at residential and commercial sites, and the underground tank demonstrates use with limited space.

The site is open to visitors during regular business hours, Monday through Friday 9AM-5PM. Guided tours are scheduled on 2nd Saturdays. Visit watershedmg.org for a schedule of upcoming tours as well as monthly rainwater and greywater classes held at the site.

Community Education Programs

Tucson Water continues to support three contracts that provide educational services to K-12 audiences and landscape professionals throughout our service area.

Tucson Water partners with Arizona Project WET (APW) and Environmental Education Exchange (EEExchange) to offer youth education programs, and Smartscape which offers adult education for landscape professionals and residents. Table 9 references program costs since FY 2008-09, giving an indication of the expansion of the education programs in Tucson over the last nine years.

	APW	EEExchange	Smartscape	Total
FY 2008-09	$26,839	$26,400	$37,064	$90,303
FY 2009-10	$65,997	$125,350	$31,802	$223,149
FY 2010-11	$58,351	$113,750	$184,201	$356,302
FY 2011-12	$69,107	$162,505	$192,237	$423,849
FY 2012-13	$136,522	$114,400	$213,764	$464,686
FY 2013-14	$206,082	$159,785	$171,573	$537,440
FY 2014-15	$203,052	$144,565	$188,034	$517,975
FY 2015-16	$233,959	$186,875	$202,114	$622,948
FY 2016-17	$252,000	$205,400	$281,812	$739,212
FY 2017-18	$252,000	$205,400	$281,812	$739,212

Table 10: Education Program Costs by Fiscal Year

Fiscal Year	Contractor	Adults/ Public	Students (Direct)	Students (Indirect)	Teachers
	Total	**47,688**	**255,500**	**147,094**	**10,361**
2018	Arizona Project WET	5,840	11,795	19,635	555
	Environmental Education Exchange		17,201		575
	SmartScape	2,364			
2017	Arizona Project WET	3,487	11,680	15,217	509
	Environmental Education Exchange		17,392		580
	SmartScape	2,151			
2016	Arizona Project WET	3,490	11,484	18,082	591
	Environmental Education Exchange		17,600		553
	SmartScape	2,211			
2015	Arizona Project WET	4,585	10,466	15,570	803
	Environmental Education Exchange		16,750		555
	SmartScape	2,303			
2014	Arizona Project WET	4,463	11,773	23,594	782
	Environmental Education Exchange		13,816		496
	SmartScape	2,121			
2013	Arizona Project WET	6,438	8,091	10,327	300
	Environmental Education Exchange		13,216		510
	SmartScape	1,887			
2012	Arizona Project WET	657	11,215	19,954	354
	Environmental Education Exchange		14,211		519
	SmartScape	800			
2011	Arizona Project WET	916	11,087	10,174	339
	Environmental Education Exchange		13,047		491
	SmartScape	1,081			
2010	Arizona Project WET		8,116	7,288	519
	Environmental Education Exchange		13,545		517
	SmartScape	1,603			
2009	Arizona Project WET		8,544	7,253	308
	Environmental Education Exchange		14,471		505
	SmartScape	1,291			

Table 11: Collective Impact of Education Partner efforts by Fiscal year

Arizona Project WET (APW)

Tucson Water and The University of Arizona Water Resources Research Center (WRRC) established the first intergovernmental agreement (IGA) with APW in 2006, sponsoring nine workshops and reaching a total of 108 teachers. Today the program has expanded to reach more than 600 teachers and 35,000 students annually. Additionally, since 2006, with Tucson Water's collaboration and support, APW has engaged 5,335 teachers, 289,177 students, and 31,261adults in STEM-based water education in the Tucson Water service area.

FY 2017-18 Activity:

Students Reached	36,365
Teachers Reached	618
Adults Reached	6,042
Audit Projected Water Savings[10]	0.4 million

APW entered into a new three-year IGA on July 1, 2016, to enhance the ability of teachers to instruct and students to learn about local issues pertaining to water. The work program defined in the IGA encompasses three educational areas: professional development, student educational programs, and community outreach.

This year, 201 K-12 teachers participated in 13 APW professional development offerings, which improved their instructional practice through real world, relevant STEM integration. Professional development includes STEM Academies and workshops to support curriculum integration.These teachers engage 13,678 students directly each year in curriculum that advances critical thinking, problem solving and collaboration skills. The average level of mastery gain for all workshops was 79%, with the one-week Tucson STEM Academy reporting the highest gains at 110%.

Additionally, direct classroom outreach resulted in the instruction of 11,680 students, including 408 students who performed water audits, replacing 107 faucet aerators, calculating an overall projected annual water savings of 85,966 gallons. Through home audits, 49 students reported replacing bathroom aerators for an estimated savings of 286,098 gallons per year.

During APW's 54 public outreach events more than 9,000 students and 5,000 adults engaged in water education activities.

Direct student educational programs include:

- 3rd grade Groundwater Flow Model
- 3rd grade Sweetwater Wetlands Water Festival
- 6th grade Groundwater Flow Model
- Discovery Program – Sweetwater Wetlands
- Drinking Water Quality Testing
- School Water Audit
- Water Festival
- Water Scene Investigation

Professional development workshops include:

- Living River Academy (two-day)
- STEM Academy (week-long)
- STEMAZing Institute (three-day)
- Recharge the Rain: Spring Academy (two-day)
- Water Festival Teacher Workshop (multiple)

Community outreach events include:

- Cyclovia
- Science City at the Tucson Festival of Books
- Science Days/Nights at the Tucson Children's Museum
- Tucson Meet Yourself
- Various school science nights

Additional information about the program is provided in the annual report available online at tucsonaz.gov/water/conservation.

[10] Water savings estimate (in gallons) is from the Water Scene Investigation program after retrofitting aerators in student's homes.

Environmental Education Exchange

The EEExchange began working under contract with Tucson Water in 1998 to develop and manage water conservation education programs. The three current programs reach more than 17,000 students annually in grades one through eight, in multiple school districts throughout Tucson. Additionally, since the partnership began, EEE has engaged 236,400 students in Tucson Water-sponsored water education programs throughout the service area.

FY 2017-18 Activity:	
Total Students Reached	17,201
Da Drops	7,361
Our Water, Our Future	4,518
El Tour de Agua	5,322

1st through 3rd Grade: Da Drops

The Water Info Van Program, which began with a short video, soon became known as *Da Drops* in honor of the animated talking water drops that take students on a journey beginning in the clouds and ending in the kitchen sink. The presentation focuses on groundwater model activities in which students experience changes in how people have used water over time. At the end of this hour-long program, the presenter passes out student activity booklets and a reusable cup for each student that encourages them to "*Brush up with Just One Cup!*"

4th and 5th Grade: Our Water, Our Future

Originally a two-part program consisting of five teacher-led activities followed by an interactive 90-minute presentation from an outreach educator. Now an hour-long presentation, *Our Water, Our Future* has reached more than 2,200 classrooms, and is now an institution for many local fourth and fifth grade teachers. *Our Water, Our Future* was revised for the start of the 2013-2014 school year, with changes to the pre- and post-visit lessons, as well as to the on-site presentation. An exciting addition to *Our Water, Our Future* is a full-color activity book given to each student at the end of the presentation.

Middle School: El Tour de Agua

After the pilot program with 50 classes in spring 2014, the program was revised before launching the 2014-2015 school year. The program focuses on water sources, water recycling, and water conservation. Students are taught to question if their water sources are reliable, safe, and sustainable. The classroom presentation is approximately one hour in length and uses a Prezi media format rather than posters for a more exciting and interactive learning experience. Teachers show a pre-visit video to students for background information, and follow up with a post-visit lesson on water conservation (using the Shower Flow Kit materials that are student giveaways). During 2016-17, the El Tour de Agua on-site presentation was revised to be more hands-on and interactive and fully launched for the fall sememster 2017. This exciting program has reached 22,000 students in 3.5 years.

Teacher evaluations indicated extremely high teacher satisfaction with classroom presenters. When asked about the effectiveness of the presenter in conveying information, teachers overwhelmingly rated presenters as Excellent and Good (99% for Da Drops, 100% for Our Water, Our Future, and 98% for El Tour de Agua).

Curriculum activities for Da Drops, Our Water, Our Future and the El Tour de Agua continue to be downloaded from the website. The number of downloads exceeds the number of Da Drops, Our Water, Our Future, and El Tour de Agua presentations, suggesting that there are teachers interested in the lessons who have not had classroom presentations or materials delivered. In addition, it is likely that we are reaching teachers beyond the Tucson area via these on-line curriculum activities.

The Sweetwater Wetlands Activity Book and Field Guide has been revised and there is now be a student version, as well as an adult version for visitors. Both books will contain the field guide that has been slightly modified from the original. Additionally, an digital field guide was created for download on Apple devices; search Sweetwater Wetlands Wildlife Field Guide in the Apple Store.

Additional information about the program is provided in the annual report available online at tucsonaz.gov/water/conservation.

Smartscape

Since 1989, Tucson Water has executed a series of IGAs with the University of Arizona for a landscape water conservation program designed to reduce water consumption. With this partnership, Tucson Water launched a WaterSmart program in 1990 aimed at homeowners to broaden the community's water conservation ethic. The first phase focused on indoor use, targeting plumbing supply retailers to promote the sale and use of water-efficient plumbing fixtures. In 1992, a series of workshops were developed to reduce water use inside and outside the home and were offered to both homeowners and landscapers. By the end of 1992, the need for training specifically tailored to landscape professionals was identified. In FY 2017-18, 105 workshops/classes attended by 963 people and 104 professionals earned their Smartscape certifications.

FY 2017-18 Activity:

Professional Workshops	60
Workshop Attendees	281
Residential Workshops	45
Workshop Attendees	682

Smartscape's "*A Training Program for Landscape Professionals*" was launched in both the Tucson and Phoenix areas in 1994 and was developed collaboratively by Tucson Water, the University of Arizona Cooperative Extension, Arizona Municipal Water Users Association, the Arizona Nursery Association, the Arizona Landscape Contractors Association, and industry representatives. The program is a comprehensive, research-based training program that instructs landscape professionals in the fundamentals of design, installation, irrigation, and maintenance of low-water-use landscapes. Key components of the program are the need for efficient water use, the regulatory environment, methods of water conservation in the landscape, and the principles of Xeriscape. The Pro series of nine classes are taught by local industry experts in both English and Spanish, which include:

- Desert Adapted Plants
- Integrated Pest Management
- Landscape Design and Renovation
- Landscape Irrigation Systems
- Landscape Water Management
- Maintaining Desert Adapted Plants
- Plant Disorders
- Plant Selection and Installation
- Plants, Soils, and Water
- Weed Control

In 2018, Smartscape implemented an exam for the Pro series, requiring course participants to pass a closed-book exam at the completion of the course. The results have been positive and move the program in the direction of requiring pros to demonstrate a base level of knowledge and proficiency.

Smartscape also offers practical landscape water conservation classes for residential water users in the Tucson area and surrounding communities. These classes are designed to assist homeowners in creating and maintaining water-efficient landscapes in addition to qualifying for Tucson Water rebates. Homeowner workshops include:

- Gray Water Rebate Program
- Hands-On Landscape Design (3-part series)
- Hands On Drip Irrigation System Design
- Hands-On Drip Irrigation Scheduling and Controllers
- Rainwater Harvesting Rebate Program

This year Smartscape also hosted the ignaural Sustainable Landscapes Expo. This was a Saturday event at Pima County Cooperative Extension, designed to bring vendors and partners together to offer information to the public on sustainable landscape design and maintenance for our desert environment. Approximately 1,000 people attended.

Additional information about the program is provided in the annual report available online at tucsonaz.gov/water/conservation.

Other Conservation Activities

Tucson Water engages various partners in a host of other conservation program activities that help to broaden the reach and impact of Tucson's conservation program. Conservation staff participate in several community outreach events, as well as attending education partner activities on occasion. Professional presentations at technical conferences are made by staff several times per year, in addition to occasional community presentations. A few specific program activitie are highlighted below.

National Mayor's Challenge for Water Conservation

The National Mayor's Challenge for Water Conservation is a friendly online competition among cities that encourages residents to pledge to take steps to achieve water and energy efficiency. Tucson has placed 6th, 1st, 2nd, 2nd, and 2nd and in 2018 was again 1st in the 300,000 - 599,999 population city category. The Challenge takes place every April.

Tucson Water promotes the Challenge through its web page, newsletters, bill messaging, media releases, and auto-replies for certain Tucson Water GroupWise mail boxes. Social media is used with Facebook and Twitter. Additionally, partnerships with organizations help to spread the word as well as Tucson Water's participation in local events during April.

Regional & National Collaboration

Tucson Water maintains active involvement with the Conservation Committee of the Arizona Municipal Water Users Association (AMWUA) and staff continues to attend meetings via phone and in person. AMWUA has created a commercial conservation workgroup to address the needs and opportunities that exist with water conservation in the commercial sector and Tucson Water has played an active role in these discussions including making presentations on our program, providing input, and suggestions on topics and speakers for consideration.

On a national level, Tucson Water has engaged with the Alliance for Water Efficiency (AWE) through use of the tracking tool, participation in an avoided cost study to analyze the role of conservation and its impact on water rates, as well as the technical working group of the AWE board. AWE has identified national interest in cooling tower technology and program implementation and Tucson Water has been participating in this new working group, as cooling towers are in important part of the Tucson Audit Program.

Retail Outreach and Promotion

A main avenue for promoting conservation and incentive programs has been placement of display racks at nurseries, plumbing supply, and home improvement retailers. In FY 2017-18 a partnership was established with Cirrus Visual to be a brand ambassador for Tucson Water and ensure that point-of-sale displays are kept filled with the most current information on residential rebates and that employees are updated on any program changes. Displays at about 20 of the highest-demand retails are stocked monthly with brochures and rebate applications. In total, Tucson Water has established relationships with 42 retailers in the service area. From tracking how customers learn about the rebate programs, staff knows that retailers are a very important part of program promotion; many customers do not know rebate exisit until talking with an employee at one of our retail partners' stores.

Community Garden Pilot Program

In 2018 Tucson Water launched a pilot program to offer more affordable potable water rates and infrastructure to qualifying community garden customers. This pilot program was developed through engagement with representatives from local community gardens, in support of Plan Tucson goals to increase urban agriculture and better serve disadvantaged communities. Gardens must be within city limits, have a potable meter feeding the garden only and backflow and meet the definition of a community garden, as defined in the City's land use code. In FY 2017-18, five gardens applied for the pilot program and all were assigned the lower rate, including one that entered into a payment plan for their backflow unit. For more information, visit: https://www.tucsonaz.gov/water/garden.

Zanjeros

In 2018 the Zanjeros, Tucson Water's professional water audit team, became part of the Public Information and Conservation Office. This team of field auditors provides our residential customers with thousands of free audits each year; these audits identify leaks and efficiency opportunities at customers' homes and around their properties. Prior to their move, PICO had one Conservation Inspector who conducted water waste inspections and commercial high-bill investigations. This position and this work has been merged with the Zanjeros team and cross-training is underway. Additional training to enhance Zanjeros skills and increase the conservation potential of these visits is planned for the next fiscal year.

Water Waste Enforcement

Enforcement of the Water Waste Ordinance (27-15) is under the purview of Conservation Program staff. Water waste typically involves overwatering, malfunctioning irrigation systems, hose washing of hard surfaces, and misting systems operating in unoccupied areas. They also provide high bill investigations for commercial properties.

Conservation Inspectors made 312 visits in FY 2017-18, and issued 174 verbal warnings; no written warning or citations were issued. Drive-by identification and phone calls are the two most common ways that water waste is reported.

In addition to inspector-identified violations, water waste is reported by community members through email, phone calls and the SCF phone app.

The fine structure for a first offense is a minimum of $250. Subsequent offenses within three years are a minimum of $500.

Appendix A – Plan Tucson Policies Addressed with Water Conservation Fee Programs

- H6: Take multiple approaches to reduce housing costs and increase affordability.
- PH8: Support streetscape and roadway design that incorporates features that provide healthy, attractive environments to encourage more physical activity.
- E4: Build and maintain partnerships among neighborhood, community, business and regional institutions and programs to increase educational opportunities.
- E7: Initiate a comprehensive approach to civic education that provides and promotes regular opportunities for members of the public to learn about the functions of the City and to take advantage of programs provided by the City.
- G1: Provide the public with regular communication and sufficient information regarding policy, program, and project planning and decisions-making via multiple methods.
- G4: Increase participation of the traditionally underrepresented populations in policy, program, and project planning and decision-making.
- G6: Coordinate and collaborate with NGOs to increase public participation.
- G7: Develop and maintain strong partnerships with regional and local NGOs, including educational institutions, non-profit organizations, and neighborhood and citizen groups.
- BC2: Continue to develop and implement local strategies, services, and incentives to enhance Tucson's business climate.
- EC3: Reduce the urban heat island effect by minimizing heat generation and retention from the built environment using a range of strategies.
- EC9: Assess and address the vulnerability of the community's health and safety, economy, and natural resources to climate change, and develop assurances that vulnerable and disadvantages populations are not disproportionately impacted by climate change.
- WR1: Continue to plan and manage the City's water supplies, quality, and infrastructure for long-term reliability and efficiency.
- WR2: Expand the use of alternative sources of water for potable and non-potable uses, including rainwater, gray water, reclaimed water, effluent, and stormwater.
- WR3: Expand effective water efficiency and conservation programs for City operations and for the residential, commercial, and industrial sectors.
- WR4: Ensure an adequate amount of water to meet the needs of riparian ecosystems.
- WR6: Integrate land use and water resources planning.
- WR7: Collaborate on multi-jurisdictional and regional water planning and conservation efforts.
- WR8: Integrate the use of green infrastructure and low impact development for stormwater management in public and private development and redevelopment projects.
- WR11 Conduct ongoing drought and climate variability planning.
- GI1: Encourage green infrastructure and low impact development techniques for stormwater management in public and private new development and redevelopment, and in roadway projects.
- GI2: Rehabilitate and enhance natural drainage systems, water detention and retention basins, and other infiltration areas for multiple benefits, such as recreation, wildlife habitat, and stormwater management.

- GI4: Expand and maintain a healthy, drought-tolerant, low-water use tree canopy and urban forest to provide ecosystem services, mitigate the urban heat island, and improve the attractiveness of neighborhoods and the city as a whole.
- GI5: Create, preserve, and manage biologically rich, connected open space; wildlife and plant habitat; and wildlife corridors, including natural washes and pockets of native vegetation, while working to eradicate invasive species.
- GI6: Protect, restore, enhance, and manage trees for their long-term health, including providing guidance on proper planting, care, and maintenance.
- PI4: Identify potential reclaimed water users, such as schools, golf courses, and sports facilities, that will support the expansion of the reclaimed water system.
- PI5: Continue to expand and diversify funding mechanisms for the repair, upgrade, maintenance, and service expansion of public infrastructure and facilities.
- RR5: Pursue interim uses and/or green infrastructure on vacant and financially distressed properties.
- RR6: Prioritize neighborhood revitalization efforts to focus on those geographic areas with the greatest need.
- LT10: Support urban agriculture and green infrastructure opportunities in new development or redevelopment when appropriate.
- LT12: Design and retrofit streets and other rights-of-way to include green infrastructure and water harvesting, complement the surrounding context, and offer multi-modal transportation choices that are convenient, attractive, safe, and healthy.

Appendix B – Rainwater Harvesting Rebate Program: A Small Group Study

Final Report

Prepared by:

Lucero Radonic
Assistant Professor
Department of Anthropology
Environmental Science and Policy Program
Michigan State University

Rainwater Harvesting Rebate Program: A Small Group Study
Final Report
September 4, 2018

Report written by Lucero Radonic
Research designed by Lucero Radonic, Candice Rupprecht, and Karen Hanshaw

Introduction

This research is the product of a two-year collaboration between Michigan State University, the City of Tucson Water Department and the University of Arizona, Pima County Cooperative Extension/Smartscape Program. In 2012, the City of Tucson launched a residential rebate program for rainwater harvesting as part of their water conservation strategies. Funds for the program were justified under the rationale that rain and stormwater could be developed as supplemental water resources for household landscapes. In the first six years since the rainwater harvesting rebate program began, over 2,000 Tucson households made use of the rebates by installing cisterns in their homes. Annual participation has increased since inception. However, an internal evaluation by the water department showed that households with water harvesting installations were not necessarily reducing their water use as indicated by their water meter readings. In fact, some of the households who had participated in this program had higher usage after rainwater system installation and, as a group, were using more water than the monthly single-family average.

Recognizing the uncertainy in these initial water use findings and that there are likely additional, unquantified benefits to this program, Tucson Water began a more robust analysis of their rainwater harvesting rebate program. This study aims to help identify participation drivers and perceptions of benefits associated with rainwater harvesting at the residential level. In other words, it seeks to explain why adoption of a water conservation technology was not accompanied by the expected decrease in potable water consumption. In the data collection process, we documented why people opted to implement rainwater harvesting, how they managed their systems, how they valued its different impacts, and how these differ or intersect with the city's public framing of rainwater harvesting as a water conservation strategy. To this effect, we integrated data from semi-structured interviews, mental models, landscape surveys, and self-reporting monthly diaries with 30 Tucson residents engaged in rainwater collection. Qualitative data was collected between 2016-2017 through a case study approach. Such a methodological approach allows for in-depth, multi-faceted explorations of complex issues in real-life settings. We found that the main motivation for residents to install rainwater harvesting systems is to create a greener environment in their properties while hoping not to tax the city's potable water system. Most rainwater harvesters conceptualize water harvesting as an additional water source available to facilitate landscape redesign or expansion.

Rainwater harvesting is an ancient technology that in recent years is experiencing a renaissance as a decentralized infrastructure for water supply and a potential climate adaptation strategy. In the United States, a growing number of state and municipal agencies have adopted or amended codes and guidelines to encourage responsible and effective rainwater harvesting practices at the residential level (See Meehan and Moore

2015). In addition, financial incentives for small-scale rainwater harvesting are growing through water conservation programs. In other words, rainwater and the low-tech infrastructure for its collection and storage are slowly being formalized as part of urban water governance regimes. Several existing studies evaluate the potential of rainwater harvesting cisterns for water supply and stormwater retention (Burns et al. 2015; Campisano et al 2016; Khastagir and Jayasuriya 2010; Mikkelsen et al. 1999; Steffen et al. 2013). In contrast, few studies explore how this water infrastructure is understood, used and valued by users themselves (Farbotko 2014). In urban areas confronted by the dual challenge of water scarcity and urban heat island effect, understanding the motivations that different actors have for implementing rainwater collection can help better understand the reasons for its success and challenges as a water conservation technology.

Summary of top-level findings

- There are two models for how residents construe and manage rainwater as a resource newly available to them. The first model corresponds to people whom primarily perceive it as a supplementary or additional water source. The second model corresponds to people who primarily understand it as a replacement or alternative to existing water sources. In both models people describe rainwater harvesting as a private source of free and better-quality water (as compared to tap water) and value it for providing them with a desert oasis in their homes.
- The majority of participants value rainwater collection for bringing diverse benefits to their households, but across the sample the establishment of a lush landscape is the most frequently mentioned and most significant benefit. In other words, the creation of a desert oasis in one's backyard was identified as the most desirable benefit of rainwater collection and as the major driver for several other benefits, including shade and wildlife habitat.
- Around seventy-five percent of participants planted new vegetation after installing their rainwater harvesting system and around thirty-one percent of those installed their systems as part of large-scale landscaping redesign projects. In line with the xeriscaping principles dominant across the city, a majority of all new vegetation was either native to the Sonoran Desert or drought-adapted. Low-water use shrubs and bushes, especially local varieties chosen to attract pollinators, were the most commonly planted type of vegetation.
- Participants who were engaged in expanding their landscape vegetation tended to include 'lush landscaping' as an important benefit in their mental model of rainwater harvesting. In contrast, those participants who did not mention lush landscaping in their mental models did not add vegetation to their yards, or added very few specimens through the course of the study.
- There is no correlation between a household's decision to increase their landscape vegetation and their level of potable water consumption. Similarly, there is no correlation between a household's use of drip irrigation technology (presence or absence of a system) and their water consumption. Instead, a household's water consumption may be better explained by their management of irrigation water (both rainwater and potable) and their understanding (or lack of understanding) of their plants' water requirements.

- There is a gap between residents' interest in following desert-appropriate landscaping practices (including rainwater harvesting) and their understanding of what this entails. Residents increased their landscape vegetation by adding primarily native and drought-adapted shrubs and bushes, but their aesthetic ideals regarding vegetation have yet to be adapted to the seasonality of the Sonoran desert.
- Participants were very conscious about collecting and using rainwater, but lacked information on how to correctly irrigate their plants (with rainwater or potable water). They had a limited understanding about a) how long to water the plants so it reaches the right depth; b) how often to water, depending on the type of plant; c) the overall water needs of the plant (low, medium, high); and d) how to modify irrigation to different times of the year.
- Many people – especially those who worked full time or travel frequently – expressed frustration at the cost and expertise required to connect their rainwater cisterns to their irrigation system, explaining that they thought automating rainwater irrigation would have been easier and would allow them to reduce their reliance on city water.
- Most of the residents participating in this study had not realized that their potable water consumption had not decreased upon installing rainwater harvesting, and most of them were neither surprised nor disappointed to learn that in some instances their consumption had slightly increased. It is important to point out too that given the low price of potable water in Tucson, its block-rate structure, and participating households' economic standing, small increases or decreases in the water bill make no significant difference to the households' budget.
- Participants are interested in continuing to learn about water-efficient landscaping and irrigation practices in order to better use their rainwater and reduce their potable water consumption.

Study Context

The city of Tucson, Arizona, is located in the Sonoran Desert, a region with an average annual precipitation of 11.6 inches (295 mm) and characterized by a fair amount of year-to-year rainfall variability. Roughly half of the annual rainfall comes with the summer monsoon and the other half during the winter. Accompanied by thunderstorms, monsoon rains are intense, short, and localized. In contrast, winter rains are lighter but arrive as large fronts contributing more significantly to aquifer recharge due to the speed at which they fall and lower evapotranspiration. Tucson has no combined sanitary and sewer system. During heavy rain events, water quickly flows off the landscape into streets and arroyos, which flow for three days maximum serving as storm drainage. Much of the remnant moisture on yards, right-of-ways, and streets rapidly evaporates in the intense summer sun. During the summer, the average high temperature is 99 degrees and one-hundred-degree weather normally occurs from May to September, with about half the days in June and July exceeding that temperature.

Research Methods

We recruited 30 rebate-receiving households with different water consumption levels to determine if there were any salient behavioral and perceptual differences in the way users with different water use levels understood and managed their rainwater tanks. Rebate-receiving households across the city were placed into one of three groups

according to their average annual water usage as per their water meter reading. Based on their water consumption group and their zip code, we used a stratified random sampling approach in an effort to include socio-economic and cultural diversity in our sample. We contacted an equal number of households from each group and were able to recruit 13 low water users (1.69-7.99 ccf), 13 medium water users (8.00 - 14.99 ccf), and 4 high water users (15.00 - 30 ccf). Selected households had at least one rainwater cistern with a minimum storage capacity of 800 gallons that had been installed within the previous 24 months. It is important to notice that qualitative case studies involve a self-selected sample given that inclusion/exclusion is determined by whether those who are randomly contacted agree or decline to participate in the project. The data collection period extended from July 2016 to July 2017 in order to gather rainwater use data for the rainy and dry seasons. For data collection we used a mixed method approach that integrated semi-structured interviews, mental models, landscape surveys, and self-reporting diaries.

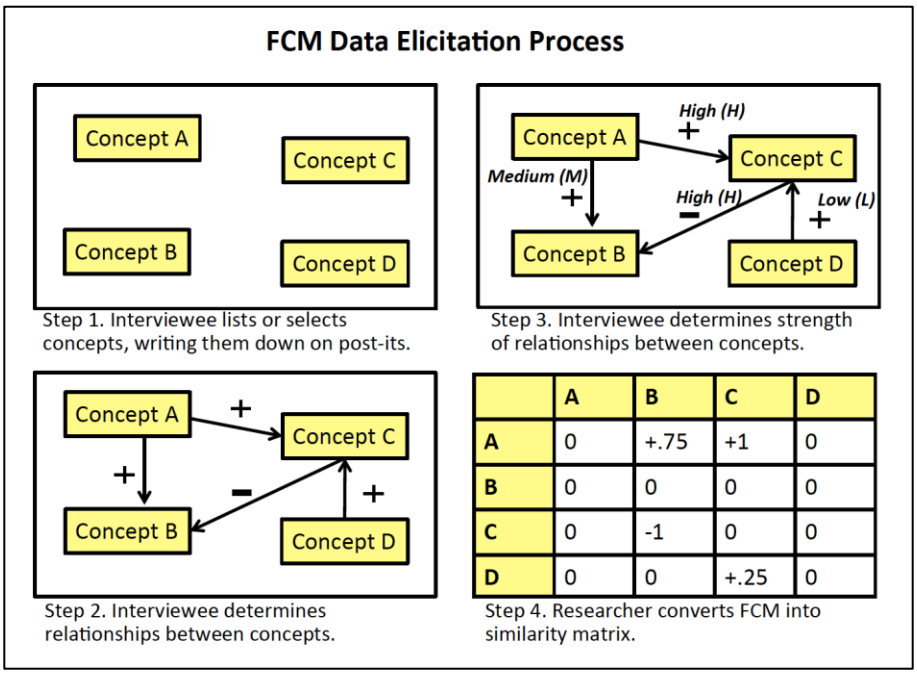
Throughout the course of the study participants were asked to maintain a log of their outdoor-related practices and submit a monthly online survey reporting their irrigation practices, use and management of the rainwater system, and any changes to their vegetation. This data allowed us to see how residents managed and integrated the use of rainwater into their weekly outdoor irrigation habits, as well as provided information about their decision-making regarding landscape vegetation and gardening. The response rate for the monthly surveys was quite low and irregular: on average 67.63 percent of participants submitted the survey every month, with a 16.32 percent standard deviation. While this data is unreliable alone, it is informative when combined with data from landscape surveys and semi-structured interviews.

At the beginning and end of the study period, we visited every household and conducted a survey of their outdoor space so that we could make note of the placement of their cistern(s), any other water-use features like swimming pools or hot tubs, and especially the type and extent of vegetation. These outdoor surveys also yielded information about weekly landscaping practices, the story of the different plants in the yard, and participants' views on what they considered to be examples of environmental stewardship by urban residents.

Hour-long, semi-structured interviews were conducted during the visit to each household. Interviews had three components (See appendix 1). The <u>first component</u> gathered data about the participants' demographic background and their connection to Tucson, specifically their length of residency in the city. The <u>second component</u> documented participants' experience with water harvesting including their motivations for implementation, as well as their cistern use and maintenance practices. The <u>third component</u> documented participants' understandings of the working dynamics of rainwater harvesting through the elicitation of individual mental models. Mental models are a person's representation of cause and effect relationships within a given system, in this case residential rainwater harvesting.

We used a semi-quantitative technique known as Fuzzy Cognitive Mapping (FCM) to elicit and measure individual mental models so that they could be scaled-up to illustrate similarities and differences in group understandings of rainwater harvesting. We asked all participants to identify the direct and indirect benefits they found to be associated with rainwater harvesting based on their experiences, and to define the causal relationship between these benefits by indicating the directionality and strength of the

connection between concepts. To indicate the causal strength they used an openly subjective scale (low, medium, or high), which was then converted to a numerical (-1 to +1) scale for statistical analysis (Fig. 1 and Fig. 2). FCM is broadly used in environmental science and natural resource management to document perceptions of specific groups in order to understand decision-making processes among resource users and refine participatory management tools.



	A	B	C	D
A	0	+.75	+1	0
B	0	0	0	0
C	0	-1	0	0
D	0	0	+.25	0

Table 1. Steps involved in eliciting and analyzing a mental model.

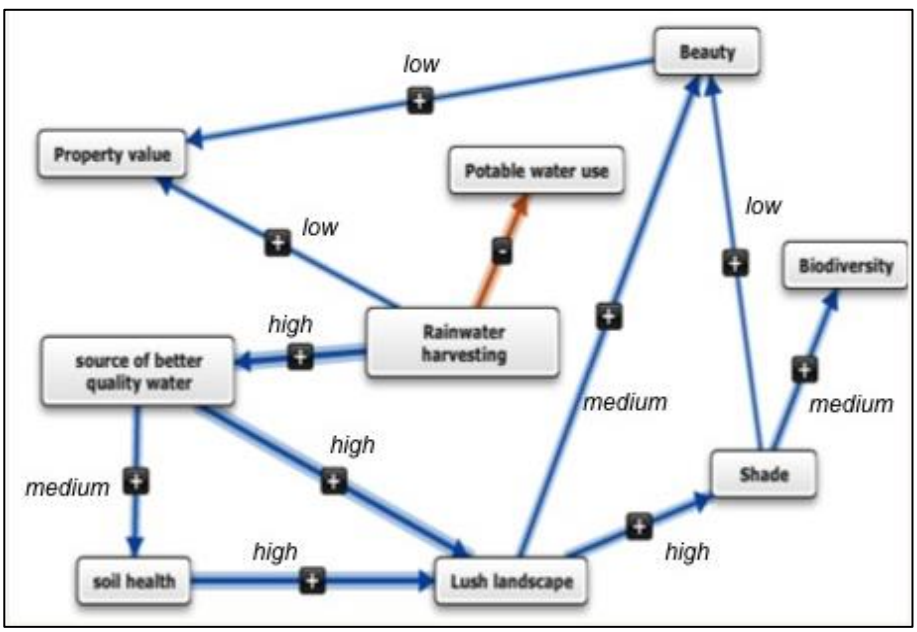


Table 2. Illustration of one individual fuzzy cognitive map (FCM) created by a research participant. Blue and orange arrows indicate positive and negative perceived causation.

For the purpose of this study, our analysis of FCMs focuses on two structural dimensions. First, the centrality score of a concept representing its degree of relative importance within the entire model elicited by a participant. This is calculated by adding the out-degree and in-degree. The out-degree indicates the cumulative strength of the influence a concept has on all other concepts, as indicated by the absolute value of all the outgoing arrows pointing away from the concept. The in-degree indicates the cumulative influence on any given concept from all other concepts, as indicated by the absolute value of all the arrows pointing to that concept (Kosko 1986; Ozesmi and Ozesmi 2004). Second, the concept's classification as a receiver, a driver, or an ordinary variable depending on how it relates to other concepts within the model drawn. Drivers are concepts that influence other concepts, but are not influenced by others. Receivers are those that are influenced by others but do not influence others. Finally, ordinary variables are those that influence and are influenced by other concepts (Gray et al. 2014) (See appendix 2).

Study Population

Despite our random sampling approach and the fact that rainwater collection is not an uncommon practice across town, most research participants were Anglo, college-educated, middle to upper class homeowners living in single-family homes with large outdoor spaces. The socioeconomic composition of our sample can be attributed to the rebate program covering most of the costs associated with rainwater harvesting, but requiring people to have a large sum of disposable income (1000-5000 USD) to cover the upfront cost associated with materials and, oftentimes, installation by certified providers. Customers need to have time, or money, or both to engage in large-scale rainwater collection. This bias is something Tucson Water is already addressing through the establishment in 2018 of a rainwater harvesting credit pilot program aimed at low-income households.

The median age of study participants was 55.53 years old, with a standard deviation of 13 years (Fig. 3). Sixty-three percent of participants were economically active and 36.7 percent were retired. Sixty percent of participants were long-term Tucson residents who had lived in the Sonoran Desert for over a decade –this includes 10 percent who were native Tucsonans. The other forty percent of participants had moved to Tucson within the last decade, with 23 percent of all participants arriving only within the last five years (Fig. 4). Many new arrivals had relocated from the U.S. Midwest and East Coast after retirement.

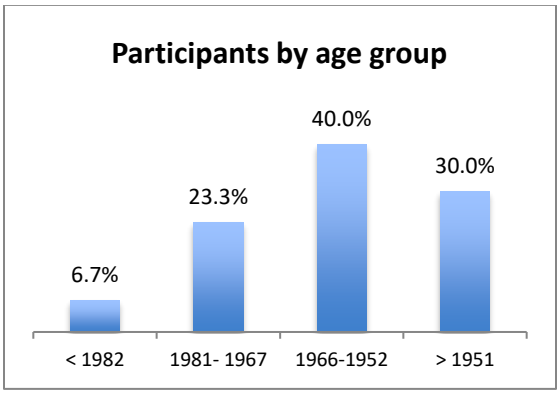


Table 3. Graph of participant ages.

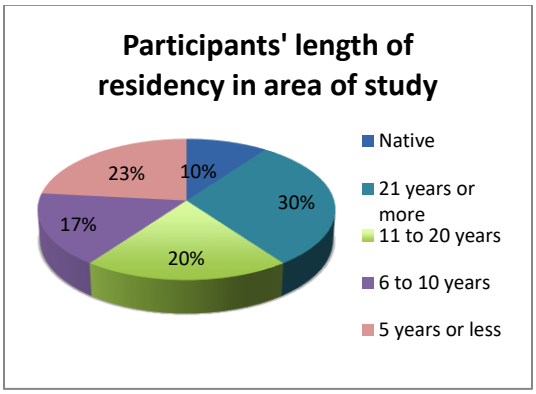


Table 4. Chart of participant's time in Tucson.

Study Findings

Users' understandings of rainwater harvesting

Mental models made by participants included 21 benefits in total. All concepts emerged within the first 20 interviews. On average, coded models had 7± 2.29 concepts and 8.43 ± 3.41 connections. High standard deviation indicates low consistency in structural characteristics across models. This demonstrates that users see rainwater harvesting as associated with many benefits but there is some diversity on the set of benefits recognized by each user.

In order to determine what benefits were most significant across all participants' mental models, we use the frequency and centrality scores from the Fuzzy Cognitive Mapping (FCM) data. Frequency scores indicate what percentage of participants included any one concept in their model, and centrality scores provide information about a concept's relative importance within an individual model. The two most frequently mentioned benefits were water conservation and lush landscaping, which were listed by 66.70 and 73.30 percent of participants respectively (Fig. 5). As used here, 'lush landscaping' means an increase in vegetation density in private property (i.e. planting more vegetation) and/or an increase in existing plants' growth and robustness (i.e. plants are larger and look healthier). Across all maps, lush landscaping had a considerably higher centrality than water conservation. On average lush landscaping had a centrality score of 2.3, while the average score of water conservation was 1.91 (Fig. 6).[1]

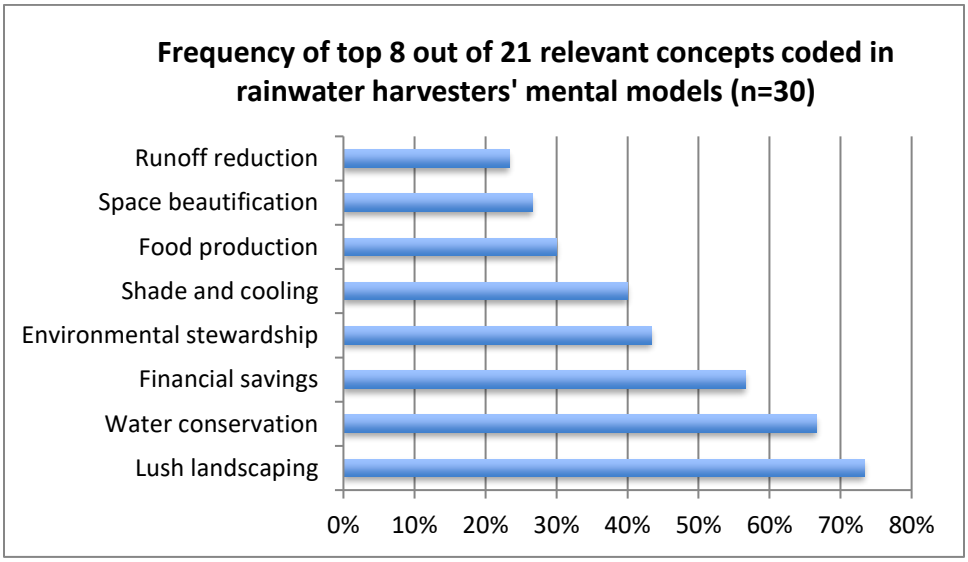


Table 5. Chart illustrating frequency of benefits identified by participants using mental models.

[1] Water supply (described as either a source of free, extra, or better-quality water) was included in sixty percent of the maps. Based on the interviews we concluded that many other people decided not to include water supply for considering it was implicitly included under rainwater harvesting (i.e. collection of water).

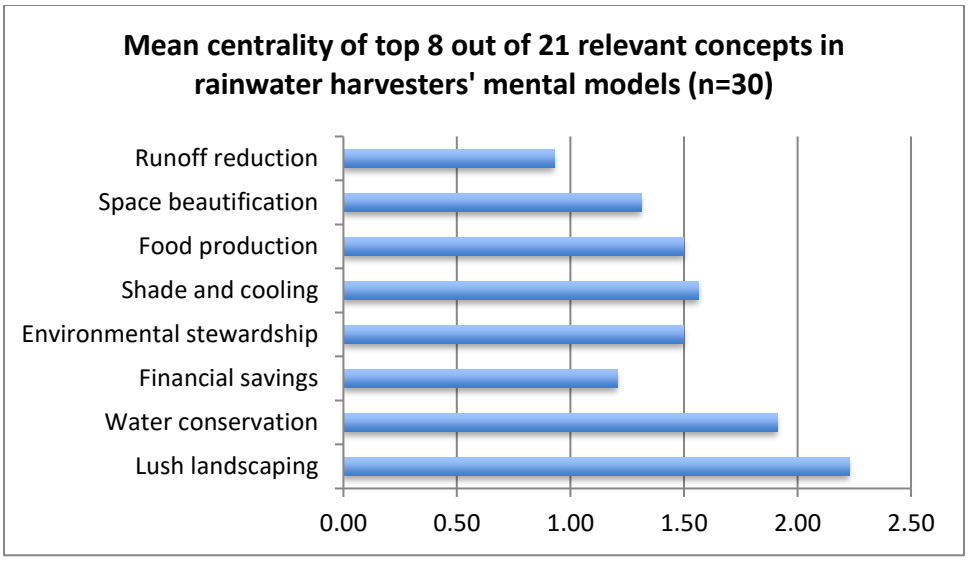


Table 6. Chart illustrating centrality of benefits identified by participants using mental models.

When comparing low and medium water users we found that among low water users water conservation had a slightly higher frequency than lush landscaping, with water conservation mentioned by 69.2 percent of participants and lush landscaping by 61.5 percent. Among medium water users, the difference in frequency between these two concepts was larger, with the former being mentioned by 84.62 percent of participants and the latter by 69.23 percent (Fig. 7). In terms of centrality scores, in both groups, lush landscaping had the highest score[2] (Fig. 8).

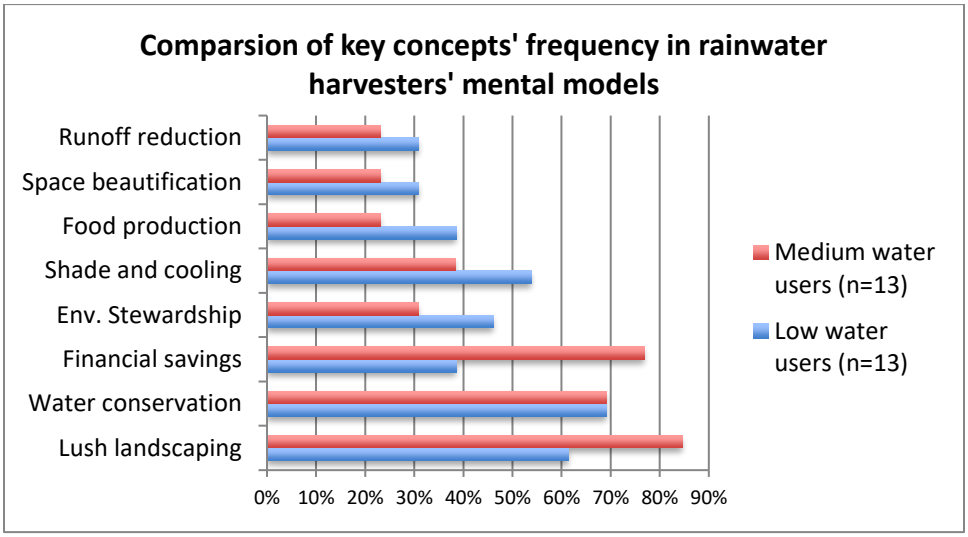


Table 7. Chart comparing frequency of named benefits for different water user groups.

[2] Given that we were able to only recruit 4 participants from the high water use group and the minimum number recommended for meaningful analysis is 10, we limit our comparison to the low and medium water user groups.

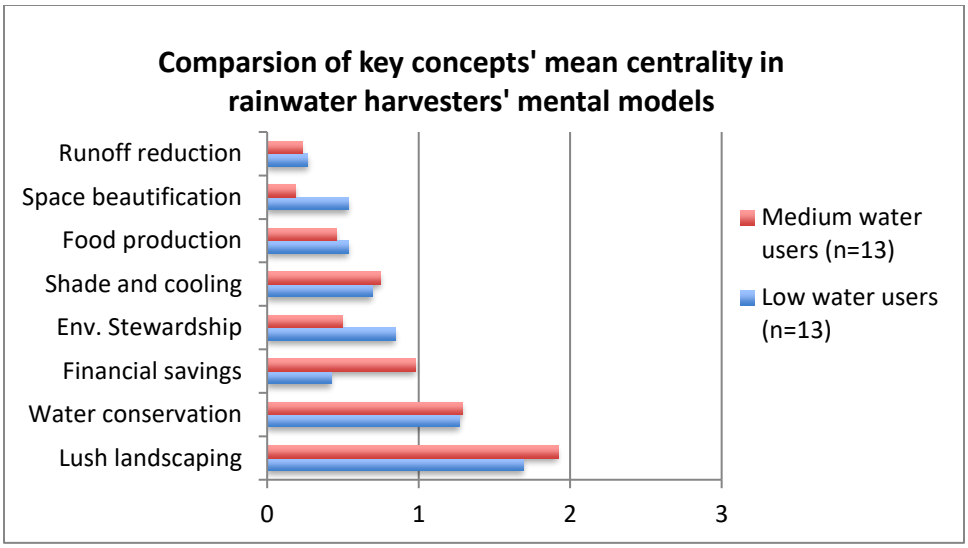


Table 8. Chart comparing centrality of named benefits for different water user groups.

This suggests that while most participants believe that reducing their potable water consumption is a benefit they can derive from harvesting rainwater, it is not necessarily integral to bringing about other benefits they are actively seeking out when collecting the rain. The establishment of lush landscape, on the other hand, is consistently presented as conducive to other welcome benefits such as shade, beautification, and even financial savings as some people believed that vegetation curtails outdoor watering by providing shade and cooling. Furthermore, lush landscaping was consistently characterized as an ordinary concept and water conservation as a receiver. As mentioned above, receivers are concepts that are influenced by others but do not influence others, while ordinary variables are those understood to also exert an influence on other concepts (See appendix 2). While we see slight difference given the small sample we found no statistically significant difference in concept frequency and centrality among low, medium, and high water users.

It was expected that financial benefits would be a motivating factor for residents, but we found that this concept did not have a salient position in people's mental models. Financial savings were mentioned by slightly over half[3] of all participants, and it had a relatively low centrality across all mental models (Fig 5 & 6, above). However, this was the only concept for which we found a significant difference in frequency between low and medium water users, with it being more frequently mentioned among higher water consumers (Fig. 7, above). When asked specifically if they thought rainwater harvesting had reduced their water bill, most residents said "yes". Most of them expressed certainty about their households' reduction in water consumption. Even when their estimated savings varied from 'little' to 'a lot', they were all certain that a reduction had occurred and that it was relatively meaningful. In contrast, a few of those who also offered an affirmative response expressed hesitation in their assessment. In general they qualified the reduction as only marginal given their household's increase in vegetation and the limited capacity of their rainwater harvesting cisterns. While no respondents

[3] This number climbed to 60% during the second interview (mental model elicitation # 2).

acknowledged an increase in their water bill, several participants explained that they were not reducing their water bill but believed that rainwater harvesting had potential to do so if they only changed their watering and landscaping practices, and/or increased their capacity (Fig. 9). Nevertheless, except for three residents, all other residents admitted not paying attention to trends in their water bill, often emphasizing that their installation of the system was not motivated by financial reasons but by environmental ones. As illustrated by one interviewee, "I did not do it to be cost-effective. I did it because saving water is good, [as it is conducive to] having hummingbirds and butterflies, and having plants that bloom flowers that attract them."

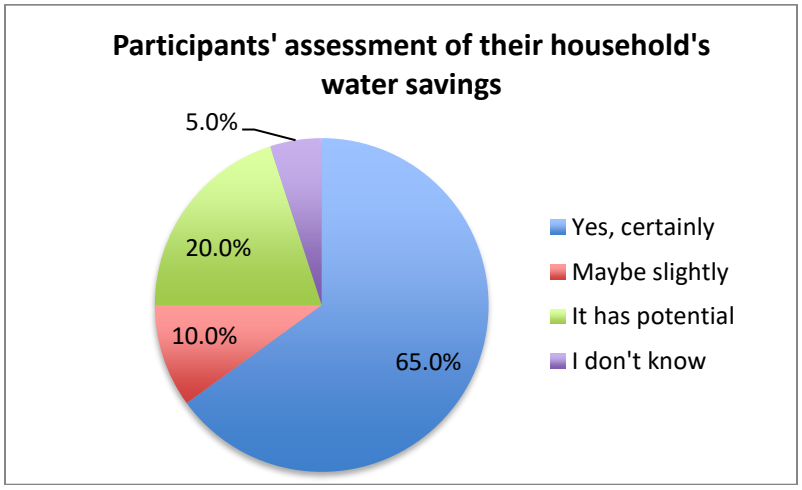


Table 9. Chart illustrating participant's perceptions of water savings.

Vegetation perceptions and practices

Interview data, landscape surveys and users' monthly logs provide potential explanations for the lack of correlation between rainwater water use and potable water savings as per the water meter, highlighting a link between this rainwater harvesting, increased vegetation and irrigation management. In this section we describe the results pertaining to the entire sample and in the appendix we present four vignettes to ethnographically illustrate the range of practices and perceptions of four people engaged in residential rainwater harvesting (See appendix 3-6).

We found that 75.8 percent of participants planted new vegetation soon after installing their rainwater harvesting system and 31 percent of those installed their systems as part of large-scale landscaping redesign projects (Fig. 10). We found that individuals who did not mention lush landscaping in their mental models did not add vegetation to their yards, or added very few specimens through the course of the study. In contrast, people who were actively engaged in expanding their vegetation tended to mention it and often assigned it a relatively high centrality. As mentioned before, 'lush landscaping' refers to an increase in vegetation density in private property and/or an increase in existing plants' growth and robustness.

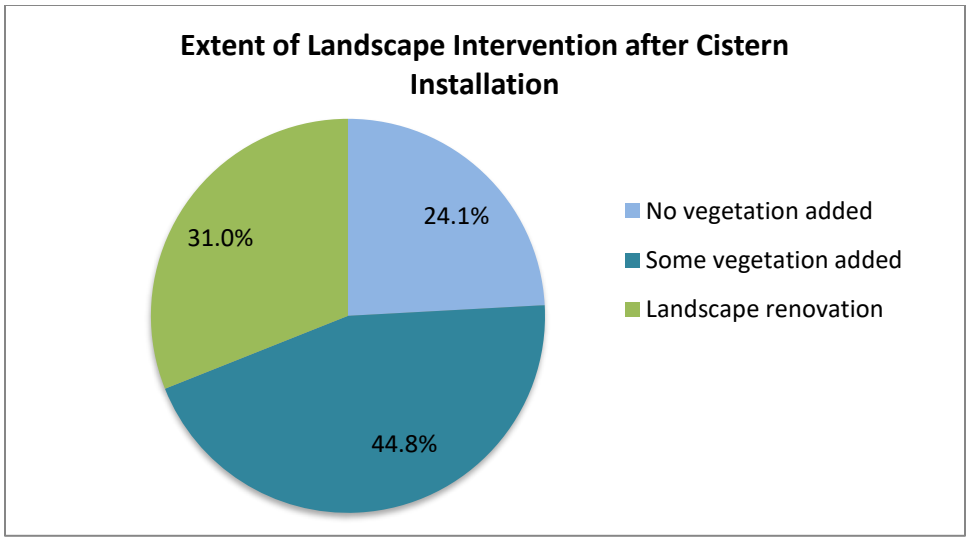


Table 10. Chart showing how customers changed landscape during/after cistern installation.

In line with the xeriscaping principles dominant across the city, a majority of all new vegetation was either native to the Sonoran Desert or drought-adapted. Low-water use shrubs and bushes, especially local varieties chosen to attract pollinators, were planted by 62.1 percent of participants. These were the most popular both in terms of number of households who added them and number of specimens planted. Low water use trees were planted by 48.3 percent of participants, with any individual households planting no more than five new specimens during the study period. All of these participants expressed an interest in creating shade for their outdoor spaces and cooling their homes (and, by extension, eventually reducing their energy bills). Cacti, agaves and succulents, which are often portrayed as quintessential types of desert vegetation, were planted by 27.6 percent of participants. Lastly, higher water use fruit-bearing and shade trees were planted in 37.9 percent of participating households and these were very few in total number of plant specimens. During interviews most people who had fruit trees were quick to point out that these thirstier plants were only viable and acceptable due to the extra source of water they now had available from the sky. In general, even if they could not identify their plants by name, participants had a clear understanding of which plants were low-water users. However, they often conflated drought-adaptive varieties with native varieties.

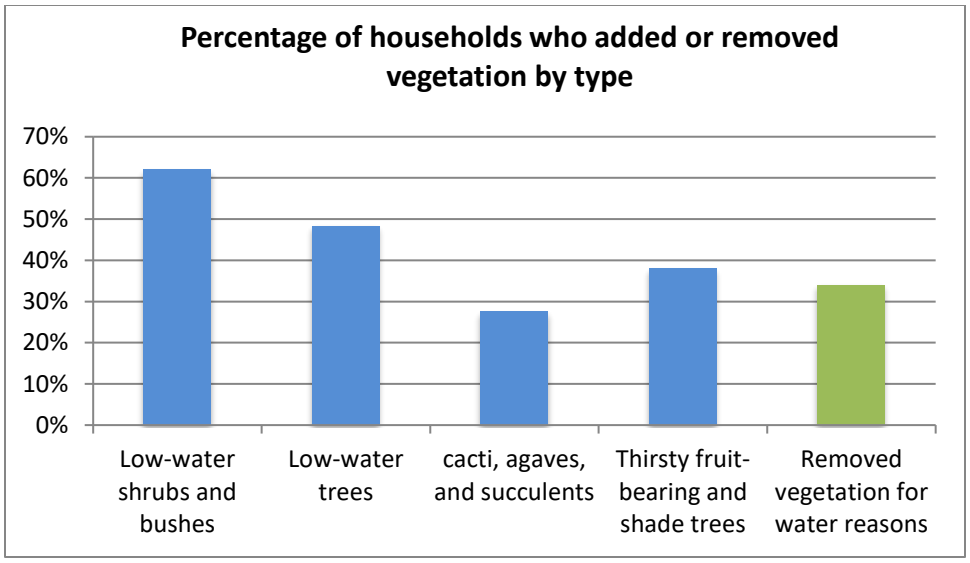


Table 11. Type of vegetation change as reported by participants.

As often as people planted new vegetation in their yards upon installing rainwater tanks, they also removed some plants due to considering them 'too thirsty' relative to Tucson's hot and semi-arid environment. About one-third of participants chose to remove water-intensive specimens from their yards. We suggest this is in part because rainwater harvesting makes water consumption into a relational and tangible experience. Even when people were not quantifying how many gallons had gone into watering a specific section of their yard, they often knew how much of *their* tank had been emptied by irrigating those plants. In interviews participants repeatedly pointed out that their biggest surprise with rainwater harvesting was realizing that despite the large size of their cisterns, water did not go far when it came to landscape irrigation. For example, one native Tucsonan who was shifting her outdoor space from what she described as a "tropical paradise" to a diverse collection of drought-adapted plants, explained, "I just don't want to water them anymore, I don't want to waste my rainwater on big water users (Participant 021)." Accordingly, soon after installing the cistern she tore out the little patch of lawn that remained in her yard and was now waiting for a mesquite tree to grow and create shade in order to plant a low-water evergreen succulent groundcover. Similarly, another participant explained "if anything dies, I rip it out and replace it with cactus and succulents. I am tired of fighting the elements (Participant 005)." In this way, participants recounted replacing beloved iris beds for spiky red yucca and orange trees for spiny mesquite trees: participants consistently substituted exotic ornamentals with desert-adapted varieties.

We expected to find that rainwater harvesting would be a driver for people to start gardening if they were not doing so already or to increase the size of their home garden. Interview and monthly diary data indicate that this was not the case. During the late spring and early fall –the best planting seasons for home gardens– no more than 45 percent of households reported to be growing herbs and/or vegetables. The size of all gardens (except for two) was relatively small, with most participants having less than ten pots or a couple of larger raised beds.

Irrigation Practices

All participants were using rainwater to supplement potable water irrigation, with a few of them stating that they were working towards becoming exclusively dependent on non-potable sources for landscape irrigation. About half of them had a working automated drip irrigation system and the rest continued to water their landscape vegetation manually with hoses (Fig 12). About half of those who did not have an automated irrigation system were contemplating installing one in the near future attracted by the possibility of making irrigation more autonomous[4]. We did not find a statistical correlation between water usage level and adoption of drip irrigation technology.

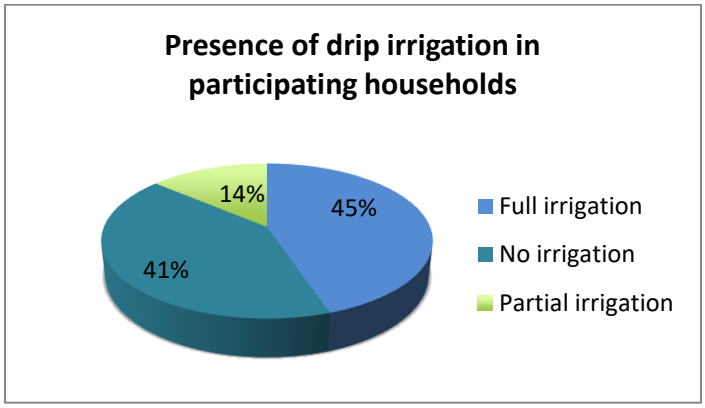


Table 12. Type of irrigation system as reported by participants.

Almost all participating households relied on hoses and buckets to irrigate their plants with rainwater. Low water pressure –which becomes even lower as water volume in the tanks decreases– was a critical limiting factor on what they could water and when they could water. Low pressure means that residents need to allocate time to allow rainwater to slowly flow through the hose and drip onto some plants' roots, and then move the hose onto the next plant and allow the dripping process to follow its slow course. This requires people to be present and attuned to their watering system. Reflecting on his water habits one participant explained, "I like to be around and watch the plants so I can regulate how much water they are getting by watching them. With four cisterns I can do four hoses at once now, and that has sped up the amount of time that I use to water things (Participant 015)." Only a few participants (10%) had their cistern(s) connected to a small pump and just a couple of those had been able to link it to their irrigation system, thus increasing the pressure, expanding the reach and reducing the time needed for irrigation. Overall many people –especially those who worked full time or travel frequently– expressed frustration at the cost and expertise required to connect their rainwater cisterns to the irrigation system, explaining that they thought automating rainwater irrigation would have been easier and would allow them to reduce their reliance on city water.

[4] Drip irrigation delivers water directly into the soil near the roots of the plants through a network of valves, pipes, and emitters. Originally developed for the agriculture sector, drip systems have been widely adopted in urban areas because they are more water efficient than other common systems such as sprinklers.

Observed Issues in Landscape Irrigation

Despite the dominance of low-water use plants in participating households and residents' concerns with water conservation, many participants seemed to have limited understanding of plant physiology, the watering requirements of their vegetation and/or the technical specifications of their irrigation system. The following malpractices were the most commonly observed and reported:

- Residents (or their landscape contractors) continue to irrigate adult native and drought-adapted plants following the watering schedule set up for their 'establishment' period. Residents understand that nursery plants need supplemental watering in order to get established in a residential landscape, even if they are native or drought-adapted, and most of them had planned to reduce the amount of water delivered or to remove them from the irrigation system once they were established. However, very few had followed through. In some cases this was because of uncertainty regarding the current water needs of the plant –"Is it ready to be weaned?" – or ignorance on how to manipulate the irrigation system.
- Residents often over-water adult native and drought-adapted plants because they are concerned or bothered by the seasonal look of dormant vegetation. This happens most often during the early summer when cisterns are often empty and residents rely heavily on potable water to give plants "an extra sip". This indicates that while users do welcome desert plants into their landscape palette, their aesthetic ideals have yet to be adapted to the seasonality of the Sonoran desert.
- Residents (or their landscape contractors) regularly set up irrigation timers to run for short durations (20-45 minutes) at a high frequency (either every day or every couple of days). This is not long enough for the water to percolate and encourages shallow roots, making the plants more susceptible to heat and drought conditions. In addition, several households had irrigation emitters placed too close to the base of the plants, rather than by the outer edge of the plant's canopy where the absorbing roots are actually located. All these constitute an inefficient use of potable water.
- Given how time-intensive rainwater irrigation can be, many residents fell short of using their rainwater as efficiently as they could. Some residents reported putting the hose at the base of a tree and forgetting about it, thereby wasting most or all of their rainwater. To avoid this problem, other residents described moving the hose quickly around from plant to plant, thereby not giving each plant enough water by not allowing the water to reach the proper depth.
- Little over a quarter of the participating households had passive rainwater harvesting, with only 13 percent of those having well developed earthworks to redirect, slow down, and retain stormwater in their property for landscape irrigation. A majority of the households did not have functional passive rainwater harvesting. We include here those few households that had small basins around some trees but these were too small or too shallow and, therefore, not functioning to their potential. Furthermore, we found that in several homes the cisterns were not connected to an overflow basin.

Conceptualizations of Water Conservation

All research participants had a general understanding of Tucson's water supply system, pointing to the Colorado River and local groundwater sources as the city's primary sources of potable water. All of them expressed some level of concern about Tucson's water security over the next generation; with 35 percent of them believing that Tucson is already experiencing a water deficit. Prefacing their reflections with some variation of "we live in a desert", participants attributed the city's vulnerable resource security to continuous real-estate development, prolonged drought in the Colorado River basin, and/or precarious water allocations through the Central Arizona Project (CAP). Participants who had relocated to Tucson within the last decade consistently cited overuse of water resources due to ever-increasing population and real estate development. In contrast, old time residents were more prone to emphasize the recurrent drought conditions affecting the region for the last 25 years along with historical pressure on water resources. Nevertheless, about 65 percent of participants also expressed some degree of confidence on how local and regional water authorities were handling the challenges at hand. As evidence people cited large-scale conservation initiatives such as recharge of the local aquifer and water storage in Lake Mead, small-scale initiatives such as the residential rebates, and the city's reported decrease in per capita water consumption.

In this context, even when mental models indicate that water conservation is not the most central component in participants' understanding of how rainwater harvesting works, their motivation for collecting the rain is discursively articulated around water conservation. Participants explained their impetus for collecting rainwater with statements such as "to lessen the use of water, period", "to preserve water resources only" and "just to save city water". For example, a woman who relocated from New Jersey three years ago explained: "We came out here having read articles on water conservation, knowing that we were moving to a desert. It only makes sense to benefit from occasional rains. It is inadequate, but better than nothing. Water is a limited resource (Participant 001)" A man from New York who had been visiting Tucson since the 1970s and permanently moved here after he retired made a very similar point when he explained: "I knew that the water deficit [in Tucson] was phenomenal. It is important for me to do everything I can to lessen the impact of getting water out of the reservoirs (Participant 002)" Similarly, a woman who moved to Tucson nearly a decade ago from semi-arid Utah explained: "Rainwater harvesting is a concept that in the desert I believe strongly in - using the resources that we have. How reckless is in the desert to be using water with impunity! (Participant 030)"

Research participants offered three distinct yet interrelated explanations for how residential rainwater harvesting was connected to water conservation (Table 13). The first and most common explanation links residential rainwater capture with reduced extraction from the local aquifer and/or the Colorado River. The second explanation emphasizes the relationship between rainwater use and potable water reallocation, thus tying into the "right source for the right use" argument. Recognizing that making water potable is capital and energy-intensive, rainwater use is seen as offsetting the potable water use in irrigation and, by extension, making that water available for drinking elsewhere in the network. The third explanation describes water harvesting as contributing to the recharge of the local aquifer through localized retention and infiltration of water in people's own

yards. In this view individual engagement in rainwater collection contributes to conservation by adding water –even if a marginal amount– to the strained local hydro-ecological system.

Exemplary Quotes from Semi-structured Interviews		
Water conservation as reduce extraction	**Water conservation as efficient use**	**Water conservation as recharge**
"Whatever we use from the tanks doesn't come out of the ground… so that means that we keep the water table a little higher (Participant 012)"	"I don't have to use water that had to be pumped and treated. It doesn't make sense to spend a lot of money on treating water [to be potable] and then dump in on the ground for your vegetation when you can use rainwater (Participant 011)"	"We are recharging where it is going in, in some small part contributing to recharge… (Participant 018)"
"I am not pulling water from the Colorado River, I am capturing water that falls from the sky (Participant 023)"	"We are using water that wasn't part of the water system cache, the water that Tucson water has said, "this is going to be for drinking", we have not taken from that, we have taken it from a different source. The water that they spent the money in cleaning for drinking can still be used for that (Participant 015)"	"It helps replenish the water table. Water just goes into the earth and eventually goes down into the water table. Wouldn't that be a passive recharge? (Participant 026)"

Table 13.

Furthermore, individual understandings on how their own engagement with rainwater harvesting contributes to water conservation were largely qualified through landscape water use and varied in scale and temporality. Some residents saw their use of rainwater as providing them with a replacement source of water and thus conducive to using less potable water in outdoor irrigation. These participants explicitly explained that with rainwater collection they were able to keep a lush landscape while simultaneously (and immediately) reducing their potable water consumption, even if the reduction was marginal. In contrast, other residents saw rainwater harvesting as an additional source of water that could be used to cap –rather than to reduce– potable water consumption and thus curtail future demand. For these participants maintaining and/or growing the vegetation around their homes was not contingent on harvesting rainwater, but access to an additional source of water allowed them to build a desert oasis while not increasing their water consumption (too much) to do it. Most rainwater harvesters articulated a connection between their household use of rainwater and the municipal water supply system; the temporality, strength, and nature of the connection is what differs (Table 14).

Reduce consumption	Cap consumption
"We don't use as much water from Tucson Water. Like I said, I don't water my citrus trees with anything but the cistern (Participant 025)"	"We have lots of trees and put additional trees. We have citrus trees, which are very thirsty. Rainwater harvesting has enabled us to water our landscaping without having to use nearly as much city water."
"I use less Tucson Water because otherwise I would have to pull a hose [with city water] and water that orange tree, and I use it to water my garden and a few potted plants. It definitely decreases my use of Tucson Water, but not to a great extent (Participant 004)"	"If you want to grow more plants, you need more water, but here you are getting more water from the rain. For example, last year I planted 12 trees and I don't use city water at all (Participant 003)"
"Probably what is happening more is that we used a little less from the tap to water our yard, and we made our yard look a little bit nicer by feeling like it was okay to water plants extra [with the free rainwater] (Participant 028)"	"And my husband likes to garden, likes to have plants and trees. He could do that either with a really large water bill that is draining the natural resources, or we could use the resources *around* us. (Participant 030)"

Table 14.

Conclusions and Recommendations

We found two models for how residents construe and manage rainwater as a resource newly available to them. On one hand, some people primarily perceive it as a supplementary or additional water source. On the other hand, other people primarily understand it as a replacement or alternative to existing water sources. In either case, people describe rainwater harvesting as a private source of free and better-quality water (as compared to tap water) and value it for providing them with a desert oasis in their homes. Rainwater harvesting seems to resolve a contradiction in peoples' values –the desire for an urban oasis and the moral imperative to not drain the city's limited water resources.

Despite rainwater harvesting not meeting the criterion to be considered an unequivocal success as per the institutional metrics of water conservation (i.e. reduction in ccf's), an overwhelming majority of residential rainwater harvesters continue to see it is a 'working well' and support its implementation across the urban landscape, often inciting their friends and neighbors to also catch the rain. Their definition of success is based on their observation of vegetation growth, shade, and/or presence of urban wildlife in their yards, which they see as at least partially attributable to rainwater. Users' scale of intervention and observation focuses on their private property; thus, is necessary to evaluate how the secondary benefits of rainwater harvesting may extend beyond the household into the neighborhood level. For example, what is the cooling radius of a home's vegetation? What is the cumulative effect in ambient temperature in neighborhoods' with high numbers of houses doing rainwater harvesting?

Among our participants there is no lack of concern about the city's water future, but as this reports indicates concern for water scarcity is not alone a determinant of people's water use behavior. Whether or not residents reduced their water usage or not after installing a rainwater tank was not determined by their sense of water crisis, but instead by their relationship towards and valuation of their backyard environment, including their knowledge about plant requirements and irrigation practices. Throughout

this study –via interviews, landscape surveys, and monthly diaries– we observed an active process of environmental learning, as rebate participants are noticeably working to transform and adapt their physical surroundings and sense of aesthetics to be coherent with the local desert environment. Nevertheless, this study points to a gap between residents' interest in establishing desert-appropriate landscaping practices (including rainwater harvesting), and their understanding of what this entails in practice.

Tucson has a well-deserved reputation for been at the forefront of water efficient landscaping, decades before California and the rest of the Southwest started to systematically do so. To continue on this path and maximize the benefits associated with rainwater harvesting, we offer the following recommendations.

- To develop a new curriculum that focuses on teaching interested customers how to begin preparation of a site plan and to create a water budget for their homes. This would involve participants reflecting on what their objective for rainwater collection is and learning to ask the right questions to identify (or requiring their provider to identify) what opportunities they have in their space and what negative issues they have going on in their yards, including percentage and distribution of low and high-water use plants, (in)appropriate irrigation, and good/bad drainage. In other words, we recommend modifying the existing rainwater harvesting rebate and credit application processes to use the three-hour class to teach applicants how to integrate this new technology into the existing structure and future vision for their yard. As a corollary to the previous point, we recommend that Tucson Water develop a new certification for local service providers to train them in these skills.
- We recommend Tucson Water and Smartscape to consider offering personalized site consultations to help participating households set target water reduction goals and determine the best outdoor water management practices –as per their specific context– to meet their goals. We recommend considering a sliding scale for payment in order to make this service available to a broader sector of the population. Relatedly, Smartscape could develop a new residential class to teach residents how to create a true desert oasis through the use of alternative water sources (i.e. rainwater and greywater), and how to monitor it. The class could focus on teaching people basic desert plant physiology, as well as how to determine the water needs of common low-water landscape varieties (through their life cycle and through the seasons), and how to irrigate their plants (by integrating and managing their potable and alternative water sources).
- We recommend that Tucson Water compile a list of local providers who offer rainwater-automating services for small-scale residential systems and to provide rebate applications with clear information on the technologies available for automating rainwater irrigation, the local providers who offer the service, and their cost. Participants expressed a need for this. We anticipate that the list of local providers is currently short. Thus, this may require reaching out to local rainwater harvesting businesses to assess how feasible it is for them to develop this new service as part of their portfolio. All of this information should be made available online and in the mandatory rebate class so participants can have this information <u>before</u> installing their cistern.

- We recommend Tucson Water modify the rebate structure to encourage households to establish passive rainwater harvesting as part of their rainwater systems. This and other studies point to the value of earthworks for desert landscape irrigation.
- We recommend that Tucson Water develop a new landscape campaign along with some targeted outreach to engage nurseries in water conservation. Participants identified locally owned and corporate nurseries as central to their learning about water-efficient plant varieties. Nurseries play an important role in residents' plant selection and the information they receive about how to care for those plants, including how to water them. We believe this is an important area of intervention given the role these private institutions seem to have in public education for water conservation, even when this is done informally.
- We recommend the establishment of an advisory research committee to lead the way on green infrastructure by serving as a liaison between Tucson Water, local expert practitioners, and university researchers to identify future research directions and specific questions. This committee could begin by review existing peer-reviewed articles and white papers on rainwater harvesting in arid lands (including this study and related publications). Based on the findings from this study, we see the need for eco-hydrological studies to monitor the effects of active and passive rainwater harvesting on urban heat island effect, urban wildlife, soil quality, and stormwater reduction at different spatial scales. We also recommend that an anthropological study be conducted among participants of the limited-income program to document their motivations, understandings, and practices associated with rainwater harvesting as a way to further environmental justice.

Bibliography

Burns, Matthew J. 2015. The performance of rainwater tanks for stormwater retention and water supply at the household scale: an empirical study. Hydrological Processes, 29(1): 152-160.

Campisano, Alberto et al., 2017. Urban rainwater harvesting systems: research: implementation and future perspectives**.** Water Resources, 115: 195-209.

Farbotko, Carol A. et al. 2014. Household rainwater tanks: mediating changing relations with water? Ecology and Society, 19(2). Available online at https://www.jstor.org/stable/26269566.

Gray, Steven A. 2014. Fuzzy cognitive maps as representations of mental models and group beliefs. In Fuzzy Cognitive Maps for Applied Sciences and Engineering. E. I. Papageorgiou (ed.). Pp. 29-48. Berlin: Springer-Verlag.

Khastagir, Anirban and Niranjali Jayasuriya. Optimal sizing of rainwater tanks for domestic water conservation. Journal of Hydrology, 381(3): 181-188.

Kosko, Bart. 1986. Fuzzy cognitive maps. International Journal of Man-Machine Studies, 24: 65-75.

Meehan, Katie M., and Anna W. Moore. 2015. Downspout politics, upstream conflict: Formalizing rainwater harvesting in the United States. Water International, 39(4): 417-430.

Mikkelsen, P.S. 1999. Collected rainfall as a water source in Danish households - what is the potential and what are the costs? Water Science and Technology, 39 (5): 49-56.

Ozesmi, Uygar and Stacy L. Ozesmi. 2004. Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecological Modelling, 176: 43–64.

Steffen, Jennifer et al. 2013. Water supply and stormwater management benefits of residential rainwater harvesting in U.S. Cities. Journal of American Water Resources Association, 49(4): 810-824.

APPENDIX 1. Interview guide for semi-structured interviews

A. Personal Information

1. Name: _____

2. What year were you born?:_____

3. Gender: Male Female Other

4. Where did you grow up? (where did you spend your childhood and teenage years)?

5. (If not from Tucson) When did you move to Tucson?

6. (If not from Tucson) Why did you move here?

7. How long have you been living at this house?

8. Do you own or rent this house? Own Rent

9. How many people beside you live in this household?

10. What do you do for a living?

11. ID: the participants highest degree

    >High school High school Associates Bachelors Masters PhD Other

12. If a two-head household, what does the partner do for a living?

13. ID: the participants' partner highest degree

    >High school High school Associates Bachelors Masters PhD Other

14. I am going to read you several household income categories, please tell me which one best represents your household income.

    a. Less than $15,000
    b. $15,000 to $25,000
    c. $26,000 to $50,000
    d. $51,000 to $75,000
    e. $76,000 to $100,000
    f. $101,000 to $150,000
    g. $151,000 to $200,000
    h. Greater than $200,000
    i. Refused to answer

B. Individual Motivation and Experiences with Rainwater Harvesting

11. How did you learn about rainwater harvesting?

12. Why did you decide you install rainwater harvesting at your home?

13. How did you learn about Tucson Water's rainwater harvesting rebate program?

14. Would you have installed rainwater cisterns if there were not a rebate? (Why?)

15. Where did you attend the RWH incentives class?

16. When did you attend the RWH incentives class? Did you do it before or after installation?

17. What do you consider the main benefits of water harvesting?

18. What do you consider the main downsides or drawbacks of rainwater harvesting?

b.1 Questions about the rainwater harvesting tank:

19. When was your tank installed?

20. What size tank(s) do you have?

21. How do you use it? (Do you water manually or is the tank hooked up to irrigation?)

22. How do you know how full the tank is?

23. How often did it overflow during the last rainy season (summer monsoon /winter rains)?

24. How did you decide what size system to install?

25. Did you have a design plan, or a vision, for how you wanted to do rain water harvesting? (what you wanted? The size? The type?)

26. Did you install your own system or hire a contractor? Tell me more about your experience with the installation process. If you hired a contractor, how did you find one and make a selection?

27. What other changes have you make in your outdoor space?

    a. Did you add new plantings? What did you add? Why?
    b. Did you remove any plants? What did you remove? Why?

c. Did you made any changes to your irrigation system? (i.e. added or removed a drip system, changed the irrigation zones, do you adjust it monthly or seasonally to reflect plant water needs, etc.)
d. Did you made any other significant changes? Explain

28. Do you have a grey water irrigation system? When did you install it?

29. Please tell me how you use water outdoors during a normal week at this time of the year (Make sure participants address: what they water, how they water it, and how often? If they wash their car and how often? If they fill out or refill the swimming pool or hot tub?) Does this change during the winter?

C. Cognitive Mapping (30-minutes)

"How would you explain why to do rainwater harvesting to someone who is unfamiliar with it? Begin by listing what are its benefits and barriers/drawbacks, and then describe the relationship between each of these components."

The person making the cognitive map freely decides what the important variables are which affect a system and then draws causal relationships among these variables indicating the relative strength of the relationships with a number between -1 and 1. What is the evidence for each variable?

APPENDIX 2. Key concepts used when analyzing mental models with Fuzzy Cognitive Mapping (adapted from Gray et al. 2014; Ozesmi and Ozesmi 2004)

N (Concepts) → Number of variables in the map (i.e., the free-listed concepts mentioned by each participant)

C (Connections) → Numbers of links between the different variables in the map (i.e., the connections indicate by each participants to exist in the system)

C/N → Number of connections divided by number of concepts. The lower the C/N ration, the higher the degree of connection in the system

Density → Number of connections present in a map as compared to number of all possible connections in the map

Centrality → The influence of a concept within a map. This is calculated based on the absolute sum of values given to all links connecting a concept to other concepts. The higher the value, the greater the importance of a concept within a map

Out-degree → The cumulative strength of the influence a concept has on all other concepts within any given map, that is, the absolute value of all outgoing arrows leaving that concept. In the similarity matrix (see Fig. 2), this is calculated by the row sum of the absolute values of a concept.

In-degree → The cumulative influence on any given concept from all other concepts, that is, the absolute value of all incoming arrows to a concept. In the similarity matrix (see Fig. 2), this is calculated by adding the column sum of absolute values of a concept.

Drivers → Concepts that influence other concepts but are not influenced by others. This is determined by the directionality of the arrows associated with a concept.

Receivers → Concepts that are influenced by other concepts but do not influence others. This is determined by the directionality of the arrows associated with a concept.

Ordinary → Concepts that influence other concepts and are influenced by other concepts. This is determined by the directionality of the arrows associated with a concept.

APPENDIX 3. Ethnographic Vignette – The story of Emily and Joe

Gardening with the Rain

Emily and her husband, Joe, moved to Tucson from Los Angeles in 2004. In her late 40s, she describes herself as a displaced gardener. Gardening –especially growing edible plants– makes her happy. "I don't like to use perfect drinking water in my garden so I opted for growing native and drought-adapted plants; it's a kind of a happy medium", she explains. They decided to install rainwater harvesting cisterns to reduce their potable water consumption because they were conscious that their water consumption was above average and that reducing the size of their yard was not an option for them. In December 2015 they installed two tanks with a total capacity of 2430 gallons. Since they both work full time they had to use their winter vacation to work on this project. Emily recalls that it took two people, two weeks of work, and two tall ladders to bring the job from start to finish, and that this made rainwater harvesting more affordable than hiring a contractor.

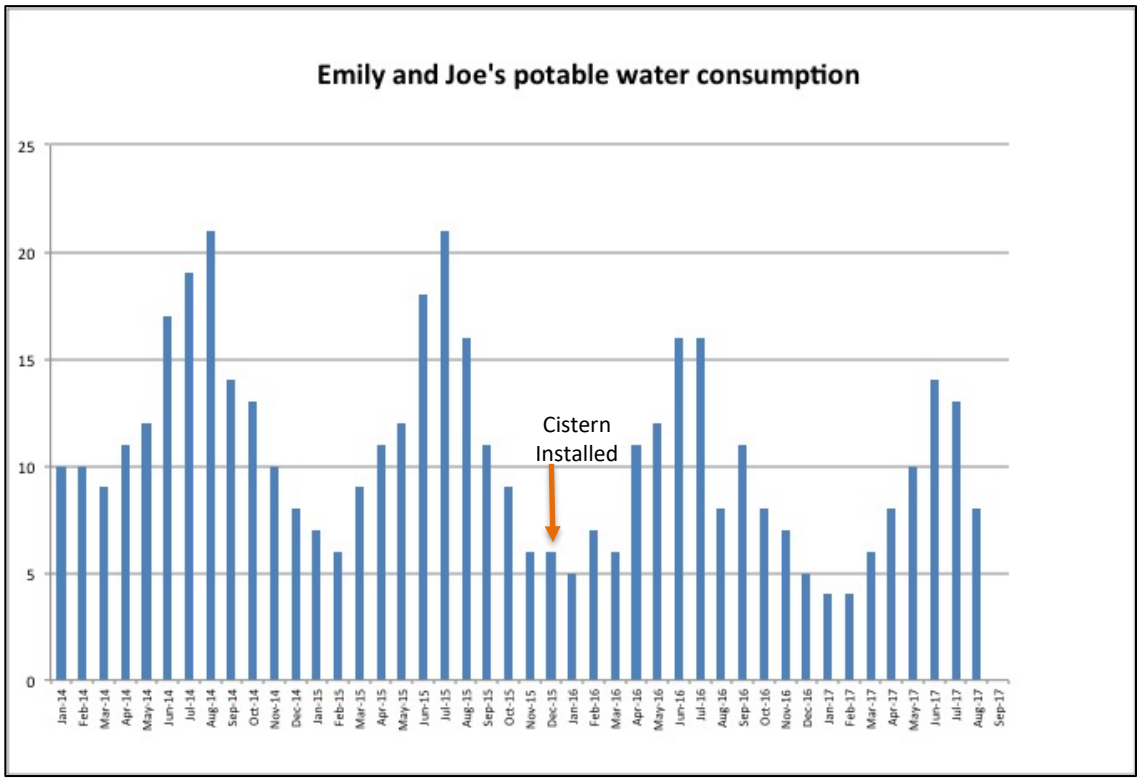
They bought their house for the size of the yard: a 1,200 square feet home on a .32 acre-lot on the east side of town. The heart of the yard is the vegetable garden: they have six 3x12 foot vegetable beds in production year round, and lots of herbs in pots and in the ground. They planted several mesquite and desert willow trees to shade the garden and the house. Beyond the garden, the yard is full of robust-looking low-water use bushes and shrubs. In their diverse yard, there are only two fruit-bearing trees –a pomegranate and a lemon. Emily explains that, after been shocked by the effect of those trees in their water bill, they try to stay away from fruit trees "because they need too much water and then they only feed the birds."

Emily and her husband are both studied gardeners. They know their plants by species name, and are eager to talk about their successes and failures cultivating different species. They have developed a desert-oriented trial-and-error philosophy influenced by permaculture. They do not limit themselves to native species but only choose plants that serve at least a dual purpose –they need to either feed them or the urban wildlife, or to provide shade– and they have to be low-water use, full-sun, and hardy down to 15 degrees. "I have tough love," Emily explains, "you either make it or you don't".

Reflecting on her outdoor water consumption, Emily explains "because I love plants, I would have probably planted them regardless of rainwater harvesting but I would have had more guilt because I would have to use city water." Their large yard is not connected to a drip irrigation system. Using a hose, she waters the plants exclusively with rainwater and switches to city water only when rainwater runs out. The drought-resistant bushes, shrubs, and trees do not need much water, which makes her rainwater last longer and reduces the time demands on her schedule. To avoid draining a tank accidentally by leaving it open, she disconnects the hose from the tanks when she is not using them. Their two tanks are part of a larger rainwater harvesting system that includes raised walkways and earthworks that direct the rainfall to the plants and reduce soil erosion into the arroyo that backs their property.

The thirstier vegetable garden is on an automatic drip irrigation system. Higher water needs translate into a higher time investment, and with both of them working full time they are not able to water the garden by hand everyday, or more during the summer. To maximize the efficiency of their irrigation system they have three zones determined by the vegetables' water-needs. The system also has a rain delay, but it is not one of those a so-called smart systems. "I am the smart part," Emily jokes, "I have to manually set the rain delay when it rains."

Two years after installing their tanks they are slowly meeting their objective. Emily is well aware of this because she keeps track of their water bill, as she carefully does with the monthly precipitation. Every month she compares the columns indicating the household's current water consumption with the consumption from the same month the year before.



APPENDIX 4. Ethnographic Vignette - The story of Emma

Learning to garden in the desert

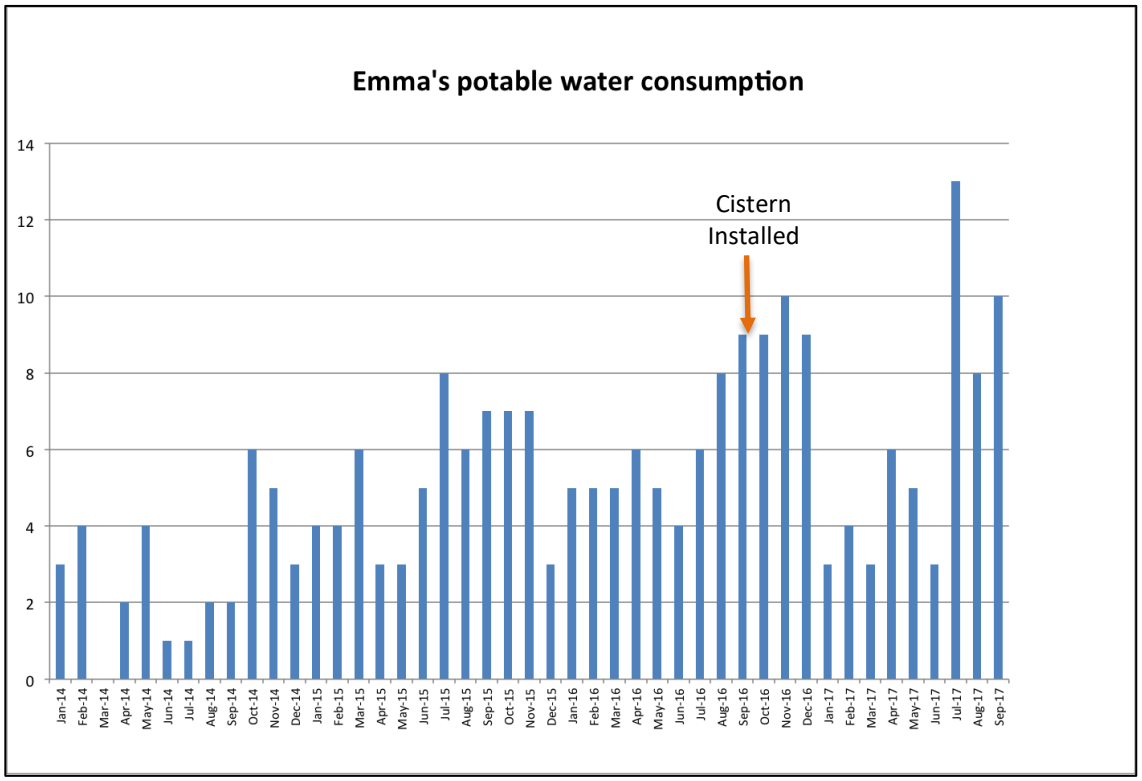
Emma is an active and vivacious woman in her early 70's, who describes herself as 'semi-retired' and continues to work as a consultant for an overseas firm. In 2012, after her husband passed away, she moved from a large mid-western city to Tucson and bought a small house on a large corner lot in a mid-town neighborhood. Her objective was to create a green and shady space where she could hang out and work with plants, as she had done when living in the Midwest. Gardening and working in the yard is "almost a way of life", she says.

When she bought this 9,300-plus square foot property, the large backyard was barren and the soil compacted. Knowing that she could not plant the same vegetation that she'd had in the temperate Midwest, she hired a local landscape designer who specializes in residential desert landscaping. Although his original landscape design was not created with rainwater harvesting –neither active nor passive– in mind, it was he who introduced her to the concept. She recalls signing up for a rainwater harvesting class and realizing she needed "to use the water that we have in the desert as intelligently as possible". Plus, she admits, she loved the idea and the "spiffy look" of those corrugated metal tanks, although she eventually settled for a plastic one because they are known for having fewer problems in the long run. In July 2015 she hired a local service provider to install two 1100-gallon tanks in her backyard.

In the three years since she moved into her new Tucson home, she has transformed the yard so that it expands her livable space outdoors while providing her neighbors with a comfortable corridor when they walk along her property. "Every tree that you see has been planted; there was nothing here before!" she emphasizes. Since the original landscape design was installed, she has modified it by adding and removing plants based on what she observes and thinks may work best. For example, she removed a pomegranate tree, which she admits to planting inspired by "a romantic idea of desert living" only to realize that its fruit would go to waste. "Seriously, who can eat so many pomegranates?" She asks laughing. Instead, she planted a few native shrubs that flower at different times during the summer and provide food for pollinators. Emma's self-conscious learning process and concern with balancing ethics and practicality in her outdoors living space is not uncommon across our sample.

Given her love for gardening and her flexible job schedule she is able to spend a significant amount of time tending to her plants. She enjoys watering them by hand, and doesn't mind having to haul buckets with rainwater and greywater across the yard out to the right of way where she has new shrubs, bushes, and agaves. But she also spends extensive periods overseas and during that time she relies exclusively on an automated irrigation system. Reflecting on her use of potable and rainwater, she explains: "How do I use rainwater harvesting? I give myself a thumbs-up. I collect it, keep track of the rains, and water with a hose and a bucket. But, how do I use irrigation? I have a long way to go there. I think I am using way too much water. I think there isn't anything planted here

that shouldn't be here. They are all drought-resistant but I am watering them too much because I have been passive about the irrigation and lazy about learning how to use those controllers. This is my self-evaluation." Since she installed rainwater harvesting her potable water consumption had increased, and so has the vegetation in her beautiful yard.



APPENDIX 5. Ethnographic Vignette – The story of Richard

Creating an oasis in the desert

Richard is a long-term Tucson resident, a full-time tech guru, and self-described plant fanatic. Originally from the San Francisco Bay Area, he and his wife moved to Tucson in 1990. Their small yard is a true mid-town desert oasis with high plant density, remarkable species diversity, and a much welcomed cooling effect. Speaking of his motivation to find alternative water sources for outdoor irrigation he explains: "We live in a desert, (where) water is scarce and may become more scarce, and we did not want to have a barren dirt yard but we wanted it to be sustainable." Installing rainwater cisterns is part of his vision to get his yard off the grid. He has four cisterns with a total storage capacity of 3,400 gallons.

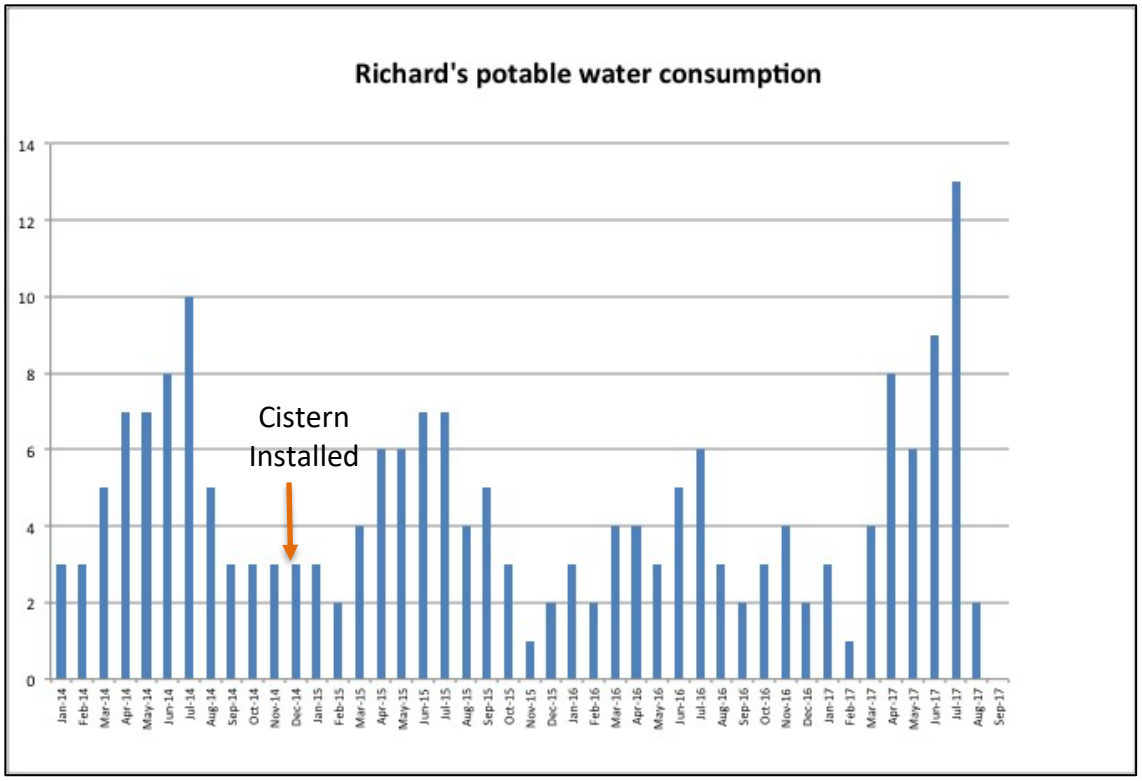
Most of the plants in his yard are mature trees and shrubs that preceded the cisterns. For Richard, his yard is a space where he can simultaneously grow trees, grow shade, and grow edibles. Every single month of the year he has at least one tree producing fruit, which he collects and shares with friends. These include a native mesquite, a heritage pomegranate, a few thirstier citrus trees, and a Jujube Tree, which he describes as "the thriftiest fruit trees we can plant in the desert". He particularly enjoys the Jujube tree as one can eat the fruit like an apple in August, or like a date in October. In addition to the mature trees, he has a small nursery with over fifty desert trees in pots packing his yard. The nursery was born in 2012 when Richard and a few other neighbors started a neighborhood-level urban forestry project aimed at establishing green walkways with native vegetation. "With these native trees", he explains, "we can make shade and cool this town."

For Richard, rainwater came in the wake of greywater. In 1992, he and his wife put their washing machine on their back patio and began using that greywater for irrigation. "We found that we could water a tree for a week by doing one load of laundry", he recalls. "We had two kids at the time, so we were doing five loads a week, so we could keep five trees going most of the year on greywater alone." Fifteen years later, when he began volunteering with Watershed Management Group, he decided it was time to add rainwater harvesting to his household's water budget. They installed his first cistern in 2008. Highlighting the cost of rainwater harvesting systems, Richard explains that they spaced cistern installations over time to wait for their budget to bounce back before investing on the next one. They installed their last two cisterns in December 2014. Along with the cisterns, came the earthworks for passive harvesting. Richard began retrofitting the existing landscape by adding basins to improve rain capture and infiltration. Today he describes himself as "a kind of gardener, who is learning to think as a landscaper." This entails learning how to keep the water that falls on his yard in his yard through passive and active rainwater harvesting.

He does not have a drip irrigation system; instead, he relies exclusively on hoses. With four cisterns, he can use four hoses at once, which decreases the time needed for watering. "I like to be around and watch the plants, so I can regulate how much water

they are getting", he explains. "I ask myself, 'do I really have to water tonight?' I wait for the plants to say 'I need water'. I don't just say, 'let's water you!' I am trying my best to be a good water steward even though I am a plant fanatic." As a careful observer, he knows that is not necessary to irrigate the mature desert vegetation during most of the year, and that he needs to adjust the irrigation frequency according to the seasons.

With a total capacity of 3400 gallons he thought they would be able to completely go off city water for their landscape. However, he was disappointed to learn that it was not the case. After a year characterized by good monsoons and good fall and winter rains, their cisterns were full through January emptied out by June, a whole month before the next summer monsoons arrived. Despite this, he feels good knowing that while his vegetation has increased; his potable water consumption has not increased at the same rate.



APPENDIX 6. Ethnographic Vignette - The story of Alex and Elaine

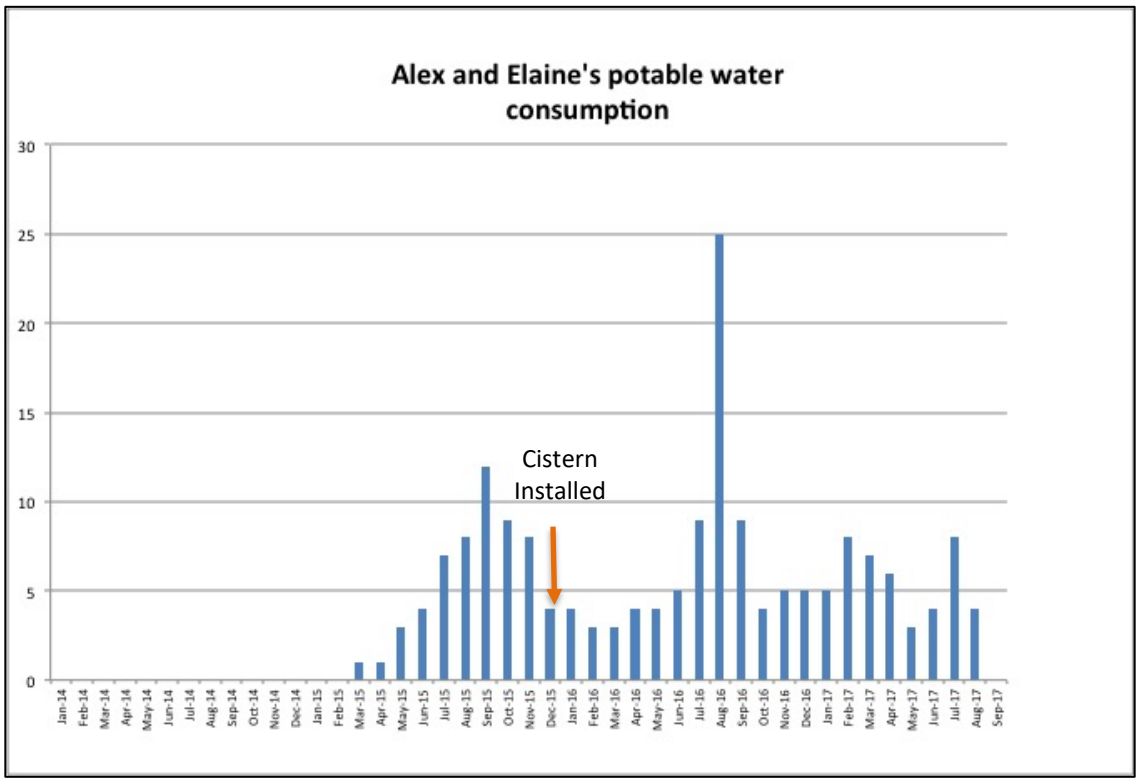
Working with the existing landscape

Originally from New York, Alex first came to Tucson in 1979. He fell in love with the desert and for years he visited every other year, until 2009 when he and his wife Elaine decided to move to Tucson to retire. They eventually bought their "dream house" – a southwestern-style home on the east side of town with gorgeous views of the Catalina Mountains. Soon after moving to their new house they put in solar panels and a few years later, in December 2015, they installed two rainwater harvesting tanks. They have a total capacity of 1,945 gallons. "We knew that we were moving to the desert and we understood that water is a precious commodity out here," he explains.

Their objective for adding rainwater harvesting was to help water the existing plants they had around the yard. He emphasizes that if they had started their backyard from a blank slate he would have created a desert yard. However, when they bought the house it already had an established landscape with several thirsty non-native trees –including a few citrus trees. They removed a lot of the high-water users and replaced them with native shrubs and bushes. As explained by Alex, their criteria for planting is "that they are native to the area, or at least acclimatized to the area, and that they do not use a lot of water once they have established themselves." Slowly they are moving towards getting rid of what he described as "the remaining water hogs." "I had this beautiful fruit tree. The first year we had great fruit, the second year not so great, but it uses so much water that it gets to the point that you might as well just buy the fruit and put something else there. You end up having a $20 pomelo. I don't want to do that."

"We are not conserving water, as we should, we know. The one big thing is that we still have to rework the drip system." They inherited the drip irrigation system from the previous owner. Alex removed parts of it and changed the irrigation schedule to water less frequently. When installing their tanks, they had planned to add a pump and connect them to the drip irrigation system but were surprised by how difficult it was to find someone to take the job. "We are having a hard time connecting [the tanks] to the drip. It is not as easy as we thought. Various companies have turned down the job saying it is "too small of a job," including those who installed the cisterns."

The outflow from one cistern is watering the new plants and a rosebush. These plants depend exclusively on rainwater. Thus far, they have had enough rainwater to irrigate. The second cistern is used to water the fruit trees. Alex gives them extra water when it is above 100 degrees. Right now, the drip system is watering every other day for an hour and a half. They only have one irrigation zone.

Their potable water consumption is much lower than the previous residents', which Alex attributes to the fact that their household is smaller and their landscape practices are quite distinct. Over the years he has removed several thirsty plants –letting them die if they can't survive in the desert heat, rather than flooding them with water in an attempt to keep them alive. Three years into rainwater harvesting, however, they have yet to see the

decrease in potable water consumption they had anticipated, which he believes is due to their inability to connect the tanks into their drip system, “We have already cut down on the amount we water, but it will get better once we finish the work, getting it completely tied in to the drip system.” Alex and Elaine remain confident that their use of cisterns will eventually be as ecologically beneficial as they had hoped.