CHARACTERIZING RESIDENTIAL WATER USE IN COLLEGE STATION AND ASSESSING THE EFFECTIVENESS OF EDUCATIONAL PROGRAMS TO REDUCE OUTDOOR WATER USE

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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May 2018

Major Subject: Water Management and Hydrological Science

ABSTRACT

Texas voters and the legislature have made water conservation an important requirement for cities. Landscape irrigation is the largest component of Texas single family residential (SFR) water use and is a prime subject area for conservation efforts. Conservation strategies may include water pricing, incentive programs, regulatory restrictions, and education interventions. The objective of this research was to characterize residential water use in College Station and to evaluate the conservation efficacy of three educational interventions to reduce outdoor water use; water budgets, irrigation check-ups, and the weekly watering program. Monthly water use for participants in each intervention provides the basis for analysis. Descriptive and correlational statistics were used to determine significant differences in water use after the interventions. Significant outdoor reductions were observed in 27% of the users participating in these interventions; total water savings for these users is close to 3,000,000 gallons per month. Users, for future interventions, can be selected from the groups found in this research with the largest conservation potential. Excess volume and frequency of overwatering are the key to find such users. This project provides practical opportunities based on results and a methodology that can be applied in other cities to reduce water consumption and achieve a more efficient demand management.

DEDICATION

To my parents who believed it was possible and pushed me to go further, and to my grandmother Olga, who supported me and is not here to see this work completed.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Ronald Kaiser, for his guidance and support throughout my graduate studies, for encouraging and pushing me with difficult questions, but especially for his patience and advice over the past 3 years. I would like to thank Dr. Wurbs, Dr. Brumbelow, for their guidance throughout the course of this research. I would like to express my appreciation to Alan Lewis, for answering my many questions, to Jennifer Nations, for her support, and to Dr. Prakash Khedun for his advice. I would also like express my appreciation to Dr. Rosario Sanchez for her guidance at the beginning of my graduate studies. I would like to thank the City of College Station Water Services Department for their vision of urban water management that made possible this research. I would like to thank all my friends in College Station, and colleagues in the WMHS, for making me feel at home. Finally, thanks to my mother, father, and brother for their encouragement and to Angela, for her patience and support.

CONTRIBUTORS AND FUNDING SOURCES

This work was supported by a thesis committee consisting of Professor Ronald A. Kaiser of the Department of Recreation, Park and Tourism Sciences and Professors Ralph A. Wurbs and Kelly Brumbelow of the Department of Civil Engineering.

All work for the thesis was completed independently by the student.

This thesis was supported by a grant from the City of College Station Water Utilities Department to the Texas A&M AgriLife Experiment Station.

NOMENCLATURE

AWC	Average winter consumption
ET	Evapotranspiration
GIS	Geographic information systems
NOAA	National Oceanic and Atmospheric Administration
SFR	Single-family residential
TWDB	Texas water development board
USGS	United States Geological Survey
WWP	Weekly watering program

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1. INTRODUCTION

Outdoor water use for landscape irrigation is estimated to account for 30% of annual residential water use across the U.S. (Vickers, 2001). It is seasonal and varies spatially based on hydro-climatological factors such as of rainfall, temperature, and humidity. Several researchers have found that social and economic factors also influence water use (Arbués et al., 2003; Friedman et al., 2014; Kjelgren et al., 2015; Olmstead et al., 2007; Worthington and Hoffman, 2008). Generally outdoor water use is highest during the spring and summer months. In dry climates, such as in the Southwest, outdoor water use can be several times higher than indoor. In Southern California, DeOreo et al. (2011) estimated that outdoor use can represent approximately 65% of the daily water use. In a study of 5 western U.S. cities found that it was, in average, about 65% of monthly water use (Vickers, 2001).

Water conservation is a growing concern for utilities and water managers. There is a great potential for savings in outdoor water use (Gleick et al., 2003). Experts estimate that up to 50 percent of the residential outdoor water is wasted to overwatering, evaporation, or run-off (USEPA, 2013a). The increase of population, urbanization and climate change makes vital to secure water supply sources for the future. Managing demand is a concern many utilities are considering side by side with their efforts to increase supply. Demand and supply are highly influenced by social and economic factors (Jorgensen et al., 2009).

The state water plan for Texas recognize the importance that conservation will have in the years to come. The Plan suggests that by 2070 ten percent of the water available will come from municipal conservation, and thirty percent will come from demand side management strategies (TWDB, 2016). The city of College Station has been pursuing educational conservation efforts to reduce outdoor water use among residential customers since 2011.

Reducing outdoor water use is a challenging activity because outdoor water use does not depend on a human need (Kjelgren et al., 2000). Utilities can use different approaches when pursuing conservation measures. According to Vickers (2001) conservation measures include pricing, upgrading hardware devices that require less water, regulatory restrictions, financial incentives and educational programs. Cities can influence outdoor water use through pricing, rebates and incentives, watering restrictions, and educational or voluntary measures. Each measure has specific advantages and disadvantages and levels of residential customer acceptance. Understanding how customers react to each one of these measures is important to know the limits of its application.

Economist posit that pricing strategies have potential to provide solutions for managing demand in cases of water scarcity (Griffin, 2001; Olmstead et al., 2007; Renwick and Archibald, 1998) but pricing is often resisted by local elected officials. When applying pricing policies, managers must understand how price will affect the homeowners' decision-making process related to consumption. Other factors, in addition to price that influence water use include family income, number of people in the household, number of bathrooms, the presence of gardens, water appliance efficiency, landscape plant material, and climate (Arbués et al., 2003; Friedman et al., 2014; Kjelgren et al., 2015; Olmstead et al., 2007; Worthington and Hoffman, 2008) are some of the most prominent ones. Customers do not respond to the marginal price of water, but to an average when this is the value showed in the bill (Binet et al., 2013; Thaler and Sunstein, 2008). Financial incentive programs general focus on rebates for installing efficient appliances or replacing turf with water saving landscapes. Appliance rebates have led to permanent reductions in water use (Price et al., 2014). But in outdoor use more technology may not reduce outdoor water use.

Declines in indoor residential water use has resulted from increased efficiency of water appliances and plumping fixtures (Vickers 2001). These generally include low volume flow flush toilets and urinals, washing machines, dish washers, faucets. In older homes utility rebates provide financial incentives for upgrades. The U.S. General Accounting Office found that federal and states laws and local ordinances and plumbing codes mandating water efficient appliances and plumbing fixtures conserves water (US General Accounting Office, 2000).

For outdoor water use regulatory restrictions can include limiting turf areas, requiring specific landscape plants, and irrigation time of day and day of the week watering requirements. They can also restrict any nonessential use like filling swimming pools. Efficacy research on regulatory restrictions is not conclusive regarding savings (Ozan and Alsharif, 2013). During a restriction in Southeast Florida it was observed that people still were using more water than the required (Survis and Root, 2012), and in some cases more than before the restriction were imposed, people still overwatered in periods of rainfall. This indicates the need to improve the communication with the different households (Survis and Root, 2012). Ozan and Alsharif (2013) analyzed multiple restrictions in Tampa, FL and found similar results. Generally, when residential customers perceive that water is scarce, they are more likely to reduce their consumption (Binet et al., 2013; Corral-Verdugo et al., 2002).

Educational interventions are intended to encourage homeowners to voluntarily reduce water consumption. They include public service announcements in different media outlets, brochures, material and program for schools, budget and consumption mailings to homeowners, websites, workshops and utility conducted homeowner irrigation checkups. Fielding et al. (2013) found that interventions can generate reductions in consumption. However, Kenney et al. (2004) found that users tend to go back to previous level of consumption after the intervention ends. Landon et al. (2016) in a homeowner survey found a limited correlation between homeowner conservation attitudes and reductions in consumption. This was corroborated by another study that found no direct relation between homeowner attitude and behavior (Heberlein, 2012). There is a difference between expressing an intent to save water and a reduction in consumption. When this difference is properly explained to users you observe better results (Aitken et al., 1994).

Water budgets are a useful approach, they can be computed with monthly data that is available in most utilities (White et al., 2004). Some utilities have used water budgets to define a price structure (Baerenklau et al., 2014), but this contradicts the goals of water pricing. It should pursue equity, financial stability, simplicity (OECD, 1997), economic efficiency, environmental efficiency, consumer acceptability, and transparency (OECD, 1999). It would be too hard for users to know the value of the budget in real time and the amount of water they are using, and this would be key information for a user to decide how much water apply in any given time. The Weekly Watering Program (WWP) applied in College Station provide users with this information. Better technology does not necessary mean less water use when we look outdoor usage, in fact, people that irrigates using a hose use about a third less water (Mayer et al., 1999) than those who possess a sprinkler system. This is contrary to the observed indoor, where more efficient technology can significantly reduce consumption. Water audits are also a common measure that is used by utilities to achieve outdoor water use reduction, in these audits, problems with the sprinkler systems can be fixed, users can learn how to better use their system and utilities could change their irrigation schedule of users in different sectors in these audits, but this is at the end a homeowner preference.

Profiling water users can help utilities to target the right customers. Conservation efforts sometimes are lost by using the right intervention in the wrong group of users (Vickers et al., 2013). This problem can be caused by the difficulty in processing information out of large datasets and other technical difficulties. Demand management activities offer many benefits for utilities, for example the cost of implementing such measures is low in comparison with supply expansions, we could look at the cost of building new reservoirs in cases where surface water is the source, or the cost of new wells, water towers and infrastructure for groundwater. These projects would require long period of times to be completed but the results of demand management can be observed in shorter periods of time. Results from this investigation will help to inform what type of program or policy can be implemented to reduce residential water use according to the characteristic of the different users in the city of College Station and can work as an example for other water utilities.

1.1 Research objectives

Classifying users for educational interventions is important to have information tailored for each group. Overwatering needs to be evaluated in terms of frequency and volume. The potential for water savings by applying only the water required by a landscape is significant (Kjelgren et al., 2000). Comparing the results from educational interventions can help to understand the potential and limitations of each one.

The purpose of this study was to analyze water use for residential users in College Station and asses the effectiveness of three educational interventions to reduce outdoor water use. This was accomplished through the following objectives:

1. Profile all residential customers in the city of College Station.
2. Analyze outdoor water use before and after each educational intervention.

The educational interventions studied here are; the water budget, the weekly notifications program and the free irrigation check-ups.

The methodology used to each objective is described in section 3.

2. STUDY AREA AND DATA

2.1 Study Area

College Station is a rapidly growing suburban community in east central Texas. The U.S. Census Bureau (2012) estimates there are roughly 100,000 residents in the city. City planning officials expect that College Station, and the central Texas region in general, will undergo significant growth in population over the next several decades (City of College Station, 2014). As a result of these projections it is expected that there will be an unmet water need in the city of around 6,000 acre feet by the year 2060 (TWDB, 2012). The city currently relies exclusively on groundwater from the Carrizo-Wilcox formation for municipal supply, which is also a major water source for agriculture including cattle, poultry and cotton, as well as oil and gas development (Nicot and Scanlon, 2012; USDA, 2012).

The local climate is humid, (Cress and Sayre, 2009), characterized by mild winters and warm, hot summers. Daily high temperatures range from 61°F in January to 96.2°F in August. Precipitation in College Station varies substantially throughout the year, with the lowest monthly averages occurring in July (2.14 inches) and August (2.68 inches) which coincide with the period of the year with the highest levels of residential irrigation water use (NOAA, 2016). About 60% of the city's residential water use occurs between April through October, coinciding with the growing season for warm season cool grasses common to this region of the United States. Peak residential water use typically occurs in August and is more than twice the total use in January, when water use is lowest.

2.2 Data

College Station has provided a database of monthly water use for 23,792 residential customers for the period 2008 to 2016. This database is account number coded to protect the identity of a specific customer. The database includes an account number for customers receiving educational water interventions. Monthly water use is determined by the utility by taking the difference between current and previous meter readings. This method is convenient for billing purposes, but meter readings do not coincide with the first and the last day of a month, and the number of days in a billing cycle varies across neighborhoods. Residential water use data was realigned to monthly consumption, according to the meter reading date, by using an algorithm that proportionally divides meter readings based on the number of days between a meter reading and the previous one to generate on consumption value per month for each user. (see Table 1).

Although the city possesses the capacity to expand pumping to meet future demands, conservation is the preferred alternative to preserve supply for future needs. Conservation is one of the main mechanisms that water managers have identified to meet these needs. Over the past six years the city has employed three educational interventions to either reduce water use, this thesis offers a comparative analysis of these interventions. These interventions include residential water budgets, irrigation checkups and weekly water notifications.

Table 1 Summary of data used in this study

Variable	Definition	Source
Monthly water use	Total water use per household (10^3 gallons)	CS Utilities – Water Services
Evapotranspiration	Monthly evapotranspiration (in.)	Texas ET Network
Precipitation	Monthly precipitation (in.)	Texas ET Network - Station US1TXBZS013 NOAA.
Irrigable Area	Area of each property that requires irrigation	Lewis (2014)
Participation in the different programs	List of households that have participated in each one of the interventions.	CS Utilities – Water Services

2.2.1 Intervention 1: Water Budgets

Within residential customers, 5565 single family residential were identified based on the criteria of having a total water consumption greater than 100,000 gallons during the months where irrigation occurs, referred as summer months here (April through October) (Lewis, 2014). The consumption by these users represent approximately 40 percent of the total SFR consumption.

Recipients of water budget intervention receive a letter at the beginning of the rainfall period outlining their irrigation performance from past year, and provide a comparison between the amount of rainfall and evapotranspiration and the total estimated water use vs the total budget for the year. A sample chart from one user in 2015 is given in Figure 1.

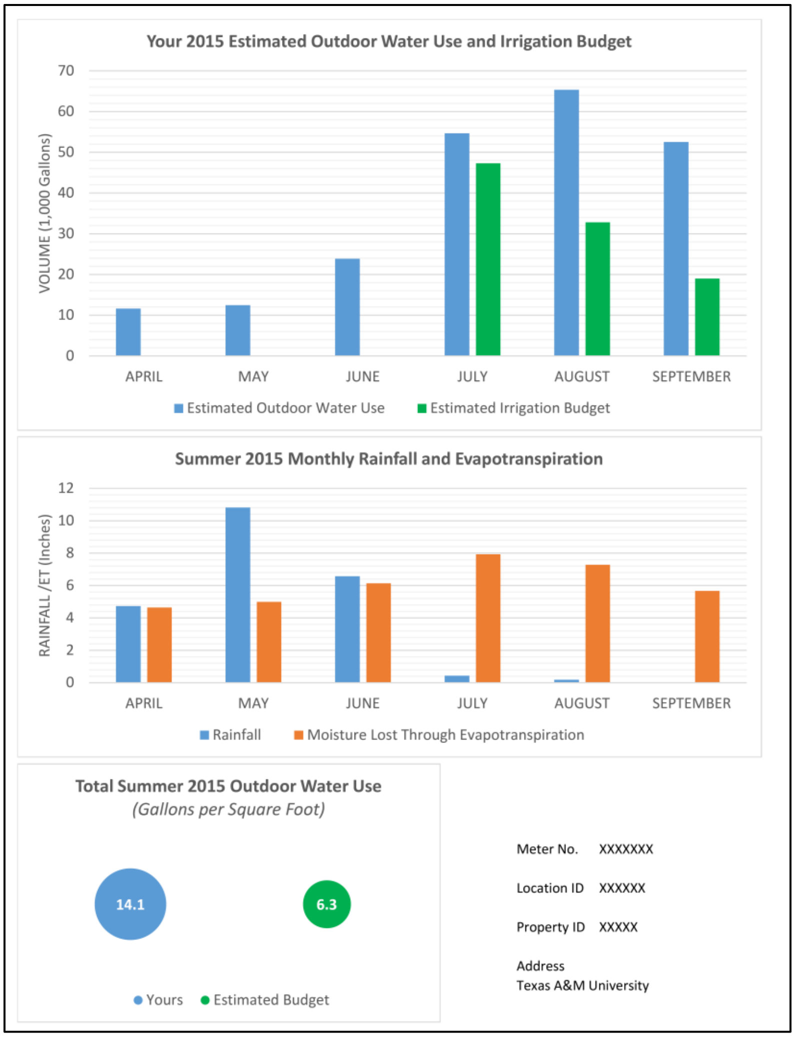


Figure 1 Sample of the water budget received by users participating in this program

2.2.2 Intervention 2: Irrigation check-ups

The irrigation system can be one of the primary sources of overwatering (TWDB, 2013). A proper system design, maintenance and operation can help reduce overwatering. Landscape irrigation evaluations (called audits, checkups) are widely used to promote efficient use and reduce overwatering (Baum et al., 2005; Olmstead and Stavins, 2009). Causes of irrigation excess are maintenance issues such as; leaks or misaligned spray heads, incorrect spray patterns, excessive irrigation zone run times and users that do not know how to program their irrigation controller (Bargar et al., 2004; Endter-Wada et al., 2008; Vickers, 2001). These type of problems can be solved with the information provided in an irrigation check-up (Nations, 2016).

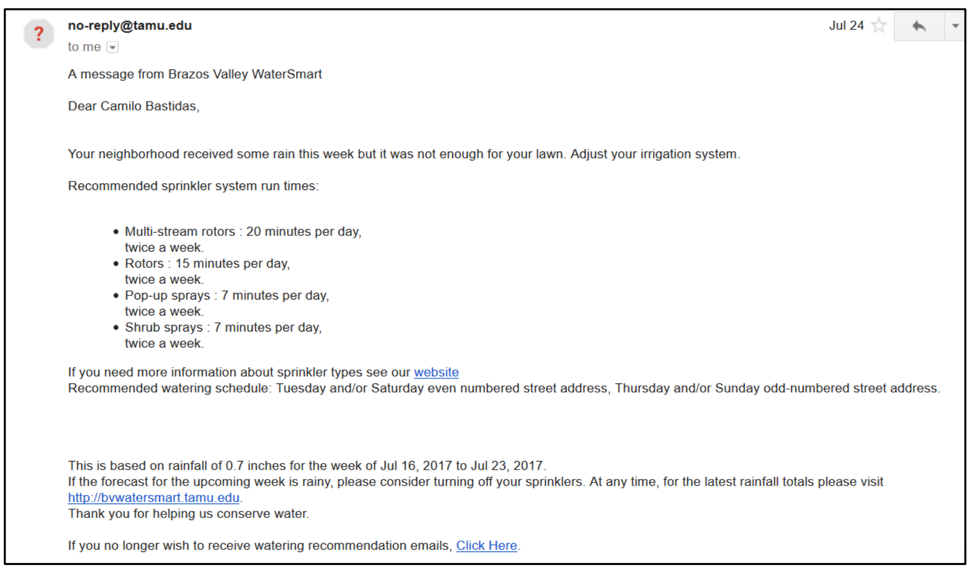
Other studies have found reductions between 5 to 30 percent after irrigation checkups have taken place (Gregg et al., 2007; Rice, 2009). The irrigation check-ups offered by the city are intended to point out water excess consumption and provide specific recommendations for fixing such problems, they do not include distribution uniformity or soil moisture measurements as described in other studies (Glenn et al., 2015; Thomas D et al., 2009). In the irrigation check-up, customers are shown how their water meters works, how to check their leaks indicator. The irrigation areas are visually inspected, with instructions for placement, maintenance and operation of the sprinklers heads (Nations, 2016). Also a recommended irrigation schedule is provided to the user with suggested days and timed for their specific landscape conditions (Nations, 2016).

2.2.3 Intervention 3: Weekly watering notifications

Participants in this program receive weekly information about their landscape water requirements for the following week. If no irrigation is required, the message will be; “Rainfall in your neighborhood this past week provided all of your lawn water needs”. In cases where irrigation is needed, the message will give information about the running times for each irrigation system. The recommended sprinkler system run times managed in this program are:

- Multi-stream rotors: 40 minutes per day, twice a week.
- Rotors: 30 minutes per day, twice a week.
- Pop-up sprays: 15 minutes per day, twice a week.
- Shrub sprays: 15 minutes per day, twice a week.

If rainfall provided part of the landscape requirement, the suggested running time will be adjusted to meet the portion still needed. Figure 2 shows a sample email sent to users. Users can register for this program in the website http://bvwatersmart.tamu.edu/.



no-reply@tamu.edu Jul 24

to me

A message from Brazos Valley WaterSmart

Dear Camilo Bastidas,

Your neighborhood received some rain this week but it was not enough for your lawn. Adjust your irrigation system.

Recommended sprinkler system run times:

- Multi-stream rotors : 20 minutes per day, twice a week.
- Rotors : 15 minutes per day, twice a week.
- Pop-up sprays : 7 minutes per day, twice a week.
- Shrub sprays : 7 minutes per day, twice a week.

If you need more information about sprinkler types see our website
Recommended watering schedule: Tuesday and/or Saturday even numbered street address, Thursday and/or Sunday odd-numbered street address.

This is based on rainfall of 0.7 inches for the week of Jul 16, 2017 to Jul 23, 2017.
If the forecast for the upcoming week is rainy, please consider turning off your sprinklers. At any time, for the latest rainfall totals please visit http://bvwatersmart.tamu.edu.
Thank you for helping us conserve water.

If you no longer wish to receive watering recommendation emails, Click Here.

Figure 2 Sample email from the WNP

3. METHODS

This study examines participants monthly and annual outdoor water use before and after each intervention. Estimating outdoor water use is complex because metering outdoor and indoor water use separately is not a common practice. In this study, the average winter consumption (AWC) method was used to estimate outdoor use, by examining monthly use during November to February where consumption is lowest. This is assumed to be indoor water use for the year. This amount is substracted form the consumption during the growing season to obtain outdoor water use. This method may underestimate outdoor water use if the household irrigates the entire year (Mini et al., 2014) however it is accepted practice in cities with seasonal irrigation (DeOreo and Mayer, 2012).

3.1 Residential users profile

Water use from all residential users in College Station were analyzed, using the methodology proposed by Wolf et al. (2015). This establishes consumption levels for winter and summer months. These consumption levels are defined by the percentile of the first year of data available. It is possible to observe changes in consumption by examining how users move between the different levels through time. The Mann Kendal Seasonal test as proposed by Hirsch R. et al. (1982) with modifications introduced by Ibiseller C. and Grimvall A. (2002) was used for trend analysis.

Decomposing the consumption into trend, seasonal and reminder improves the understanding of water use variations in the city. It was possible to observe which components of the data have the biggest importance and to see how the trend varies over time. Users that do not irrigate (or do it with insignificant volumes) were identified by examining variations between winter and summer water use. Their average consumption was compared to the rest of the users to observe the annual variability in both groups.

3.2 Effectiveness of the educational interventions

3.2.1 Intervention I: Water budgets

A water budget is an accounting of the water that goes in and out for outdoor water use. If we assume that the water requirements are equal to the evapotranspiration that occurs, then the water budget will be; Budget=Evapotranspiration–Precipitation. With this equation, we can obtain the amount of water that is not supplied by precipitation, which equals, in theory, the volume that people would need to apply by irrigation. In order to obtain the specific budget for each customer we need additional information, equation 1 (Lewis, 2014) shows the water budget equation used.

$$Q_{IR}(t) = cA_{irr}(k_c ET_o(t) - P(t)) \qquad (equation\ 1)$$

Where Q_{IR} is the water budget volume for month *t* (gallons), *c* is a conversion factor to volumetric units (7.48 gal/ft^3), A_{irr} is the irrigable landscape area (ft^2), k_c is the crop coefficient for St. Augustine grass (0.65). ET_o is the average monthly potential evapotranspiration (in), and P is the cumulative monthly precipitation (in).

With a water budget thee volume of water required for a landscape can be calculated Ideally this method should take into account the different plant types and the efficiency of the irrigation system used (USEPA, 2013b). In this study, landscape areas were derived from Lewis (2014) who estimate them by combining appraisal records obtained from Brazos Central Appraisal District with planimetric mapping data furnished by the City of College Station. This resulted in highly accurate delineations for all buildings, driveways, and sidewalks.

The changes in volumes, number of months over the budget and the value of efficiency indices will help to estimate the results of this intervention. We examined at changes in this excess volume, related to the specific climatic condition for each month, trends and changes in the volumes and the indices were estimated to evaluate the evolution of the water use of these users. Indices proposed by Glenn et al. (2015) (equation 2) and Survis and Root (2012) (equation 3) were used to assert the most inefficient users. Compliance with the budget was analyzed using the number of times a user exceeds the budget and the volume of excess applied.

$$Landscape\ Irrigation\ Ratio\ (LIR) = \frac{Landscape\ Water\ Use}{Landscape\ Water\ Need} \qquad (equation\ 2)$$

$$Conservation\ Effectivenes\ Ratio\ (CER) = \frac{Target\ Use}{Actual\ Use} \qquad (equation\ 3)$$

3.2.2 Intervention 2: Irrigation check-ups

In this intervention, the location ID's for the users participating was obtained from College Station Utility company. Users receiving the notifications were analyzed using methodology described in section 3.1. Changes between outdoor water use before and after each intervention were identified using the Wilcoxon rank test, applied as proposed by Bauer (1972) and Wolfe (1973). In this study, the two-sample test was applied to estimate whether the distribution of x (before the intervention) and y (after the intervention) differ by a location shift. The samples sizes used to compare after and before intervention outdoor water use, and the presence of abnormal large values suggest that this test would give better result that the parametric alternative.

To test how many users in are decreasing their consumption in the past years the Mann-Kendall Seasonal (MKS) test was applied. The Mann-Kendall statistic in this case is calculated for each season using equation 4, and the statistic for the entire series in estimated using equation 5 (Hirsch R. et al., 1982). In this study, the test was applied assuming annual seasons, this means that each month is compared only with the same month (equation 4) and then it is averaged for the entire period (equation 5).

$$S_g = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(X_{jg} - X_{ig}\right), g = 1,2,\dots,m \qquad (equation\ 4)$$

$$S_g = \sum_{g=1}^{m} S_g \qquad (equation\ 5)$$

Where, *g* represents each month, *i* and *j* represent the years, *sgn* is the sign of substracting the value for one month from the value for the same month in the previous year, *n* is the number of years available (9) and *m* in this case is equal to 12 (annual seasonality).

3.2.3 Intervention 3: Weekly watering notifications

Rainfall information came from 17 rainfall stations in the city providing near-real time information and the Thiessen polygon method was used to find the station corresponding to each neighborhood. In Figure 3 we have monthly data from 11 of these stations (those without missing data from 2015 to 2016) and Figure 4 shows the locations of the stations in the city.

This program started in 2015 and the number of participants is expected to increase. The differences observed in Figure 3 suggest that the approach used, by using multiple rainfall stations will provide better information that previously used approaches where rainfall from a single rainfall station was used. Data was analyzed using the software R developed by R Core Team (2016).

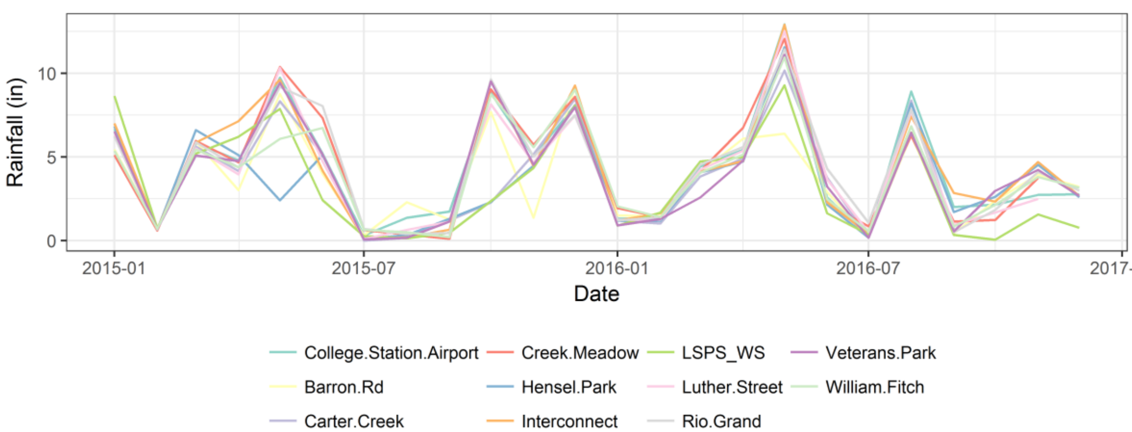


Figure 3 Rainfall in 11 stations in the city of College Station from 2015 to 2016

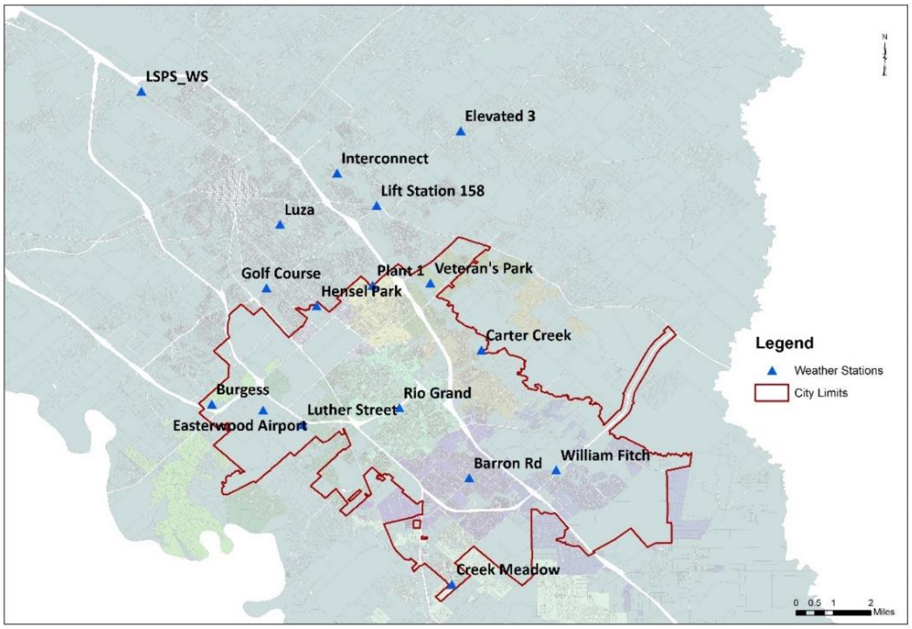


Figure 4 Locations of weather stations used to estimate weekly landscape requirements

4. RESULTS AND DISCUSSIONS

4.1 Residential customers profile

There are 23,792 residential customers in College Station. This list includes apartments and duplexes and 13,976 are single residential family. Of the total users, 479 have cero consumption in the study period (2008-2016). These could be older accounts that are no longer in use, and the city has not purged the record. There are 755 accounts with no consumption in 2016.

A single person in an efficient house can consume as low as 1,500 gallons per month (Runfola et al., 2013; Vickers et al., 2013). Wolf et al. (2015) propose a 1,000 gallon per month as a safe low metric to remove from conservation analysis. It was assumed that accounts with consumption below 1,500 gallons per month have no potential for conservation, since it is the low benchmark for efficient use, and were removed from the data used.

In the dataset analyzed we found 1,511 users with a monthly average consumption below 1,500 gallons for 2016 and 267 for the entire period of analysis. These users are removed from further analysis. After removing these group of users, we ended up with 20789 customers used for the analysis. Table 2 summarize the accounts that were removed from the dataset before any analysis.

The residential users consume (in average) 2,040 10^6 gallons every year. The monthly variation of water use in residential users can be observed in Figure 5. Data indicates that the largest use occurs from May to October. The consumption in these months can be as much as 3 times the consumption in December, January or February (the months of lower use).

Table 2 Water Use Data available (2008-2016)

Monthly water use data (2008-2016)	# of accounts
Total	23,792
Accounts with no consumption from 2008 to 2016 (accounts closed)	470
Accounts with an average consumption lower than 1,500 gallons per month from 2008 to 2016	267
Accounts with no consumption in 2016 (accounts closed between 2008 and 2016)	755
Accounts with an average consumption lower than 1,500 gallons per month from 2008 to 2016	1,511
Accounts that will be used for the analysis	20,789

The average monthly consumption is 8,837 gallons for all users. The largest users, consume more than 50,000 gallons every month, in average. If we look at the median consumption, we find some of them are not constantly consuming large amounts of water, in half of their records, they use less than 15,000 gallons per month. Their large average is caused by one or two months of extraordinary large consumptions. Isolated events don't have potential for conservation, they can be addressed using new technologies, such as smart metering, to detect leaks and other issues on time. We have users that consume in average more than 50,000 gallons per month and that half of the time are using more than 50,000 gallons per month. In these group of users, we have the largest conservation potential. We must look not only at the volumes used, but also at the frequency at which largo volumes are applied to find users suitable for conservation efforts.

Table 3 Top residential users in College Station

Total Water Use	Months with use	Monthly Average (10^3 gallons)	Median Consumption (10^3 gallons)
10,406	99	105	14
10,387	108	96	13
10,034	106	95	8
8,588	104	83	7
8,611	108	80	68
8,304	108	77	70
5,855	78	75	81
2,371	33	72	70
7,379	108	68	57
6,480	108	60	49

Annual variability is highly important in water use classification in College Station. In the summer months water consumption is higher than the rest of the months. Consumption in the summer months (April – October), and in winter months (November – March) will be evaluated separately. The goal is to find users that are suitable candidates for future and present conservation programs.

The mean winter consumption, as defined here, is 5,878 gallons per month and during summer months it is almost as twice this value (10,390 gallons). The median consumption is 4,516 and 6,320 for each period respectively. This difference between the median and the average consumption indicates that there is a group of users that have large consumptions during summer months, driving up the average.

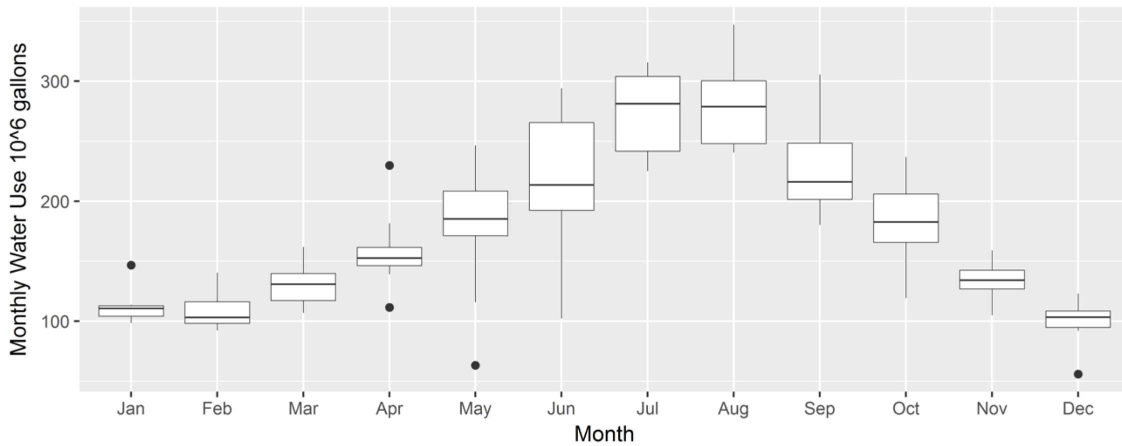


Figure 5 Monthly water use by the residential customers in College Station from 2008 to 2016

In fact, 7,528 users do not change their consumption significantly from winter to summer months, it remains nearly constant all year long indicating that they do not irrigate. The monthly consumption for these users is listed in Figure 6. We observe variations across the year, but smaller in comparison to the ones in Figure 5.

About 36 percent of residential users do not irrigate, or they use very little water outdoor. These 7,528 users show no potential for outdoor conservation. Table 4 shows the difference in use between users that do not irrigate and those who do. Average water use in summer months, among those who irrigate, can be more than three times their winter use.

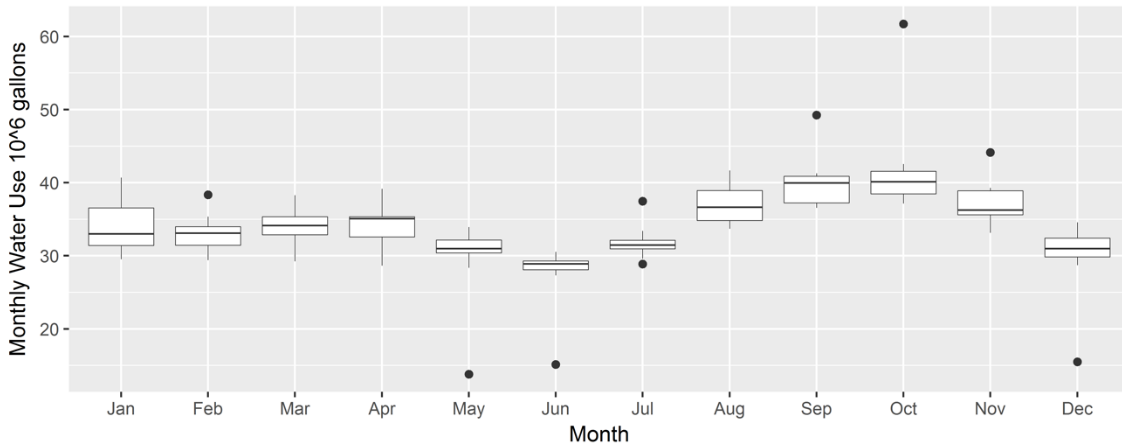


Figure 6 Monthly water use by the 7,528 users with minimum annual inter-variability in their consumption

The differences between the volume of water used in summer months and winter months for all residential users are presented in Figure 7. Consumption in the winter months present small variations, insignificant in comparison with changes observed in outdoor use.

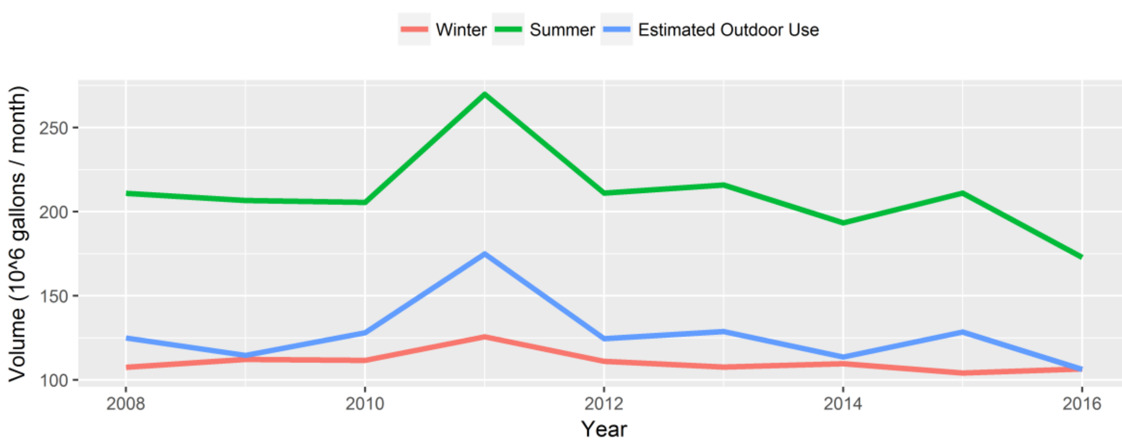


Figure 7 Annual volume of water used by all residential customers in College Station from 2008 to 2016

The estimated outdoor water used is computed for all users, but we should not forget that an important group of them do not irrigate. The volumes are given in gallons per month to make comparison easier between the different categories and standardize the units. The volume used in summer months can be more than 250,000,000 gallons, more than double than the summer use, and half of these volume correspond to outdoor water use. Estimated outdoor water use in the city accounts for about 70% of the use in summer months and 50% of the annual consumption. Water use in the winter months doesn't vary significant from one year to the next. The fluctuation observed in summer months can be explained by looking at outdoor water use changes.

Table 4 Average water use by month (10^3 gallons) for users that irrigate and users who do not

Month	Users that do not Irrigate	Users who irrigate
Jan	4.5	5.3
Feb	4.4	5.1
Mar	4.5	6.7
Apr	4.5	8.7
May	3.9	10.6
Jun	3.7	13.7
Jul	4.2	17.8
Aug	4.9	17.9
Sep	5.3	14.0
Oct	5.6	10.4
Nov	5.0	6.9
Dec	4.0	5.1

4.1.1 Classification and trends in water use

User were classified according to levels of consumption, using seasonal percentiles from the first year of data available (2008) into groups of similar consumption. In conservation efforts saving the biggest volume is the goal, then users in level 3 and 4 should be the focus. Four categories have been defined using the following criteria;

- Level 1: users with consumption below the 50^{th} percentile.
- Level 2: users above the 50^{th} and below the 75^{th} percentile.
- Level 3: users above the 75^{th} and below the 90^{th} percentile.
- Level 4: users above the 90^{th} percentile.

Levels have been defined for winter (indoor), summer (indoor + outdoor) and for the estimated outdoor water use. It is easy to identify potential candidates for conservation programs by selecting users in the top levels. These users are not necessarily more inefficient than the rest, but it is in these groups where we find the biggest potential for savings (in volume) despite the efficiency. Table 5 shows the resulting levels for each of the categories used. Table 6 shows the number of users in each of these levels for each year between 2008 and 2016. The number of accounts in level 4 decrease over time, for winter, summer and outdoor use, people are moving to lower levels of consumption. The city of College Station has tried several educational interventions with the largest water users in the city since 2011 and implemented an increasing block rate structure in 2008. Users in level 4, for summer months, consume more than 168,000 gallons from April to October, resulting in a monthly average of 18,000 gallons. A user in level 4, for outdoor water use, consumes more than 126,000 gallons. Each consumption section is evaluated separately, a user can be in level 4 for outdoor use may not be in the same level when looking at total use in those months. During winter months, users that consume more than 50,000 gallons are in level 4. Users that are in level 4 during winter and summer, consumed more than 218,000 gallons of water in that year.

Table 5 Monthly consumption levels (10^3 gallons)

Levels	Winter	Summer	Outdoor
1	< 4	< 6	< 2
2	4 - 7	6 - 14	2 - 8
3	7 - 10	14 - 24	8 - 18
4	> 10	> 24	> 18

The accounts without consumption during winter and summer also decrease, this means that some of the accounts analyzed were opened after 2008. In 2011, the year of the drought, outdoor water use was the highest in the city, we have the largest number of accounts in levels 3 and 4 during this year. Another important result from Table 6 is that in all years we have more than 1,000 households that consume more than 10,000 gallons per month in the winter, 540 of them have been in this category of consumption for the past two years. There are more than 1,000 users consuming more than 24,000 gallons during summer months all years, except for 2016. Users in categories 4 and 5 can be selected, as a first approach for future educational interventions. In the next section, the consumption of users in educational programs will be analyzed and how they rank in relation to all users.

Table 6 Number of users in each level of consumption in each year (Budget program).

Winter

Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 4	7,104	7,142	7,367	6,578	8,163	8,980	9,161	10,489	10,242
4 - 7	5,586	5,661	5,898	5,545	5,963	6,097	6,354	6,336	5,922
7 - 10	3,621	3,866	3,942	4,522	3,801	3,510	3,462	2,835	3,122
> 10	1,901	2,026	1,850	2,724	1,761	1,469	1,453	1,112	1,432
NC	2,577	2,094	1,732	1,420	1,101	733	359	17	71

Summer

Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 6	6,962	7,105	7,819	6,817	8,180	8,112	9,459	8,982	10,791
6 - 14	5,397	5,802	5,605	4,654	5,837	6,064	6,242	6,648	6,279
14 - 24	3,899	4,196	4,033	4,425	3,941	4,157	3,495	3,859	2,844
> 24	1,897	1,524	1,561	3,395	1,651	1,652	1,163	1,291	780
NC	2,634	2,162	1,771	1,498	1,180	804	430	9	95

Estimated outdoor

Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 2	5,729	5,757	6,385	5,588	6,783	6,468	7,753	7,212	8,495
2 - 8	5,739	6,863	5,987	5,171	6,299	6,827	6,672	7,125	7,120
8 - 18	3,919	4,283	4,212	4,682	4,142	4,459	3,815	4,288	3,306
> 18	1,773	1,113	1,753	3,215	1,599	1,534	1,271	1,418	820
NC	3,629	2,773	2,452	2,133	1,966	1,501	1,278	746	1,048

NC: No consumption in the period.

In Figure 8 we have the variation of residential water use over time and the trend estimated by decomposing the time series using STL (Seasonal and Trend decomposition using Loess). The seasonal component was selected to be periodic (identical for all years) to observe the variation in the trend and not in this component. The results indicate that seasonality is the most important factor to explain the variation over time in water use, as we would expect, and this seasonality is driven by outdoor water use. The values observed in May and June in 2016 are unusually low, corresponding with large negative values in the reminder. Trend in water use for total volume consumed change its direction in 2011 to a decreasing trend, but in general, its variation is low enough to conclude that there is no trend in water use for all users. The result of the seasonal Mann-Kendall trend test also suggests a decreasing trend, but this result is statistically nonsignificant.

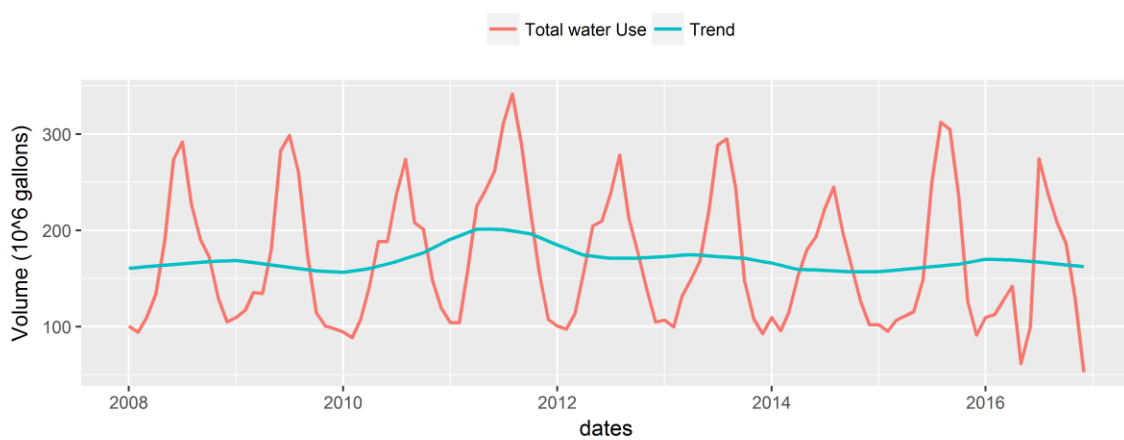


Figure 8 Total water use by residential users in College Station and trend

Applying this test individually to residential customers in College Station with a record longer than 24 months (19751 customers), with a confidence level of 95%, indicates that 11589 users have significant trends in their consumption. In 8806 cases this trend is downward, while in the rest (2783) it is upwards. Of these users, we have 68 which are constantly in the top consumer levels shown in Table 6. These 68 users can be the primary target of future conservation plans; they are the largest users in the city and their consumption increases significantly over time.

4.2 Effectiveness of the educational interventions

Assessing the effectiveness of educational interventions is not an easy task, the variability of outdoor water use and monthly rainfall makes it hard to estimate savings. Relation between rainfall and outdoor water use is an important indicator. If a customer uses more water on a dry year, according to their landscape needs, this cannot be considered inefficient. However, analyzing yearly rainfall is not enough to provide an insight in whether a user is inefficient or nor. If that rainfall occurs in winter months, outdoor water use cannot be related to the rainfall in that year. Evapotranspiration volume doesn't vary drastically from one year to the other (Table 7) as rainfall does. Also, intra-annual variability is almost the same for all year. The combination of these 2 variables is what should drive customer decisions for setting their irrigation system.

Table 7 Annual rainfall and evapotranspiration in College Station

Year	PET (in)	Rainfall (in)
2008	53.74	26.95
2009	52.95	37.89
2010	52.35	27.21
2011	61.75	17.51
2012	54.80	38.56
2013	58.54	41.97
2014	58.23	40.81
2015	54.82	58.34
2016		46.82

Monthly rainfall is more suitable to be related with outdoor water consumption, but daily distribution it is also important. If rainfall in a month exceeds the amount of water required by the landscape, the budget for that month will say that no water is required. If that rainfall occurred in the last 3 days of the months when all water consumption had already taken place, all outdoor water use will be wrongly marked as an excess. Since water consumption is available in a monthly basis, a more detailed analysis of rainfall won't lead to better results. In Figure 9 we observe the annual variation of rainfall in the period of analysis. 2011 have the lowest rainfall values for the period. 2015 and 2016 are the rainiest years, and the rainfall occurs in the summer months. If users are becoming more perceptive about landscape water needs then we can anticipate that 2015 and 2016 should have lower outdoor water consumption than previous years.

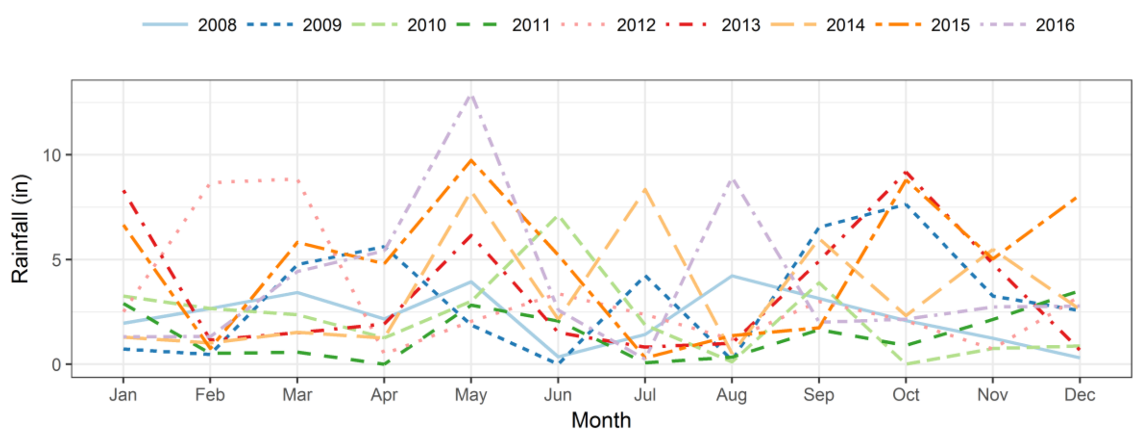


Figure 9 Monthly rainfall in Easterwood Field station from NOAA (2008 – 2016)

4.2.1 Intervention 1: Water Budgets

5565 users were selected for this program. In Table 8 we find the number of users in each level of consumption associated to the values presented in Table 5. We observe that users in this program are distributed across all levels of consumption, however most of them are in the uppers levels. Most users in this program used between 14,000 to 24,000 gallons each summer month in 2008. The number of people using more than 24,000 in summer months (level 4) decreases over time. There were more than 100 accounts in this group that show 0 consumption in 2008, but in 2016 we have less than 10. 2011 is the year with the larger consumption, we have more than 4000 users in this group consuming more than 23,000 gallons in the summer months for that year. Consumption in this group decreases over time (Figure 10). Starting in 2012 we observe a decreasing trend in outdoor water use in this group.

Table 8 Number of users in each level of consumption in each year (Budget program).

Winter

Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 4	1120	1103	1097	744	1317	1592	1613	2193	1837
4 - 7	1700	1654	1810	1434	1815	1858	1887	1920	1782
7 - 10	1597	1666	1719	1937	1551	1444	1421	1021	1248
> 10	972	1045	879	1394	833	622	592	378	644
NC	131	52	15	11	4	4	7	8	9

Summer

Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 6	436	467	605	354	631	608	938	849	1228
6 - 14	1655	1792	1727	1056	1801	1776	1989	1947	2248
14 - 24	2034	2243	2135	2010	2031	2078	1842	1903	1521
> 24	1250	957	1035	2087	1049	1048	744	821	518
NC	145	61	18	13	8	10	7	0	5

NC: No consumption in this period.

Applying the MKS test to residential customers in College Station with a record longer than 24 months (5519 customers), with a confidence level of 95%, indicate that 3370 users have significant trends in their consumption. In 2926 cases this trend is downward, while in the rest (444) it is upwards.

All users in this program have data pre and post interventions. Using the Wilcoxon rank test, with a confidence level of 95% to detect changes we find that 328 users have increased their consumption after being part of the budget intervention and 2,178 users have significantly decreased their outdoor water use. For 3,014 users no significant change was detected. The average change in volume for the 2178 users that had a positive change was 1,660 gallons per month (in outdoor water use), while the average increase was 846 gallons per month. Most of the users that participated in this program (97%) have a weak negative correlation with rainfall, meaning less outdoor water use as rainfall increases.

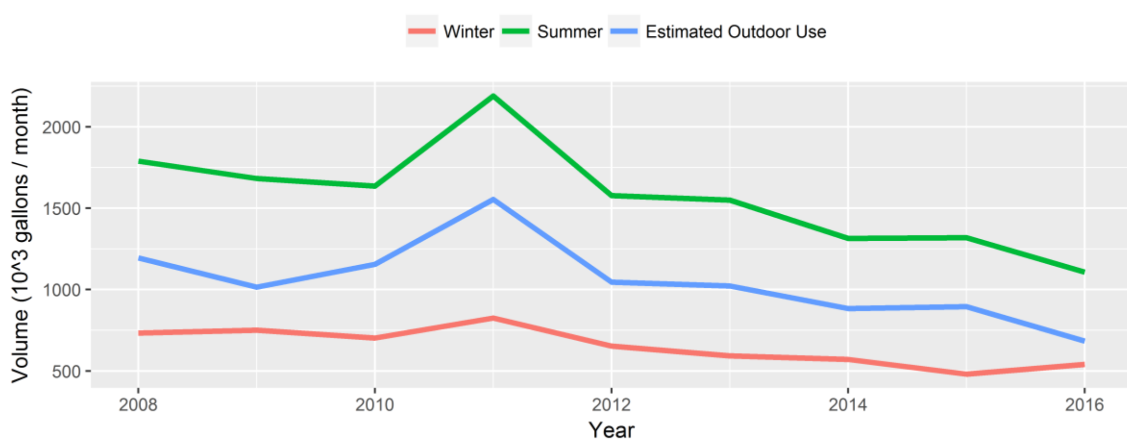


Figure 10 Average consumption by users in budget intervention (2008 – 2016)

In Table 9 we have the distribution of the number of months each user has exceeded the budget amount from 2012-2015 (28 months in total). Some users that were previously receiving the water budget were below it most of the time. Their budget will show they are below the requirements and this can lead them to consume more water. The water budget is now being sent to users that overwater frequently.

Table 9 Number of months each user has exceeded the budget amount between 2012-2015

Number of months over the budget	Number of users
0 - 4	64
4 - 8	565
8 - 12	927
12 - 16	1077
16 - 20	1335
20 - 24	1112
24 - 28	440

The number of users receiving the budget has been reduce to 500, users that had been constantly over the budget, with an exceeding volume larger than 50,000 gallons each year. 497 users were found to comply with these conditions. The excess volume of this group (9% of the users) of users can represent up to 28% of the annual excess by all users in this intervention.

The size of the budget has a direct impact in the number of users that exceed it. In 2011 the budget size was the largest of all, then we have less users exceeding it. In Figure 11 we can observe that in months when the budget is zero we have the largest number of users exceeding the budget. This indicates that users were still irrigating and rainfall had provided all the water the landscape needed. Combining the results from

Figure 11 and Table 10 we observe that the largest excess volume is also generated in those months.

Table 10 Excess volume (1,000,000 gallons) by all users in the budget compares to the 497 selected by being above the budget from 2012-2014

Year	2012	2013	2014	2015
Excess Volume by all users.	203	194	225	214
Excess Volume by the 497	57	52	61	58
Percentage of all excess	28%	27%	27%	27%

Figure 11 Number of users over the budget (blue) and deficit (red) (evapotranspiration – rainfall) from 2012 to 2015

In Table 11 and Table 12 the results of the LIR and CER are presented. According to the LIR 1290 users need to improve their irrigation efficiency. According to the CER 2431 users are ineffective in their outdoor water use. These indices do not provide information about the efficiency in the months where we have observed the largest volume of water being wasted, and the largest number of people exceeding the budget. Using these indices to select and target inefficient users could lead to miss those users that waist the largest volumes.

A combined approach looking at frequency of overwatering and the excess volumes is the most efficient way to find those users with the biggest potential for a conservation intervention that uses the budget as the target. A new index combining both factors can be developed, specifically, for each level of reduction wanted. Percentages related to the budget will fail in this purpose.

Table 11 Categories of use according to the indices LIR

Justifiable water use		Number of Users
Efficient	LIR ≤ 1	2241
Acceptable	1 < LIR ≤ 2	1989
Unjustifiable water use		
Inefficient	2 < LIR ≤ 3	790
Excessive	3 < LIR	500

Table 12 Categories of use according to the CER

Values	Category	Number of Users
0 > CER ≤ 0.34	Highly Ineffective	684
0.35 > CER ≤ 0.67	Ineffective	1747
0.68 > CER ≤ 1	Effective	1108

In Table 13 we have the total excess volume by all users receiving the budget. The excess volume decreases in the last years. The smallest value is observed in 2011, because the budget is that year is the largest of all. 200 million of gallons are wasted every year by the users receiving a budget. In 2008, 2014, and 2015 the budgets are the smallest, but in 2014 and 2015 the excess volumes are smaller than in previous years. This indicates that conservations programs are having a positive effect in reducing the excess volume.

Table 13 Total excess volume and budget size (1,000,000 gallons) by year (April to October) for all users in this intervention

Year	Excess Volume	Budget	Year	Excess Volume	Budget
2008	280	265	2012	203	352
2009	185	328	2013	194	366
2010	229	353	2014	225	288
2011	166	664	2015	214	293

4.2.2 Intervention 2: Irrigation check-ups

Irrigation checks up have been offered since 2010 in the city of College Station. Nations (2016) analyzed the results from the irrigation check-ups offered by the city between 2012 and 2013 for 173 properties and found that significant reductions were achieved after the check-up. From 2010 to 2015 303 users have received irrigations checks-up. 278 users received 1, 22 users received 2, 3 users received 2 and 1 user received 4 check-ups. 296 of these users have also received the budget in past years.

In Table 14 we present the number of users in each level of consumption associated to the values presented in Table 5. We observe that most users in this program are in the upper levels of consumption in 2008. The number of users in level 4 decreases significantly over time. There were 11 accounts in this group that show 0 consumption in the summer months of 2008, but in 2016 we have none. Consumption in this group decreases over time (Figure 12) even though we have more accounts in 2016.

Table 14 Number of users in each level of consumption in each year (Irrigation check-ups)

Winter									
Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 4	45	38	51	28	52	92	84	143	87
4 - 7	76	74	78	50	89	75	100	89	88
7 - 10	101	97	103	105	94	89	78	56	85
> 10	72	86	67	116	64	45	39	15	43
NC	9	8	4	4	4	2	2	0	0
Summer									
Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 6	5	5	9	2	4	10	17	19	38
6 - 14	49	62	62	22	65	69	96	83	106
14 - 24	121	128	127	102	136	133	126	134	118
> 24	117	100	101	173	94	88	62	67	41
NC	11	8	4	4	4	3	2	0	0

Applying the MKS test to all users with a record longer than 24 months (292 out of the 303) that received an irrigation check-up, with a confidence level of 95%, indicates that 195 users have significant trends in their consumption. In 184 cases this trend is downward, while in the rest (11) it is upwards.

A total of 292 users in this program have enough data pre and post interventions. The results from the Wilcoxon test indicate that 9 users have increased their consumption after receiving an irrigation check-up and 114 users have significantly decreased their outdoor water use. For 169 users, no statistically significant change was detected. The median volume decreased for the 114 users that had a positive change was 1,800 gallons per month (in outdoor water use), while the median increase was 757 gallons per month. All users that received an irrigation check-up have a negative correlation with rainfall, 33 of them have a moderate (-0.75 < C < -0.5) correlation with rainfall.

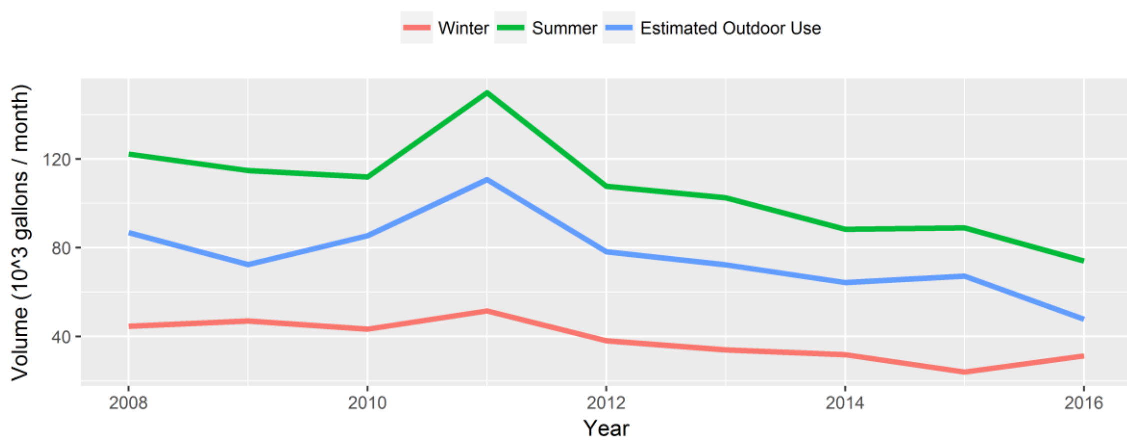


Figure 12 Average volume of water used by that received an irrigation check up from 2008 to 2016

4.2.3 Intervention 3: Weekly watering notifications

Sixty-four users were identified to have registered for this intervention. 33 of them were also participating in the water budget intervention. In Table 15 we find the number of users in each level of consumption associated to the values presented in Table 5. According to this table we observe that most users in this program are from the lowers levels of consumption. The number of users in level 4 decreases over time. There were 9 accounts in this group that show 0 consumption in 2008, but in 2016 we have none. Water use in this group decreases over time (Figure 13) even though we have more accounts in 2016 than in 2008. Users participating in more than one intervention present higher levels or reductions.

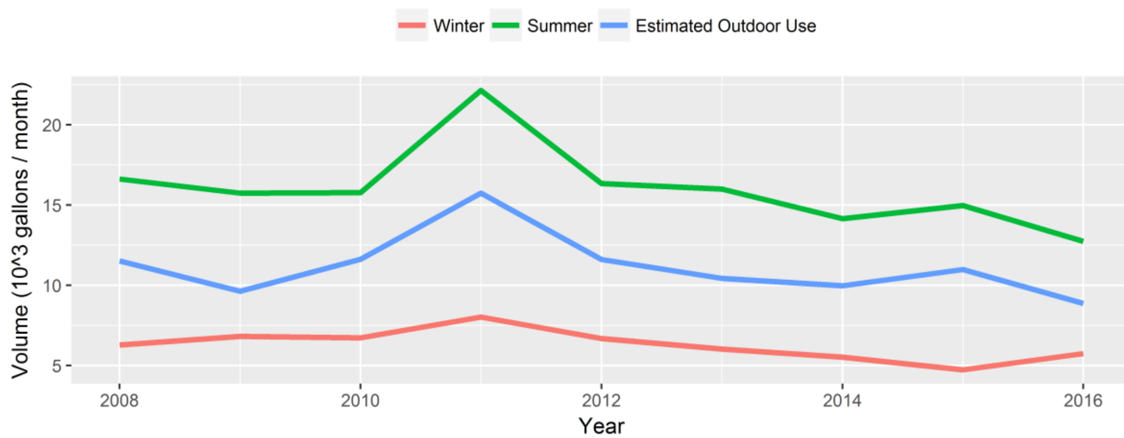


Figure 13 Average volume of water used by users in the weekly watering program from 2008 to 2016

Applying the MKS test to residential customers in this program with a record longer than 24 months (59 customers), with a confidence level of 95%, indicates that 38 users have significant trends in their consumption. In 32 cases this trend is downward, while in the rest (6) it is upwards. A total of 59 users in this program have data pre and post interventions. The Wilcoxon test was applied, with a confidence level of 95% to detect changes. For users in this intervention, outdoor water use in 2015 and 2016 was compared with 2013 and 2014. It was found find that 2 users have increased their consumption after participating in the WNP and 8 users have significantly decreased their outdoor water use. For 49 users, no statistically significant change was detected. The median volume decreased for the 14 users that had a positive change was 1,900 gallons per month (in outdoor water use), while the median increase was 846 gallons per month. Most of the users that participated in this program (97%) have a negative correlation with rainfall but none of these values can be considered significant.

Table 15 Number of users in each level of consumption in each year (weekly watering program)

Winter									
Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 4	14	9	15	8	16	20	21	30	19
4 - 7	20	20	21	11	20	20	23	22	28
7 - 10	15	19	10	25	11	16	15	8	13
> 10	6	7	11	13	12	4	3	4	4
NC	9	9	7	7	5	4	2	0	0

Summer									
Consumption 10^3 gallons	2008	2009	2010	2011	2012	2013	2014	2015	2016
< 6	6	6	6	3	8	9	10	5	9
6 - 14	20	16	19	8	19	14	19	24	29
14 - 24	16	24	22	25	21	25	25	27	22
> 24	13	9	10	21	11	12	8	8	4
NC	9	9	7	7	5	4	2	0	0

NC: No consumption in this period.

4.2.4 Results from all interventions

In Table 16 we have the results of the MKS trend test in the users from the different interventions. People that received an irrigation check-up register the largest value for decreasing trends and the largest percentage of users with trends. Irrigation check-ups are a direct intervention, the irrigation expert will suggest changes in miss functioning pieces, schedules, and timing and can set those changes if the user agree. In the other interventions it is the user who should adjust the settings of their irrigation system. For the budget, and the WNP the results are similar, in this type of interventions it is not possible to know how many users are using the information given. SFR users that didn't participate in any program have the lowest percentage of trends in their consumption, 15 points below the rest of the interventions. The decreasing trends in this group are also the lowest. The weekly watering program was implemented 2 years ago, then, data post intervention is shorter than the rest of the interventions.

Table 16 Comparison of trends found in users that have been part of the different educational interventions and users that have not

Record	Budget		WNP		Check-ups		NP	
	#	%	#	%	#	%	#	%
Total	5519		59		292		3252	
No trends	2149	39%	21	36%	97	33%	1777	55%
With trends	3370	61%	38	64%	195	67%	1475	45%
Decreasing	2926	87%	32	84%	184	94%	1125	76%
Increasing	444	13%	6	16%	11	6%	250	17%

NP = SFR users that irrigate and haven't participated in any program.

Turning off the irrigations system in moments where rainfall has provided all water required by the landscape could lead to important water savings in the city. The WNP provides the information required to do this, but the number of people registered for it is still low. Including users in the upper levels of consumption that constantly over water their landscape in this program can help to reduce their consumption. A new communicational approach is required to motivate them into the conservation programs going on.

Average volumes of water saved by users participating in each intervention is presented in Table 17. The largest change is observed in the WNP program, but this is also the program with least users participating and less post intervention data (2015 and 2016). Volume changes since 2008 also indicate that there has been significant reduction in the volumes of water used in the city.

Table 17 Average change in outdoor water use and estimated monthly saving for all users in each program

Intervention	Average change after the intervention. (10^3 gallons)	Number of users with estimated reductions.	Estimated savings. (10^3 gallons per month)
Budget	1.66	1620	2689
WWP	1.92	8	15
Check-ups	1.81	114	206

5. SUMMARY AND CONCLUSIONS

The present study offered an insight into residential water use in the past nine years in College Station. Water use data obtained in a monthly format permitted the estimation of outdoor water use in the city. A past study provided irrigable area of a group of users in the city, this allowed the estimation of specific and accurate water budgets for them. Separating indoor and outdoor consumption is not an easy task, since they are not measured separately, there are different methods available for doing this. The selection will depend on the location of the area of analysis. Prior studies (Glenn et al., 2015; Survis and Root, 2012) have analyzed irrigation efficiency using indices to evaluate the effectiveness of measures to reduce outdoor water use. Such indices do not provide information in months where rainfall provides all water a landscape needs. In this study was found that it is during those months when more users overwater and the largest volumes of water are wasted.

Excess irrigation can also be used to access irrigation efficiency, but larger lots will have larger excess volumes. The excess volume can vary according to the budget size, and not to changes in irrigation practices. In the drought of 2011 less users applied excess irrigation, but the volumes used are the largest for the period of analysis. These last facts show the limitations of using excess volume to assess irrigation efficiency. Irrigation efficiency indices in this study where estimated in a monthly basis, and excess volumes were estimated for the same period. Conservation and demand side strategies will become more popular in the years to come, understanding how users will react to this type of strategies should me the most important factor when deciding which one to apply. This study can provide an insight in how users reacted to different educational interventions in College Station.

Tools as the water budget can help users to be better informed about their landscape needs, understanding the concept of evapotranspiration can be key in having users more willing to change their irrigation practices. Strategies like the WNP provide near real time information have a great potential to help users in reducing the volumes of water wasted. A different communicational approach that makes them interested in this type of information is needed to increase user's participation.

Direct interventions, such as an irrigation check-up lead to bigger savings, because specific problems can be addressed for each user. The irrigation check-ups were found to have the biggest water savings among all interventions, however their reach is not as big as, for example, the WNP, where we could have all users that irrigate in the city registered. Irrigation check-ups are offered in a request basis. Users with the largest excess volumes in the city, that are constantly in the top levels, and increasing their outdoor use can be a primary target for irrigation check-ups.

Changes in the median consumption after each intervention were identified using the Wilcoxon test, in all interventions, positive changes were observed. There were statistically significant changes in 33% of the users after receiving the WNP and in more than 40% of the users that received a budget or an irrigation check-up. In 70 % of this cases for the WNP the change was a decrease in consumption. For users receiving a budget or an irrigation check-up that number goes up to 87% and 93% respectively. The average change in the median, for users participating in any intervention, that reduced their consumption significantly, was close to 1,800 gallons per month. A small group of users also increased their consumption after participating in these interventions, most of them were applying less water than the suggested by the budget. The customers profile can help target only users that are excessively above it. Defining a threshold or index that can help separate inefficient users is still needed.

Users react to educational measures different than to other measures; pricing, restrictions. A major part of users that registered for the WNP belong to lower categories of use in the city, they might be applying less water to their landscape than the indicated by the deficit. A deeper analysis including irrigable area for more residential customers in the city can help to select only users that apply more water than the required for these and future interventions.

The largest potential for water savings in the city is found in outdoor water use, there is a group of users with high consumption during winter months, no census data was used to evaluate if this consumption can be considered inefficient. Volumes used in summer months are still the largest and there is potential for more reductions. The largest volumes are wasted in months were rainfall occurs and it is larger than the landscape requirements, if users turn off their irrigation system in those months important volumes of water can be saved.

Conservation and demand side strategies are becoming more important as time passes by. This study offered the results of several conservation strategies in a considerable period. Utilities can observe the reductions achieved in the city of College

Station and implement similar educational interventions. Hopefully the results showed in this study can motivate other utilities to pursue conservation efforts and a more efficient outdoor water use in their cities.

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