ESTIMATING THE POTENTIAL OF URBAN WATER-USE CONSERVATION IN TEXAS:

A Pilot Study of Two Planning Regions

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Timothy T. Loftus, Ph.D., Project Manager
Lacey L. Smith, M.A.Geo.

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Timothy T. Loftus, Ph.D.
Professor of Practice and Meadows Endowed Chair in Water Conservation,
Department of Geography and
Chief Water Conservation Officer, Meadows Center for Water and the Environment
Texas State University
601 University Drive
San Marcos, TX 78666-4684
tloftus@txstate.edu / 331.442.9394

and

Lacey L. Smith, M.A.Geo.
Program Planner
Alliance for Water Efficiency
Chicago, Illinois

August 31, 2018

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THE MEADOWS CENTER
FOR WATER AND THE ENVIRONMENT
TEXAS STATE UNIVERSITY

601 University Drive, San Marcos TX 78666
512.245.9200 | MeadowsCenter@txstate.edu | www.MeadowsWater.org

Contents

Terms Used in Paper

Acronym/Initialism	Descriptive Name
AMI	advanced metering infrastructure
AWWA	American Water Works Association
CARL	current annual real losses
CII	commercial, institutional, & industrial
ELL	economic level of loss
GED	gallons per employee per day
GIS	geographic information system
GPCD	gallons per capita per day
IWA	International Water Association
ILI	infrastructure leakage index
KWEC	Kunkel Water Efficiency Consulting
MG	million gallons
MGD	million gallons per day
NAICS	North American Industry Classification System
TWDB	Texas Water Development Board
UARL	unavoidable annual real losses
WSP	water service provider

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I. Introduction to the Final Report

Water-use conservation and efficiency measures are expected to make a significant contribution to ensuring safe and adequate water supplies for a growing Texas population. For example, the current state water plan, “Water for Texas: 2017 State Water Plan” includes numerous water conservation management strategies that are planned to account for nearly 28 percent, or 2.3 million acre-feet per year, of all the recommended water management strategy volumes put forward by approximately 2,600 water user groups in 2070. Municipal conservation accounts for over one-third of these planned conservation strategies and nearly 10 percent, or 811,000 acre-feet per year, of the annual volume expected from all recommended water management strategies in 2070.

Is the annual volume of water supply expected from municipal conservation an over- or under-estimate of its potential? This study sought to investigate the potential of urban water conservation to help solve Texas’ chronic water challenge. The study focused on residential, commercial, institutional, and industrial water-use sectors using data collected from the Texas Water Development Board, the literature, and other relevant sources. As a pilot study, two of 16 water supply planning regions were evaluated: Regions C and K. Estimates of potential naturally involve assumptions and, when made in this study, they are explained where appropriate.

This study took place in three distinct phases and is presented below in a similar fashion. The first phase or component of this study evaluated utility water loss, presented in section II and titled, “Economically Recoverable Water in Texas: An Underappreciated Water Management Strategy?” Rather than consider average cost estimates of repair relative to cost recovery associated with water saved from water loss control efforts as was originally proposed, this component of the study estimated a new value of the economically recoverable subset of utility water loss and compared that value amount to planned investments in water loss control. This decision was made due to the fact that reliable cost estimates of repair were not found in the literature. To augment the revised approach, the amount of recoverable water was also compared to volumes expected from water loss control efforts as presented in the 2017 State Water Plan. Certain values of this study component were normalized for extrapolation statewide. As of this writing, this component of the study has been resubmitted (i.e., a revised second draft following incorporation of reviewer comments) to the Texas Water Journal for publication consideration. Thus, it appears here with a couple of minor updates to the resubmitted manuscript. This component was also accepted for presentation at the WaterSmart Innovations 2018 conference in Las Vegas, Nevada. This study component was performed and written by the primary author with assistance from two graduate students.

The second component of this study, presented in section III and titled, “Residential Water Conservation Potential in Texas: A Pilot Study of Two Planning Regions” follows the recoverable water loss component. The residential conservation potential component was a joint effort by both study authors with Ms. Lacey Smith’s contribution coming after her graduation in August 2017 with a Masters in Applied Geography (M.A.Geo.) degree. This component is presented as a stand-alone manuscript and is ready for submission to a peer-reviewed journal for publication consideration.

The third and final study component, presented in section IV and titled, “Estimating the Conservation Potential of the Commercial, Institutional, and Industrial Water-Use Sectors in Texas Water Supply Planning Regions C and K: Executive Summary” features Ms. Smith’s directed research project where she estimated the conservation potential in the commercial, institutional, and industrial sector, commonly referred to as the CII sector, as partial fulfillment of her M.A.Geo. degree requirements. This last study component is presented in executive summary format. Should the reader wish to review the full directed research report written by Ms. Smith, a digital copy is available through Alkek Library at Texas State University, San Marcos.

Literature cited throughout this comprehensive final report is organized and presented following each of the three study components where the citation originally occurs. Formats may vary due to the particular style requirements of a journal (e.g., section II). Footnotes are numbered sequentially throughout this final report. Finally, a summary section concludes this final report with an integration of key results from the three study components.

II. Economically Recoverable Water in Texas: An Underappreciated Water Management Strategy?

A. Abstract

Conversations about the value or “true cost of water” and the nationwide infrastructure maintenance gap, encourage a reconsideration of the value of utility water losses. Water loss audit data (2014) for two planning regions that are home to almost a third of Texas’ population and include three of the five largest cities are examined to explore the value of economically recoverable water losses from a perspective that better reflects the regional scenarios under which the state water plan is developed. The volume of real and apparent losses is valued per a new regional average composite price to arrive at an estimation for the water that should be feasible to recover. Normalized values of economically recoverable losses are generated to arrive at a statewide estimate of valuation. Industry standard financial and operational performance indicators are also developed and compared to a larger, multi-state dataset. Results are presented in the context of state and regional water supply planning in two ways: 1) comparing the volume of economically recoverable water to the volume of supply expected from water loss control strategies, and 2) the newly assessed value of recoverable water is compared to the estimated costs associated with water loss control strategies.

Keywords: utility water loss, economic level of loss, water audits, value of water, water supply

B. Introduction

The United States faces a significant need for water delivery infrastructure maintenance and repair. Historical underpricing of drinking water is one reason for the state of infrastructure disrepair (Beecher 1997). The American Water Works Association (AWWA), for example, estimates that $1 trillion is needed to maintain and expand water service to meet demands over the next 25 years (AWWA 2012). In a related manner, the American Society of Civil Engineers gives the nation’s drinking water infrastructure a grade “D” in their 2017 Infrastructure Report Card (ASCE 2017). The state of the nation’s water delivery infrastructure is one reason water supply is a rising cost industry (Beecher 1999). More recently, the AWWA (2016a) declared the North American water industry to be at a crossroads regarding nonrevenue water – the difference between system input volume and billed authorized consumption – of which real losses from leaking pipes are a major component.

Reducing utility system water loss has traditionally been viewed as a form of water conservation. A new emphasis on utility water loss is supported by studies that reveal the potential for recovery of lost revenue (or sunk costs) and new tools for its capture. The International Water Association (IWA) and the AWWA, for example, offer a water loss audit methodology that is being used by a growing number of utilities, also referred to as water service providers, across the country (AWWA 2016b). The AWWA Free Water Audit Software complements the IWA/AWWA method and enables utility staff to improve desktop accounting for water throughout the distribution and billing systems including their nonrevenue water.

For Texas, the grade for drinking water infrastructure is D+, an improvement over the previous grade of D-, but an assessment nonetheless of $33.9 billion for drinking water infrastructure that is needed over the next 20 years (ASCE 2017). At the same time, Texas population is growing rapidly and placing increasing strain on the state's water resources (TWDB 2016). Reducing utility-side water loss, therefore, holds great promise as a strategy for helping to make ends meet with respect to the growing imbalance between projected water demand and existing supplies during a prolonged drought.

The purpose of this pilot study is to evaluate water loss audit data from calendar-year 2014 as reported by water service providers (WSP) from two of sixteen regional water planning areas to the Texas Water Development Board (TWDB). Operational and financial performance indicators will be presented along with a reframing of the cost impact of apparent and real losses identified in water loss audits in order to better reflect water scarcity in Texas and its assumption in state and regional water supply planning efforts. Towards that aim, the economic level of loss – the level of leakage below which it is not cost effective to invest in reducing leakage further down (Farley and Trow 2003) – is estimated here for several water service providers within the two planning regions and normalized to produce both regional and state-level estimates of the financial impact of water loss that is thought to be economically feasible to recover.

It is acknowledged here that cost (of supplying drinking water), price (paid by ratepayers for delivery on demand), and value of water are different yet related terms (see, Raucher 2005). These terms all have some bearing on the thesis of this study which is to reconsider the financial impacts of nonrevenue water for regional planning purposes in a state that will be severely challenged for water when the next drought of record occurs.

C. Background

In 2003, the 78th Texas Legislature enacted House Bill 3338 during a Regular Session to require that a retail public utility providing potable water, conduct a water audit based on the most recent annual system water loss. Thus, all retail public water suppliers in Texas are required to submit a water loss audit to the TWDB once every five years. The first year for this requirement was 2005, and reports were subsequently submitted in 2010 and 2015. Additionally, any retail water supplier that has an active financial obligation with the TWDB, or has more than 3,300 service connections, are now required to submit an audit annually (Texas Water Code, Section 16.0121). The annual water loss audits covering a calendar year are due on the first of May the following year.

The TWDB collects water audit data via an online form that is based on the AWWA audit software. Data inputs can be assigned a validity score that is a modified version of what is featured in the AWWA audit software. Validity scores from the AWWA audit software, for example, are totaled and placed into one of five levels, with a maximum score of 100 points. AWWA validity score levels are characterized to provide basic loss control guidance to water service providers. The Water Loss Audit Manual for Texas Utilities (Mathis, Kunkel, and

Howley 2008) has a more streamlined guidance matrix with a total of 85 points possible.[1] The guidance matrix has (sub)total possible points assigned by category: Water Supplied (20), Authorized Consumption (20), Apparent Losses (15), Real Losses (10), Cost Data (10), and System Data (10). The Texas guidance matrix does not sum points and assign data validity levels as the AWWA does, but offers three scoring categories (i.e., 0-40, 41-70, 71-85) that suggest in general terms the level of accuracy and, thus, usefulness of the data collected.

In 2017, the 85th Texas Legislature enacted House Bill 1573 which amends Section 16.0121 of the Texas Water Code to require that 1) water audits be completed by a person trained to conduct water loss auditing and 2) the TWDB shall make training on water loss auditing available without charge via the Board's website. This Act took effect September 1, 2017. Given that these new requirements aim to improve system understanding and, thus, accuracy and validity of data reported, it is reasonable to expect higher water loss audit data validity scores in the future.[2] To quantify the extent to which this might occur, it will be necessary to consider audit data in greater detail both prior to and after this new law took effect.

D. Water-Planning Regions C and K

Two of sixteen water planning regions were chosen for this pilot study. Region C includes all or part of 16 counties in north-central Texas and includes the Dallas-Fort Worth metropolitan area where the city of Dallas is the third largest city in Texas. The population of Region C was 6,477,835 or about 25 percent of the state's population in 2010 (US Census Bureau 2017). The Dallas Water Utility, largest in the region, serves a population of 1,232,360 while the second largest water service provider in Region C, the city of Fort Worth, serves 781,100 people.[3] Region C's population is projected to be 7,504,200 in 2020, about a 16 percent increase during the current decade (Freese and Nichols, Inc. et al. 2015a).

Regarding the relationship between water demand and available supply, Region C's potential water shortage (with existing supplies during a worst-case drought) is projected to grow from 125,037 acre-feet per year in 2020 to 604,016 acre-feet per year in 2040.[4] In response, the 2017 Region C Regional Water Plan presents 259 water loss control management strategies that are expected to produce water savings of 26,646 acre-feet[5] per year in the decade beginning 2020 at an expected annual cost of $36,546,937 or an annual unit cost of $1,372/ac-ft or

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[1] The data validity scoring scheme was modified to total 100 points beginning with the 2015 audit reports.

[2] Without third-party validation (i.e., Level 1 validation), however, self-reported data validity will remain suspect regardless of complementary efforts to improve the quality of audit reports.

[3] Population served figures come from 2014 Water Audit Reports submitted to TWDB and shared with author.

[4] Water need or potential shortage is based on projected population growth/water demand and existing supplies. Any imbalance between demand and supply is predicated on a scenario of recurrence of drought of record conditions and not implementing any water management strategies presented in regional water supply plans.

[5] Tally by author of individual water loss control strategies listed in App. Q, Table Q-10 after corrections applied as referenced in the following footnote.

$4.21/kgal[6] (personal communication with Brian McDonald, Senior Project Engineer, Water Infrastructure Planning, Alan Plummer Associates, Inc., July 24, 2018, via email).

Region K includes all or part of 14 counties and generally follows the Colorado River from central Texas in the northwest part of the region to the Gulf of Mexico in the southeast. Region K had a population of 1,410,328 in 2010 (US Census Bureau 2017) and is home to the city of Austin, the fourth largest city in the state. Austin Water, the region's largest water service provider, serves a population of 896,363.[7] Region K's population is projected to be 1,737,227 in 2020, a 23 percent increase during the current decade (Lower Colorado Regional Planning Group 2015a).

Region K's potential water shortage is projected to grow from 373,563 acre-feet per year in 2020 to 387,321 acre-feet per year in 2040. The Lower Colorado (K) Regional Water Plan does not present any explicit water loss control management strategies for the next decade or beyond as is done in the Region C plan. Rather, "leak reduction" is included only in the city of Austin's "conservation" water management strategy. Thus, it is not possible to determine expected savings/supply or costs associated solely with water loss control apart from the other conservation measures listed: landscaping, efficiency, etc. (Lower Colorado Regional Planning Group 2015b).

Collectively, these two water planning regions capture both urban and rural areas that are located predominately in the eastern, more populated half of the state and are composed of almost a third of the state population.[8] Findings from this sample of two regions are instructive about the state as a whole. Table II.1 provides water supply/demand and other data for the upcoming decade taken from the 2017 Interactive State Water Plan[9].

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[6] The published cost of $3.74/1,000 gallons of water saved in Appendix K, Summary Table K.3, 2020 column, of Region C's approved plan, is in error per email communication with Brain McDonald, Allan Plummer Associates, July 24,2018. Appendix Q, Table Q-10 of Region C's plan also features a couple of errors, most notably with the 2020 unit cost listed for Fort Worth; which should be $1,061 rather than the $357 currently published, per the same email communication. There are 259 water loss control strategies that are estimated to produce one or more acre-feet per year during the 2020s for a total of 26,646 acre-feet of water saved at a combined cost of $36,546,937. A tally of water loss control strategies downloaded from the Interactive 2017 State Water Plan sums to 26,638 acre-feet. Costs are not included in this file. The discrepancies in water volumes listed here and in Appendix K, Table K.2 of the Region C plan are minor: less than one-tenth of one percent.

[7] *Ibid. 3*

[8] 31.4 percent in 2010

[9] Interactive 2017 State Water Plan: https://2017.texasstatewaterplan.org/statewide

Table II.1. Water demand/supply/needs for Regions C and K, Texas in the next decade.

2020 (decade)	**Texas Planning Region (acre-feet/year)**	
	C	**K**
Projected Annual Water Demand – All Water-Use Sectors	1,723,325	1,183,325
Projected Annual Water Demand – Municipal Water-Use Sector	1,481,530	306,560
Existing Supplies – All Sectors	1,650,227	998,867
Existing Supplies – Municipal Sector	1,390,169	457,961
Needs (Potential Shortage) – All Sectors	125,037	373,563
Needs (Potential Shortage) – Municipal Sector	106,718	7,881
Strategy Supplies – All Sectors	191,811	436,423
Strategy Supplies – Municipal Sector	164,144	174,777

E. Water Loss Audit Data

In June of 2016, a request was made of the Texas Water Development Board for Regions C and K water loss audits from 2014, the most recent and complete set of audits available at that time. Data were made available from the 106 (87 from Region C and 19 from Region K) WSPs that submitted a report during an off-year (i.e., audit data for 2015 by all systems per the five-year cycle were not yet available). Thus, the audits received by the author represents the WSPs that either have at least 3,300 service connections or have borrowed money from the TWDB.

From the data file for 106 WSPs, the top 27 water service providers (Table II.2) were selected for many of the analyses because this subset produces 85 percent – 333,259.83 million gallons/1,022,735 acre-feet – of the total system input volume of 392,764.71 million gallons/1,205,349 acre-feet distributed by the 106 WSPs. As it turns out, all but one are situated within Region C.

Table II.2. Top 27 water service providers based on system input volume (2014) in Regions C and K, Texas.

Public Water Service Provider	Region	Public Water Service Provider	Region	Public Water Service Provider	Region
Dallas Water Utility	C	City of Frisco	C	City of Southlake	C
City of Fort Worth	C	City of Richardson	C	City of Coppell	C
City of Austin Water & Wastewater	K	City of Carrollton	C	City of Sherman	C
City of Arlington	C	City of Mesquite	C	City of Keller	C
City of Plano	C	Town of Flower Mound	C	City of Farmers Branch	C
City of Irving	C	City of Grapevine	C	City of Euless	C
City of Garland	C	City of Lewisville	C	City of Bedford	C
City of McKinney	C	City of Allen	C	City of Desoto	C
City of Grand Prairie	C	City of North Richland Hills	C	City of Colleyville	C

Other analyses use a variable “n” based on data plausibility. The current state of data is unvalidated, but it does undergo some filtering by the TWDB staff (personal communication with John Sutton, Municipal Water Conservation Manager, Water Science and Conservation, Texas Water Development Board, July 27, 2017, via email.) Data from the two regions have been combined into one dataset. Table II.3 features several characteristics of WSPs that have been partitioned based on their size.

Table II.3. Public water service provider characteristics for Regions C and K, Texas (2014).

WSP Size Class	No. of WSPs	Range of Population Served	Average Population Served	Average System Input Volume in acre-feet/year	Total System Input Volume in acre-feet/year	Average No. of Service Connections	Average Production MGD/acre-feet per day	Average Deliveries MGD/acre-feet per day	Avg. Miles of Main	Total Miles of Main
X-Large	3	781,100 - 1,232,360	969,941	185,715	557,145	260,047	165.80/509	142.54/437	4,089	12,268
Large	12	91,429 - 369,308	178,305	28,906	346,877	67,124	25.81/79	23.01/71	829	9,951
Medium	58	10,005 – 68,667	28,463	4,836	280,523	10,788	4.32/13	3.87/12	228	13,208
Small[2]	33	190 – 8,819	2,936	336	20,805	1,168	0.30/0.92	0.25/0.76	28	1,566
TOTAL	**106**	**N/A**	**N/A**	**N/A**	**1,205,350**	**N/A**	**N/A**	**N/A**	**N/A**	**36,993**

Note: Average production and deliveries do not include wholesale. Averages for small water service providers are median values. All other size classes feature mean averages. MGD = million gallons per day.

Nonrevenue water, as a percentage of system input volume, can be calculated, but has shortcomings as a measure of WSP operational performance (AWWA 2016b). The percentage of nonrevenue water derived is biased against WSPs with relatively lower consumption and sensitive to average operating pressures which are often set to overcome the amount of relief present in a service area (Farley and Trow 2003). For these reasons and others, both the AWWA and IWA prefer use of a scaling factor where losses are expressed relative to number of service connections or miles of water main. The infrastructure leakage index or ILI in loss control parlance is the ratio of current annual real losses to unavoidable annual real losses and is the best operational performance indicator for comparisons between systems (AWWA 2016b). With these caveats shared, nonrevenue water percentages for the full dataset of 106 WSPs analyzed here range from 4-47 with a median value of 16.

F. Valuing Water Loss

Water loss is segmented into two types: real losses and apparent losses. Real losses result from actual leaks in transmission and distribution pipes, storage tanks, and on service connections up to the point of customer metering. Traditionally (i.e., IWA/AWWA water loss audit methodology), this water is valued at variable production cost and the TWDB-approved water loss audit methodology in Texas follow this tradition. It is important to note, however, that the AWWA supports using a retail water rate to value real losses if scarcity is part of the local/regional context within which water service providers operate (AWWA 2016b). The rationale is simple: every drop of leaked water saved can be projected as a water sale to someone using that same source.

The other type of water loss, apparent losses, results from data handling or billing errors including faulty customer meters and unauthorized consumption (e.g., theft). This type of lost water is valued using the retail water rate since water was delivered, but revenue was not captured in return. Real and apparent losses constitute the majority of nonrevenue water which also includes two types of unbilled authorized consumption: metered and unmetered. This study does not concern itself with unbilled authorized consumption that was reported to be 2.5 and 4.5 percent of total system input (n = 106) for metered and unmetered consumption respectively.[10] This is not to say that the amount of nonrevenue water attributed to unbilled authorized consumption is inconsequential. Rather, this study is focused on real and apparent water losses and the value of such.

Audit inputs in both methodologies include a retail rate for water. The TWDB's audit guidance document acknowledges that typical utility water rate structures feature multiple tiers

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[10] These percentages of unbilled authorized consumption are calculated such that they are included in the nonrevenue water total for the entire dataset (n=106) calculated at 19.3 percent (i.e., sum of nonrevenue water volumes / sum of total system input volumes or 75,725,919,325 / 392,764,711,972).

of pricing and guides utilities (i.e., WSPs) to use a single composite price rate to represent the retail cost of water adding, “where appropriate, use the tier with the majority of the consumption.” (TWDB 2018). It is suggested here, nonetheless, that the reported retail rates are neither calculated to reflect actual bills paid by ratepayers nor do they appear to be determined in a consistent fashion across reporting water service providers. Additionally, real losses in Texas could be valued at a retail rate rather than a variable production cost as suggested above and for reasons explained in more detail next. Thus, audit data likely undervalue water losses.

The threat of drought in Texas is very real. Droughts occur on such a regular basis that regional water supply planning, conducted to produce updated plans every five years, is predicated on a recurrence of the most severe drought condition ever experienced by a water user group within each planning region, referred to as the drought of record.[11] Given this planning context, the 2017 State Water Plan indicates that $63 billion must be spent to narrow the gap between existing supplies and projected water demand out to 2070.[12]

Capturing utility system water loss is viewed as a potential water supply. Region C’s current plan as mentioned above includes water-loss control among the many recommended water management strategies. Both types of water loss, therefore, can be valued at retail price in order calculate the benefit/cost ratio of this supply option. Furthermore, valuation using retail price will better reflect, though not necessarily fully capture, scarcity in a drought-prone state where surface water is overallocated relative to its availability during a record drought (Sansom 2008; McGraw 2018).

Valuation using retail price also speaks to the needs of both water service providers and the communities they serve (Beecher and Shanaghan 1999) and should come closer to capturing the opportunity cost associated with impacts of urban water use/loss on other competing uses and the environmental cost related to impacts, for example, on environmental flows (see Freebairn 2008). Protecting environmental flows and the aquatic species that such flows maintain in Texas is an evolving issue since passage of Senate Bill 3 in 2007 (Sansom 2008). Protecting the flow of natural springs, baseflow, and aquifers from overdraft (see, for example, Chaudhuri and Ale 2013; Sheng 2013) are other compelling reasons for pricing/valuing water to help minimize negative externalities. Elsewhere, an attempt to estimate the shadow price of system leakage as a proxy of the environmental and resource/opportunity costs of water losses, is predicated on using the retail price of water, divined from utility bills, delivered to end-users (Molinos, Arce, and Sala-Garrido 2016). Thus, assigning a defensible retail value to real and apparent losses has value for multiple reasons.

To examine the difference in retail price reported and a retail rate calculated from current rate sheets, an average monthly water bill was developed that is based on consumption of 8,000

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[11] The drought of record within each region can vary, but for the state as a whole, the worst-ever one-year drought of record occurred in 2011. The drought from 1950-1957 is the drought of record for the state as a whole.

[12] According to the 2017 State Water Plan, just one planning group (Region P) was able to recommend water management strategies that, upon implementation, are able to meet all identified needs among its water user groups. The remaining 15 planning regions were unable to identify feasible strategies that met both Texas planning requirements and all needs within their regions (pg. 103).

gallons per residential (single-family) household.[13] Table II.4 illustrates the disparity in retail price between rates reported in water loss audits and rates calculated for this study using current rate sheets in a manner that is consistent across water service providers.

Table II.4. Retail price of water for top 26 water service providers in Texas: reported vs. calculated from current water rates ($).

	Water Audit / Average Current Rate	**X-Large WSP (3) Audit / Current**	**Large WSP (11) Audit / Current**	**Medium WSP (12) Audit / Current**
Retail Price per 1,000 gallons	3.94 / 5.22	3.68 / 5.37	4.29 / 4.93	3.64 / 5.27
Retail Price for 8,000 gallon bill	31.52 / 41.76	29.44 / 42.96	34.32 / 39.44	29.12 / 42.16

Note: Lewisville, one of the top 27 WSPs, is not included due to reported data implausibility. Thus, n=26 rather than 27. Seventy-four percent of rate sheets were revised in 2016 or 2017, which will tend towards slightly higher current rates from those used in 2014 audits.

The difference between retail price reported in the audits and an average calculated retail price following the logic presented above ranges from 15 to 46 percent higher, with an average of 32 percent, for the rates calculated from current rate sheets using the assumed monthly household consumption of 8,000 gallons. This difference is unlikely to be explained solely or even mostly by current rates that for the majority of the WSPs have increased during the last three years as noted in Table II.4. Dallas Water Utility, for example, reports a retail rate of $1.80/1,000 gallons in 2014 versus their current reported rate of $1.90/1,000 gallons; an increase of under six percent.

Rates calculated here do not include wastewater treatment charges that the AWWA indicates can be included in an approach to valuing real losses using retail price if wastewater treatment charges are included in the water bill. And no additional attempt has been made to more carefully estimate the environmental and resource costs (i.e., cost of negative externalities and opportunity cost alluded to above) that has been innovatively estimated by Molinos, Arce, and Sala-Garrido (2016) to be 32 percent of the delivered water price. Thus, the rates that were calculated consistently across the sample, based on average household water use in Texas, and presented in Table II.4, might be considered conservative at capturing scarcity/opportunity, environmental, and other costs despite being greater than reported rates in the study year.

Finally, the average (median) variable production cost reported by the top 27 water service providers is $1.87 per 1,000 gallons.[14] This production cost value is a little less than half of the

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[13] Monthly consumption is based on 2.84 persons per household (US Census Bureau 2017) and 94 gallons per capita per day (single-family residential, statewide average) derived from Mace and Hermitte (2012). The monthly bill, from which a per 1,000 gallon rate is derived, includes any fixed or minimum charge, charge based on meter size, and applicable volumetric rates, Thus, the water bill for 8,000 gallons is what a ratepayer will receive and is presented either as an average of all 26 WSPs used in this particular analysis or an average from grouped WSPs that are similarly sized.

[14] The variable production cost of $1.87, taken from the top 27 water service providers is somewhat higher than the average taken from the 98 water service providers that reported plausible data; see Table 5.

reported (2014) retail price (average of $3.94) and a little more than a third of the retail price calculated from current rate sheets (average of $5.22). Applying retail price to real losses, therefore, results in a significantly higher valuation of economically recoverable water than is currently the case when its value is equated with its variable production cost.

G. Performance Indicators

Industry standard performance indicators, both financial and operational, were calculated from audits reported to the TWDB for comparison (Table II.5) to a composite water loss audit data set from five states including Texas data from 2010 and 2013 (Andrews and Sturm 2016).

Table II.5. Median water loss performance indicators for Regions C and K, Texas: 2014 Water Audit Reports to TWDB

Data	Performance Indicator	Median	Andrews & Strum (2016) Median	Unit
Financial	Retail Cost (n=99)	4.00	4.67	$/1,000 gallons
	Variable Production Cost (n=98)	1,680.00	950.00	$/MG
	Annual Reported Cost of Real and Apparent Losses (n=94)	238,921	---	$/year
	Nonrevenue Water as % of operating cost	---	7.8	%
Operational	Apparent Losses	5.81	5.73	gallons/service connection/day
	Real Losses (normalized to service connections)	32.03	39.88	gallons/service connection/day
	Real Losses (normalized to miles of main)	1,424	785.54	gallons/miles of main/day
	Real Losses (normalized to pressure)	0.47	0.59	gallons/service connection/day/psi
	Infrastructure Leakage Index (n=50)	2.82	2.48	Dimensionless
	Data Validity Score	38	73.1	Points out of 85 / Points out of 100

Note: n varies due to implausibly high or low reported data, or retail or variable production cost data that were deemed inaccurate. For operational performance indicators, n = 106 unless otherwise noted. MG = million gallons

Differences in four indicators warrant comment. First, retail prices found in the Andrews and Sturm (2016) composite data set are almost 17 percent higher than retail rates reported in 2014 Texas water loss audits despite the former coming from mostly older data (i.e., 2010-2014). Since most of the data in the composite data set come from states other than Texas, the comparison suggests that Texas retail water rates are either set low, reported low, or both. Secondly, there’s a big difference in real losses normalized by miles of main: 1,424 gallons per mile of main per day in this study versus 785.5 gallons per mile of main per day in the Andrews and Sturm (2016) dataset. The Texas data from 2014 is nearly double that from the composite data set. This could be the result of older infrastructure that is generally in poorer condition or a reflection of a different split between urban and rural service areas among the Texas utilities. Examining this operational performance indicator alone will not explain the difference in results.

The third noticeable difference between the Texas data and the composite data set concerns data validity scores. As suggested above, Texas measured on a different scale than the AWWA method in 2014. But even when viewed as an adjusted data validity score of 45 (i.e., 38/85), the average audit data validity score is very low in Texas compared to the composite data set. Lastly, real losses, normalized to service connections, is nearly 20 percent lower in the 2014 Texas dataset than what was found in the multi-state composite dataset. While one can only speculate about the reason for this difference, one plausible explanation emerges when considered along with the other operational performance indicator, real losses normalized by miles of main: the current study dataset likely reflects a more urban/suburban and thus, higher density service area than the composite dataset evaluated by Andrews and Sturm (2016).

H. Economic Level of Loss

Not all water loss that is technically recoverable is economically feasible to recover (US EPA 2010). The economic level of loss (ELL) is the point where the value of the water saved is less than the cost of making any additional reduction in system water losses (Farley and Trow 2003). The economic level of loss only considers the direct costs incurred by the water service provider, not the environmental and scarcity costs of urban water use that is more fully captured by another metric, the Sustainable Economic Level of Leakage that has been proposed by Ofwat (2008), estimated by Molinos, Arce, and Sala Garrido (2016), and discussed by others. That said, the ELL is also a function of how water is valued and entails both a short-term ELL and long-term ELL as elucidated by Farley and Trow (2003). Furthermore, Farley and Trow (2003) describe supply-side and demand-side options for maintaining system capacity (i.e., headroom) when considering the calculation of ELL.

While it is up to each water service provider to determine their unique economic level of loss, it is unknown as to how common this understanding might be among water service providers. Furthermore, the ELL is not a calculation whose result remains static. A WSP's economic level of loss will vary over time and in response to the degree of active leakage control that is implemented (Farley and Trow 2003). In any event, it is a best management practice for water service providers to pursue water loss control to the point where they reach an economic level of loss, at a minimum. Such a level of loss exists somewhere between unavoidable annual real losses (UARL) and current annual real losses (CARL) per the IWA/AWWA water loss audit methodology (AWWA 2016b).

Here, two techniques are considered for estimating the ELL. First, a simple midpoint between CARL and UARL volumes is selected, given the regional scale nature of the analysis. A second estimation technique is detailed in a report that evaluated water audit data for Pennsylvania water utilities (Kunkel Water Efficiency Consulting (KWEC) 2017). In short, this technique considers median values of customer retail unit cost of water (for apparent losses), variable production cost (for real losses), and normalized apparent/real loss indicators. Utilities with values for these three variables that are found to be greater than the median values calculated from the full dataset of utilities were thought to have the greatest economic incentive for recovering apparent and real losses.

Both approaches were applied to the top 27 WSPs. Eighteen of the 27 WSPs qualified for further calculations when applying the midpoint technique. Applying the KWEC technique (tested on real losses only) resulted in a smaller sample size (n=7) and given the greater-than-median-value criteria involved, did not capture the three largest utilities. Thus, given the pilot nature of this study, small resultant sample size from applying the KWEC method, and the argument made in this study for using retail price rather than variable production cost for identifying the economic value of real losses, a decision was made to apply the simple midpoint method: a volume of water that is halfway between UARL and CARL. The midpoint method is applied in Table II.6 below.

I. Extrapolation of Regional Results

Table II.6 illustrates a number of normalized loss values, economically recoverable loss estimates, and more. Results from Regions C and K data analysis are shown in one column and extrapolated statewide as shown and explained in the notes below the table. The purpose of Table II.6 is to arrive at an approximation of the combined annual financial impact of both apparent and real losses in utility operations statewide that are estimated to be economically feasible to recover.

Table II.6. Population, water usage, loss, and value estimates for Regions C and K and State of Texas.

	Regions C and K (2014)	State of Texas (2010)
Population Served	6,816,020[a]	25,260,000
Total System Inputs (MG/ac-ft)	392,764 / 1,205,348[a]	1,456,350 / 4,469,374[b]
Avg. Economically Recoverable Real Loss (gallons)/person/year[c]	2,519	(assumes 2,519 gallons/person for entire population)
Value of Economically Recoverable Real Losses/ person/year[d]	Calculated for water (1,000 gallons) valued at: a) variable production cost - $4.71 b) audit reported retail - $10.08 c) current rate retail price - $13.15	
Value of Economically Recoverable Real Losses/ year based on pop. served	a) $32,103,454 b) $68,705,482 c) $89,630,663	$118,974,600 - $332,169,000
Average Economically Recoverable Apparent Loss (gallons)/person/year[a]	590	(assumes 589.85 per person for entire population)
Value of Economically Recoverable Apparent Loss per person per year	$2.36 -$3.08 Calculated for water valued at audit reported retail ($4.00/1,000 gallons) and by the current rate retail price ($5.22/1,000 gallons)	
Value of Economically Recoverable Apparent Loss/ year based on pop. served	$16,085,807 - $20,993,342	$59,613,600 - $77,800,800
Average Economically Recoverable Real and Apparent Loss (gallons)/person/year	3,109	(assumes total loss of 3,109 per person for entire population)
Value of Economically Recoverable Real and Apparent Loss/person/year	$12.44 - $16.23 Calculated for water valued at reported retail ($4.00/1,000 gallons) and by the current rate price ($5.22/1,000 gallons) for Regions C and K.	
Total volume (MG/ac-ft) of Economically Recoverable Real & Apparent Losses	21,191.01 / 65,033	78,533.34 / 241,010
Total value of Economically Recoverable Real and Apparent Losses/year based on population served	Applying retail rates only: reported: $84,791,289 - current: $110,624,005	$314,234,400 - $409,969,800

Notes: a. includes entire dataset from Regions C and K (2014; n=106) unless noted otherwise. MG = million gall.

b. Source: Maupin et al. 2010 (public water supply sector only)

c. n=52 because negative (CARL-UARL) values in dataset led to exclusion of 54 WSPs. Real loss volume of 27,565.12 MG * 50% = economic level of loss volume of 13,782.56 MG / population served (n=52) of 5,471,921.

d. n=52 as in c. above. Range of value was calculated by multiplying 2,518.78 – the average economically recoverable real loss per person per year – by the median reported retail price ($4.00/1,000 gall.) and by the average retail price calculated from current rate sheets ($5.22/1,000 gall.)

J. Discussion and Conclusions

This is a regional-scale study of nonrevenue water and that component of such that is estimated to be economically recoverable. A regional average water bill has also been calculated for the purpose of assigning a value to economically recoverable water losses that is argued to be more appropriate for the drought-prone nature of the study area.

Regarding real losses, it is suggested here that the practice followed by the WSPs as reported in water loss audits – assigning a variable production cost to gallons – grossly underestimates the value of economically recoverable water leaking out of the distribution system by nearly three times: approximately $32.1 million using a variable production cost per gallon versus $89.6 million using a regional average retail rate per thousand gallons (Table II.6). Given this difference in assigned values, it seems fair to ask about the potential consequences of this undervaluation. Might the undervaluation suppress investment in reclaiming water lost to leakage and by comparison lead to overinvestment in other supply strategies? Perhaps the answer to that question depends in part on the volume of water loss that can be economically recovered.

The total volume in 2014 of economically recoverable water from the two regions, both real and apparent losses, is 21.19 billion gallons/65,032 acre-feet (Table II.6). For perspective, the volume of economically recoverable water estimated here for Regions C and K is over 22 percent of projected annual water demand (all water-use sectors) in 2020 for both regions.[15] More strikingly, the recoverable water estimate represents over 36 percent of projected annual water demand within the municipal water-use sector of both regions in 2020 where the leaky infrastructure is situated.

Region C alone projects municipal water supply savings of 8.682 billion gallons/26,646 acre-feet per year during the next decade from enhanced water loss control programs (i.e., as planned water management strategies; Freese and Nichols Inc., et al. 2015b). This annual amount of savings expected from water loss control strategies implemented in Region C represents over 15 percent of total projected annual water demand and 18 percent of projected annual municipal water demand in 2020 (Table II.1). Water savings from Region K's water loss control strategies are unknown since they are included in the more comprehensive category of conservation. But there is little reason to believe that the city of Austin's investment in water loss control will yield a volume of water sufficient to make up the difference between the economically recoverable water volume estimated here, 21.191 billion gallons / 65,033 ac-ft (Table II.6), and the amount planned for recovery in Region C. Capturing nonrevenue water and doing so more aggressively per the volume of economically recoverable water estimated here, is not an inconsequential water supply strategy.

Comparing the volume of economically recoverable water for the one year studied to that volume planned for recovery in one year of the next decade (Region C only) indicates that there is a considerable amount of potential water supply that is being ignored. For perspective, this volume of recoverable water within Region C alone is sufficient to meet the residential needs of

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[15] The 2017 State Water Plan projects annual water demand in 2020 for both Regions C and K will be 2,906,000 acre-feet across all water-use sectors and 1,788,090 acre-feet for the municipal water-use sector alone.

a city sized between Corpus Christi (population 325,773) and Arlington (population 392,772) for one year.[16]

Aside from the volume of water under consideration, what about planned investments? Combined with apparent losses, the bulk of economically recoverable nonrevenue water from the two planning regions has been estimated to have a retail value of over $110 million in the one year examined. This estimated value is three times the amount of $36.5 million that is planned to be spent on water loss control strategies in Region C each year over the course of the next decade with costs expected to be incurred by Region K, including city of Austin, presently unknown. Once again, the significant difference between the value of economically recoverable water and funds planned for water loss control in Region C is not likely to be narrowed by much if the city of Austin's cost for water loss control implementation could be included to enable an "apples-to-apples" comparison.

The statewide impact for one year of ignoring this bulk of nonrevenue water that is estimated to be economically feasible to recover ranges from $314 million using the audit reported retail price of water and as much as $400 million using a retail price that is derived from average ratepayer bills. While these numbers are based on 2014 data, they are very likely to be similar for each of the years since then.

This is the era of greater transparency and accountability at all levels of government. Given the magnitude of infrastructure repair needs, rate of population growth in Texas, and the proposed cost of implementing myriad water management strategies to make drinking water ends meet, it does not serve public discourse to either ignore the economically recoverable portion of nonrevenue water or underestimate its value. This is especially true given that recovering nonrevenue water, particularly real losses, is now considered a source of new water in state and regional water supply planning efforts.

Lastly, if the environmental and scarcity costs of withdrawals from aquifers and surface water on environmental and spring flows in Texas are to be fully captured in water rates, then the new values of most nonrevenue water estimated here will only increase in response. Thus, there is an urgent need for more aggressive action to recover nonrevenue water and a strong economic case to be made for doing so.

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[16] This assumes the same gpcd of 94 as used to derive average household use and the resultant monthly water bill. City population estimates are from US Census Bureau Quick Facts.

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III. Residential Water Conservation Potential in Texas: A Pilot Study of Two Planning Regions

A. Abstract

Drawing on the published literature and 2014 water use data obtained from the Texas Water Development Board for water planning regions C and K, residential indoor water use is tallied and broken down by individual indoor fixture type. With combined regional population data, a gallons per capita per day (gpcd) is identified that serves to compare current use with potential use derived from usage behavior assumptions and different levels of upgrades to water efficient fixtures. Results indicate a significant potential for reducing gpcd from current use levels to fully efficient indoor use. Outdoor residential water use reduction estimates are identified based on limiting outdoor irrigation to one day per week and assuming two levels of savings potential. Current outdoor rules and ordinances among the top 27 water service providers (WSPs; accounting for 85 percent of the residential use among the 106 WSPs in the dataset) are tabulated and compared. Estimated savings are placed within the context of expected (2020) water demand and needs/potential shortages of both planning regions.

Keywords: water conservation, water efficiency, residential water use, outdoor water use

B. Introduction

Attracted by the prospect of a strong job market, favorable climate, and no state income tax, individuals and families are flocking to the Lone Star State. Population in Texas, for example, grew by nearly 21 percent from 2000 to 2010. By 2020, the State Water Plan estimates a population of approximately 29.5 million which is 17 percent greater than 2010.[17] Such growth greatly exceeds that being experienced by the country as a whole.[18]

New Texans are also expecting water to be readily available. By contrast, there is a gap between projected water demand in Texas and existing supplies during a record drought. And while this gap will narrow by 2070 in response to a significant investment in new water management strategies, it will not be closed according to the state water plan. How then will Texas make water ends meet in the face of such robust growth?

The 2017 State Water Plan (TWDB 2016) outlines the need to spend $63 billion by 2070 to narrow the difference between projected demand and existing supplies under a drought of record scenario. With each new state plan, conservation is expected to play an increasingly important role in its contribution to new water supplies. Currently, municipal conservation represents nearly 10 percent of the recommended water management strategies by strategy type in the state plan (TWDB 2016). The expected contribution to water supply from municipal conservation is 204,000 acre-feet per year in 2020, growing to 811,000 acre-feet per year in 2070. These volumes represent six and ten percent of total strategy supplies in 2020 and 2070 respectively.

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[17] US Census Bureau, Quick Facts: Texas. Population in 2010 was 25,146,100. https://www.census.gov/quickfacts/TX

[18] Population in the USA grew 13.2 percent from 1990 to 2000 and 9.7 percent from 2000 to 2010. The most recent estimate for 2017 indicates a decadal growth rate of about 8 percent by 2020.

Statewide, municipal water-use conservation as a water management strategy will only grow in importance.[19] The purpose of this study is to estimate the water-use conservation potential in the residential sector of two Texas planning regions: Regions C and K.[20]

C. Background

Water conservation in Texas as elsewhere has been enabled by legislative mandates for water-efficient home fixtures. In 1991, the 72nd Texas Legislature passed the Water Saving Performance Standards for Plumbing Fixtures Act (HB 2176 / SB 587) that introduced low-flow rates for toilets, showers, faucets, and other fixtures. National standards followed with the federal Energy Policy Act (EPAct) of 1992 (Public Law 102-486; effective Jan. 1, 1994). State standards were strengthened by the 81st Texas Legislature (2009, HB 2667) that set higher/more efficient fixture standards, effective January 1, 2014, following a phase-in period that began in 2010 (Table III.1). Water-use reductions that result from new efficiency standards represent passive conservation and such savings are built into demand projections in the state water plan.

Table III.1. Water efficiency standards in Texas as of January 1, 2014.

Toilet (gallons per flush)	**Urinal (gallons per flush)**	**Faucet (gallons per minute)**	**Shower (gallons per minute)**
1.28	0.5	2.2	2.5

Given the long life of water-using fixtures (e.g., 20 years for toilets) there likely remains a large installed base of inefficient fixtures. More than a hunch, the status of existing fixture water use and related potential for conservation has been confirmed by the Residential End Uses of Water, Version 2 study by DeOreo et al. (2016).

Legislation to advance water conservation in Texas has not focused solely on fixture standards. The Water Conservation Advisory Council, created by the 80th Texas Legislature (2007, H.B. 4), is charged with monitoring the state's progress with water conservation.[21] Findings are made public in a biennial report during even-numbered years to the governor and other high-ranking elected officials. The 84th Texas Legislature (2015) further enabled the Water Conservation Advisory Council to make recommendations for legislation to advance water conservation. The first set of such recommendations were made in the 2016 report (WCAC 2016). Two of eight recommendations were agreeable to the legislature and resulted in new requirements: designation of a conservation coordinator at retail public utilities with 3,300 service connections or more, and enhanced water loss audit training by the utility staff person that is responsible for completing the annual water loss audit report for submission to the Texas Water Development Board (TWDB).

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[19] The 2017 State Water Plan projects annual water demand for the municipal category in 2020 to be 28 percent of total demand in Texas.

[20] There are 16 Regional Water Planning Areas in Texas.

[21] Texas Water Code, Title 2, Subtitle A, Chapter 10

At the federal level, the United States Environmental Protection Agency created the WaterSense program in 2006. The aim of WaterSense is to standardize certification of water-efficient products that operate using 20 percent less water than the rates mandated by the EPAct (NCSL 2015). While adherence to this program is voluntary, it has been widely accepted by manufacturers and retailers. The WaterSense program claims to have helped save 2.1 trillion gallons of water since the program's inception (USEPA 2017).

As noted above, water conservation is a key water demand management strategy laid out in Texas' 2017 State Water Plan (TWDB 2016). Texas Water Planning Groups, by way of their regional water plans, have put concrete numbers to the amount of water that they want to save by using conservation measures only. Texas Water Planning Region C, Dallas/Fort Worth, aims to gain 55,628 acre-feet per year from municipal conservation in 2020, or 29 percent of their proposed strategy supplies. The annual contribution to new supplies grows each decade such that by year 2070, 131,056 acre-feet of water per year is expected from municipal conservation[22] (TWDB 2016).

Municipal conservation in Region K, including Austin, aims to save 31,273 acre-feet of water per year in 2020, or 7.2 percent of new strategy water supply volume. Quite the opposite from Region C, municipal conservation in Region K trends upward throughout the planning period in terms of both expected volume of water and the percentage of new water contributed to supplies relative to other strategies. By 2070, municipal conservation in region K is expected to produce 86,255 acre-feet, or 11.6 percent of new strategy supply volumes (TWDB 2016). Municipal conservation in Region K, however, includes water loss control strategies unlike in Region C where water supply volumes and costs expected from reducing real and apparent losses in utility systems are separate from those expected from conservation as a water management strategy. Thus, it is unclear as to how much of this new supply volume can be attributed to new or enhanced water loss control efforts versus proactive conservation from behavior-change measures and incentives that are practiced and taken up respectively by ratepaying customers.

D. Challenges of Water Conservation Efforts

Lending support for enhancing water supply through conservation and efficiency as opposed or in addition to construction of new infrastructure projects such as pipelines or reservoirs is generally known to be prudent. New infrastructure projects can be costly, controversial, and damaging to the natural environment. Entire bodies of research are devoted to the deleterious effects of reservoirs, dams, and pipelines on the health of aquatic resources. The takeaways from this research are clear: altering the hydrologic system of a body of water is "the primary cause of ecological impairment in river and stream ecosystems" (USEPA 2017). Furthermore, the financial cost of constructing new "hard" infrastructure projects is known to be much higher per gallon of water gained in capacity than the cost of conservation measures (Richter 2014, TWDB 2016, USEPA 2017).

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[22] The annual contribution in water volume increases each decade, but the relative contribution trends downward throughout the planning period. For example, by 2070 municipal conservation accounts for 9.1 percent of strategy water supply volume.

Despite its importance as a water management strategy, conservation has its challenges. It requires societal change in the perception of water use as well as behavioral changes by individual users (Brooks 2005). This requires more effort than the supply that could be gained through a "top-down decision to build a reservoir or pipeline that can be made unilaterally by a government agency" (Richter 2014, 91). Many water users may be complacent in regard to their water use, assuming that since water has always been cheap and abundant, it will continue to be so. Water users may also believe that whatever efforts they make to conserve water are inconsequential compared to overall use and thus, may not feel compelled to make any changes at all (Woodhouse 2009). There is a considerable and ongoing need, therefore, to raise water literacy among the general public (Richter 2014).

Another recognized problem often inherent in water conservation is the so-called "conservation conundrum": as customers successfully decrease their water use, revenue to water utilities can decline, making it difficult for utilities to cover the costs of service provision (Richter 2014, Beecher 2010). The decrease in revenue may force utilities to raise water rates, thereby discouraging and frustrating customers who expected their water bill to decrease as a result of their decreased water use (Beecher 2010). This will continue to be an issue for water utilities and customers alike. Customer frustration must be countered with awareness of the true costs of water provision, while utilities must reexamine their rate structuring to ensure that they can continue to maintain infrastructure and employment when the efforts of water conservation begin to be realized. Another problem inherent to water management is the so-called "hydro-illogical cycle" (Wilhite 2012), wherein humans often respond, for example, to drought only when it becomes severe, but become complacent once they experience another rainfall. The threat of water scarcity due to climate change and population growth, including development patterns that lock in relatively high water use for decades to come (Beckwith 2014), does not disappear during the next rainfall event.

E. Study Area

This study analyzed residential water use in Texas Water Planning Regions C and K. Region C consists of all or part of 16 counties (Collin, Cooke, Dallas, Denton, Ellis, Freestone, Fannin, Grayson, Henderson, Jack, Kaufman, Navarro, Parker, Rockwall, Tarrant, and Wise) in the North Texas region, including the Dallas and Fort Worth/Arlington metropolitan statistical areas (Freese & Nichols, Inc. et al. 2016). In 2010, Region C's population, based upon United States Census data, was 6,477,835, or approximately 25 percent of Texas' population (Freese & Nichols, Inc. et al. 2016).

Region K is also known as the Lower Colorado Region due to being situated within the Lower Colorado River Basin (LCRWPG 2015). Region K is comprised of Bastrop, Burnet, Blanco, Colorado, Fayette, Gillespie, Hays (partially), Llano, Matagorda, Mills, San Saba, Travis, Wharton, and Williamson counties (LCRWPG 2015). The largest city in this region is Texas' capital, Austin (LCRWPG 2015). Region K's 2010 population was 1,410,328 and, astoundingly, this figure is expected to double by the year 2070 (LCRWPG 2015). Travis

County, home to Austin, contained 73 percent of the population of Region K in 2010 (LCRWPG 2015).

Regions C and K are important to the future of Texas because of their largest cities: Dallas, Fort Worth, and Austin. These cities help drive the economies of both regions and are among the top five largest cities in the state (TSLAC 2017). Water conservation in these regions is particularly important in the context of projected water shortages, perhaps as soon as the year 2020. As noted above, both Regions C and K cite water conservation as a recommended water management strategy to be deployed to address projected shortages (LCRWPG 2015, Freese & Nichols, Inc. et al. 2016,).

F. Literature Review

1. Indoor Water Use and Conservation Potential

One of the seminal works of water conservation research is the Water Research Foundation's *Residential End Uses of Water*, first published in 1999 (Mayer et al. 1999), and updated with the release of *Residential End Uses of Water, Version 2* in 2016 (DeOreo et al. 2016). These two studies collected data on indoor end uses of water, an avenue of study that had not been fully pursued by previous research.[23] Identifying detailed household water use by end use has led to useful information about which specific fixtures in homes are using the most and least amount of water. In both iterations of this study, researchers used survey instruments as well as home metering to analyze water use and water use behaviors.

The two *Residential End Uses of Water* studies, conducted approximately 17 years apart, enable detection of change in indoor water use. Primary findings include, a reduction in indoor water use of 22 percent – from 177 gallons per household to 138, with a corresponding reduction in per capita use from 69.3 to 58.6. Secondly, there is a considerable increase in the percentage of homes using fixtures that meet EPA's WaterSense efficiency criteria. For example, the percentage of toilets and clothes washers increased from 8 to 37 percent and from 6 to 46 percent respectively between the 1999 and 2016 studies. That said, the latter study documented considerable remaining potential for high-efficiency toilets.

Koeller (2017) used United States Census Bureau data to estimate the existing installed base of inefficient residential toilets in states that implemented low-flow toilet standards prior to the EPAct of 1992: Arizona, California, Georgia, Texas, and Colorado. This study also considered the incentive programs for toilet replacement offered to homeowners and multifamily development managers. By surveying water utility managers, Koeller (2017) determined an estimate of how many inefficient toilets had been replaced with efficient toilets and an estimate of how much water could be saved, given a 100 percent replacement rate of inefficient toilets. With efficiency defined as 1.6 gallons or less per flush, this study concludes that approximately 79 percent of the installed base of toilets are efficient.

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[23] The more recent *Residential End Uses of Water* study surveyed outdoor use as well.

Camp, Dresser & McKee, Inc. and Water Accountability, LLC. (2011) conducted a study to determine potential water savings available in the state of Wisconsin. Their study approach was somewhat novel because it considered public opinion and likely public (dis)satisfaction given the application of different conservation measures. Despite this search for customer reactions to conservation measures, the survey instrument was distributed to water utility managers, who in turn provided their opinion as to whether their customer base would be satisfied or dissatisfied with the measure in question.

The survey results indicated that voluntary and incentive-based conservation measures have the most positive effect on customer satisfaction, while ordinances and rates tend to negatively affect customer satisfaction. The surveys showed that one-third of utilities are currently providing conservation education and information programs for their customers. Two concerns, however, from the utility managers were how to fund conservation programs and concern over the possible loss of revenue due to implementation of conservation measures.

2. Collecting End-Use Data: Surveys

Customers have been surveyed on their water use behaviors in attempts to determine how water is allocated to different uses within the home. This method was used in the first and second iterations of "Residential End Uses of Water" (Mayer et al. 1999, DeOreo et al. 2016), as well as various other studies in the early stages of water conservation research. Surveying customers directly can be better than an estimation technique if direct survey responses feature accurate data/information. Since only a sample of a larger population can be captured via a survey, issues of sample representativeness and/or nonresponse bias can limit the inferential capability of the data captured.

3. Collecting End-Use Data: Home Metering

In-home water tracking has become more common, more reliable, and more accurate with the implementation of Advanced Metering Infrastructure (AMI) systems. Early in-home water measuring equipment was cumbersome, a burden on residents, and was obvious in nature: residents were always cognizant of the fact that their water use was being scrutinized (Mayer et al. 1999). New technologies such as water flow data recorders and flow trace analysis software can now be deployed with minimal annoyance to the homeowner. These technological advancements may also mean reduced need to request homeowner/dweller time to complete water use behavior surveys by phone or by mail.

Home water use tracking has undergone technological advancements. Early technologies such as mechanical flow monitors recorded flow profiles but were not able to differentiate between end uses in the home (DeOreo et al. 2016). This technology was later supplemented by devices that could be affixed to specific individual fixtures (Aher et al. 1991), but it was recognized by many researchers that further progress in the study of residential water use and conservation was impeded by the lack of accessible and comprehensive end use data (DeOreo et al. 2016). In 1993, William DeOreo developed technology to trace water flow and subsequently analyze it on a computer to identify distinctive end uses in the home (DeOreo et al. 2016). This technology allowed for better data analysis and was adopted by other researchers.

4. Measuring Outdoor Water Use

Outdoor water use can be challenging to quantify due to the influence of wide locational and seasonal variability on outdoor water requirements, the presence of one customer meter for all residential use (typically), and other factors. A study of single-family residential water use in Texas encountered these factors and estimated that on a statewide average, 31 percent of annual use is applied outdoors (Hermitte and Mace 2012). The breakdown of indoor/outdoor use stemmed from taking the lowest monthly usage during the calendar years of study and using that amount (multiplied by 12) to represent indoor usage. The difference between that amount and total annual use was presumed to represent outdoor use. One phase of the Hermitte and Mace (2012) study found that 89 percent of the cities studied used between 25 and 50 percent of all the water they consumed outdoors.

Many of the most current residential water use studies (DeOreo et al. 2011; Heberger, Cooley, and Gleick 2014; DeOreo et al. 2016) analyze outdoor water conservation potential by calculating a “theoretical irrigation requirement” or a “landscape water budget”, i.e. the minimum amount of water necessary to sustain any given piece of property based on its landscaping, plants present in the environment, and climate conditions in the region. These calculations often involve the use of a geographic information system (GIS) and remotely sensed data (e.g., LIDAR) to identify specific plant cover.

Some researchers turned to other quantitative methods to verify the accuracy of the “theoretical irrigation requirement” figure. DeOreo et al. (2011) and DeOreo (2011) conducted site visits to some homes in their study that had already been analyzed using GIS and LIDAR, inspecting plant cover and landscaping and comparing it to results of remote analysis. These two studies, along with DeOreo’s Residential End Uses of Water (2016), also used meters to log water use and surveyed water customers regarding their outdoor water use behaviors.

Estimates of outdoor water conservation potential are presented differently by different studies. Without one uniform scheme for comparing these figures, it is difficult to draw conclusions. Heberger, Cooley, and Gleick (2014) estimate that outdoor water conservation potential ranges from 30 to 70 percent of water used that could be saved. DeOreo (2011) found that approximately 63 percent of evaluated residential water users were overirrigating their properties. However, the over-irrigation was not found to be excessive in most homes. This study concludes that there is outdoor water conservation potential of around 35 percent. DeOreo et al. (2016) estimate that only 13 percent of evaluated residential water users were overirrigating given the minimum amount of water required. They estimate conservation potential between 20 and 50 percent based on implementation of landscape conservation programs.

5. Advanced Metering Infrastructure (AMI)

Advanced metering infrastructure (AMI) systems are of benefit to ratepayers because they provide real-time water use data. They also benefit water utilities by enabling them to quickly identify and repair issues in the water system, and to reduce (or delay) the number of expensive supply-side water projects (Rafter 2012). AMI systems can further empower water utilities to provide improved customer service. Rafter (2012) explains that, while water customers may not fully avail themselves of the data gathered through AMI, water utilities can offer this data to customers when a question regarding water use arises. With increased costs for many utility services, it is contingent upon the water service provider to justify costs imposed on their ratepaying customers. A water utility using an AMI system to its fullest extent can show water customers exactly when water is being used in their home (Rafter 2012). Providing daily and even hourly water use data enables both customers and utilities to use water more wisely and identify leaks or system damages quickly. Quicker identification of major problems means quicker response: if a utility can identify the exact location of a water main break, they can send repair teams out immediately to target the specific area, instead of having these teams search the entire system for the source of the problem (Rafter 2012).

AMI allows utilities to inform their consumers in water use, thereby encouraging water conservation behaviors that minimize waste. It is difficult to prove this concept, however, as quantifiable measures of improved water and monetary savings are hard to obtain and water-savings results vary with demographics, technological variants, communication pathways, and situation (Boyle et al. 2013). Nevertheless, one eighteen-month Australian study by Sydney Water found that by using Intelligent Water Metering to detect and manage network pressure and to mitigate leakage, utilities were able to save 0.528 million gallons each year in long-term leaks across 141 households (Doolan 2011). In the same study, the 161 households with in-home displays of their real time water use, saw an average reduction of 7-10 percent or 4,227 gallons per household (Doolan 2011). Integration of AMI, therefore, not only saved water by improving leak detection, but by influencing consumer behavior towards conservation of water.

One example of a community in the United States that has integrated AMI is the eastern part of the San Francisco Bay area, whose drinking water and wastewater is provided by The East Bay Municipal Utility District. With their pilot AMI program, the utility detected leaks on customers' properties that, once fixed, reduced water use by 20 percent, saving water for both the customers and the utility. (Mutchek and Williams 2014).

G. Methodology and Results

1. 2014 Residential Water Use Calculations

Data for the 2014 calendar year were obtained from the TWDB for Regions C and K. Data columns representing commercial, institutional, industrial, and agricultural water use were removed from the TWDB dataset. Data preparation allowed for the calculation of total residential water use in Regions C and K (Table III.2). Due to data limitations, single- and multifamily water use volumes were combined for the purpose of analysis.

Table III.2. Residential water use: Regions C and K, 2014.

Water Use Category	Volume (Gallons)	Volume (Acre-feet)
Total Residential	220,925,592,588	677,996

It was also necessary to address several data gaps. The water use data for the City of Celina, City of Fate, City of Royse City, and City of Mansfield, for example, were not present in the dataset. The totals for all cities were identified using their water department websites, save for the City of Fate. The City of Fate did not respond to requests for information, so their water use was not included in the final totals. It can be reasonably assumed that the City of Fate, with a population of just under 11,000 (2016) would not skew the total water use by any significant factor.

Many analyses of residential water consumption divide total use into single- and multifamily homes or focus on only one of these categories (DeOreo et al. 2011). One Texas Water Development Board water use dataset consulted in this study does divide residential water use into single- and multifamily. For the purpose of analysis, however, the data were not divided into these categories for two reasons. First, there is a lack of information in the literature about the ratio of indoor to outdoor water use in multifamily homes. While the indoor to outdoor water use ratio is available for single-family homes in Texas (Hermitte and Mace 2012, Hoffman 2016), it was not found for multifamily homes in Texas or any other state. Single-family homes in Texas use, on average, between 29-31 percent of their water outdoors and 69-71 percent indoors (Hermitte and Mace 2012, Hoffman 2016). It would be expected that families and individuals residing in multifamily structures use less water outdoors because they are not typically responsible for upkeep of a lawn or other outdoor space requiring irrigation. Lack of data to prove this observation and any assumption made about such percentages would thus only be conjecture.

The second reason for combining single-family and multifamily water use into a unified category of residential water use is data limitations. Upon close analysis of the Texas Water Development Board's dataset, there were some gaps that indicated several potential errors in the reporting of water use data. One such example is the water use data for the city of Dallas: despite its position as Texas' third largest city, Dallas has zero volume of water reported for multifamily accounts in 2014. The reason for this is not immediately clear. It may be a data entry error, it may be that Dallas does not split residential water use into single- and multifamily use, or it may be the case that multifamily water use has been reported in a different category of use. This is not uncommon, as apartment complexes are often reported as being commercial water users, thus relegating what is in fact residential water use to the commercial water use category (TWDB 2015).

For these reasons, single-family and multifamily water use were combined under the broader heading of "Residential Water Use". Combining these two sectors may affect the final results of the analysis, given that the ratio of indoor to outdoor water usage applicable to single-family residences is being applied to multifamily residences as well. Assuming that multifamily residences use less water outdoors, the final water use and conservation potential totals for outdoor water use will be skewed somewhat higher, while the totals for indoor water use will be skewed somewhat lower. This was deemed acceptable to avoid the forced assumptions that would have been necessary to analyze single-family and multifamily water use separately.

At this point in the analysis, it was necessary to divide the total residential water use into indoor and outdoor residential water use. The literature offers some guidance as to the exact nature of this division, and some estimates were made to account for location-specific data. Hermitte and Mace (2012) determined that 69 percent of residential single-family water use takes place indoors, while 31 percent is used outdoors. Hoffman (2016) calculates a similar breakdown, with indoor use accounting for 71 percent and outdoor use accounting for 29 percent of total residential use. The Hoffman (2016) figures were calculated by analyzing water use in different types of homes, i.e. single-family, multifamily: 2-4 units, multifamily: 5 or more units, mobile homes, etc. Hoffman (2016) estimates that mobile homes, specifically, devote 25 percent of their water use to outdoor use. This estimate seemed too high, so the indoor/outdoor breakdown was recalculated to reflect mobile home outdoor water use representing only 15 percent of total use. This decision was based on anecdotal rather than empirical evidence. This adjustment lowered the indoor/outdoor breakdown to indicate that 72 percent of water is used indoors and 28 percent is used outdoors. This figure was applied to the total water use volumes above to estimate the following volumes of indoor and outdoor water use in Regions C and K (Table III.3).

Table III.3. Residential indoor versus outdoor water use: Regions C and K, 2014.

Water Use Category	Volume (Gallons)	Volume (Acre-feet)
Residential Indoor	159,066,426,663	488,157
Residential Outdoor	61,859,165,925	189,839

Calculating the total residential indoor volume enabled the computation of the residential indoor gallons per capita per day (GPCD) figure, or the number of gallons of water one person uses on average every day. The total residential indoor volume figure was divided by the population of the region and divided by 365 to determine the region's indoor GPCD. The average residential indoor figure for Regions C and K was calculated to be 62 GPCD. By comparison, DeOreo et al. (2016) discovered usage of 58.6 GPCD in their study.

Further analysis of indoor residential water use relied on numbers set forth in the most recent *Residential End Uses of Water* study (DeOreo et al. 2016). This study used survey and water logging data to break down the end uses of water in the average household. They found that 24 percent of indoor water is used for toilets, 19 percent for faucets, 19 percent for showers, 16 percent for clothes washers, 14 percent is lost through leakage, 4 percent goes to "other" uses including evaporative cooling, humidification, and water softening, 3 percent is used for baths, and the final one percent of indoor water is used in dishwashers (DeOreo et al. 2016). While DeOreo et al. (2016) acknowledge that their study was not designed to be representative of all North American locations, we applied these percentages to our total indoor water use volume nonetheless. The resulting calculations of total water volume going to each end use or fixture type in 2014 are featured in Table III.4.

Table III.4. Indoor water use by fixture type: Regions C and K, 2014.

Fixture/Use	2014 Volume (gallons)	2014 Volume (acre-feet)
Toilet	38,175,942,399	117,158
Faucet	30,222,621,066	92,750
Shower	30,222,621,066	92,750
Clothes Washer	25,450,628,266	78,105
Leaks	22,269,299,733	68,342
Other*	6,362,657,067	19,526
Bath	4,771,992,800	14,645
Dishwasher	1,590,664,267	4,882
TOTAL	**159,066,426,663**	**488,157**

The water volume totals in Table III.4 were then divided by 365 (days per year) and by combined regional population to determine gallons per capita per day (GPCD) of water devoted to each end use (Table III.5).

Table III.5. Gallons per capita per day (GPCD) by indoor fixture type: Regions C and K, 2014.

Fixture	Current Use (GPCD)
Toilet	14.9
Faucet	11.8
Shower	11.8
Clothes Washer	9.9
Leak	8.7
Other	2.5
Bath	1.9
Dishwasher	0.6
TOTAL	**61.9**

Rounding of individual values may not sum to actual total.

2. Indoor Water Use Conservation Potential

Here we estimate potential from a combination of water-use behaviors and full use of efficient fixtures across both regions as defined by current fixture standards in Texas. Heberger, Cooley, and Gleick (2014) calculated a hypothetical, fully-efficient indoor GPCD figure which they then compared to the current GPCD figure to determine a percentage of potential water conservation. This was determined to be a useful methodology for the current study. Some of their figures were used as-is, and some updates were made to their figures to align more closely with other sources in the literature (Table III.6).

Table III.6. Assumptions and calculations of individual daily water use by fixture type.

Fixture	Fully-Efficient GPCD Assumptions
Toilet	5 flushes per person per day at 1.28 gallons per flush. Adopted calculation from Heberger, Cooley, and Gleick (2014).
Faucet	Households upgraded to have fully water-efficient faucets use 18.1 gallons of water in faucets each day (DeOreo 2011). This figure was divided by 2.75, the average number of persons per household in Texas (TWDB 2015), to determine a fully efficient GPCD of 6.6 gallons.
Shower	5 showers per person per week (Vickers 2001) for 8.7 minutes each with conserving showerhead rated at 2.0 gallons per minute and throttle factor of 72% for actual flow rate of 1.44 gallons per minute. Adopted calculation from Heberger, Cooley, and Gleick (2014).
Clothes Washer	2.3 loads per person per week at 14.4 gallons per load. Adopted calculation from Heberger, Cooley, and Gleick (2014).
Leaks	Heberger, Cooley, and Gleick (2014) assume that leaks are reduced to zero. To reflect a more conservative scenario, we assume that leaks are reduced by 50%.
Other	Heberger, Cooley, and Gleick (2014) do not account for an “Other” category in their method. In the 2016 Residential End Uses of Water study (DeOreo et al. 2016), however, “other” water uses (including humidification, evaporative cooling, and water softening) are estimated to account for 4% of indoor use. We assume that these uses remain constant.
Bath	We assume that water use in baths remains constant. Bathing behavior is not affected by efficient fixtures as baths are reliant on a fixed volume of water: the tub must be filled, no matter how long it takes or how little water comes out of the faucet. Furthermore, the 2016 Residential End Uses of Water study (DeOreo et al. 2016) indicates that water use in baths has not changed in a statistically significant way since the same study was conducted in 1999. For these reasons, we assume that water use in baths remains consistent from current use to fully efficient use.
Dishwasher	The average person does less than one load of dishes per week, or approximately 0.1 loads per day (DeOreo et al. 2016). The most water-efficient dishwasher currently on the market uses a maximum of 3.5 gallons per load (USEPA 2018). These two statistics indicate that a fully water-efficient GPCD for dishwashers is 0.35 gallons.

These assumptions helped to compute a hypothetical, fully-efficient GPCD figure, which was then compared to the GPCD derived from the two planning regions calculated in Table III.5. Using this methodology, this study found that if Texas Water Planning Regions C and K had implemented fully efficient residential indoor water technology in 2014, water use could have been reduced by about 43 percent, from 61.9 gallons per capita per day to 35 gallons per capita per day (Table III.7).

Table III.7. Current versus fully efficient indoor use by fixture type: Regions C and K, 2014.

Fixture	Current Use (GPCD)	Fully Efficient Indoor Use (GPCD)
Toilet	14.9	6.4
Faucet	11.8	6.6
Shower	11.8	9.0
Clothes Washer	9.9	4.7
Leak	8.7	4.0
Other	2.5	2.0
Bath	1.9	2.0
Dishwasher	0.6	0.4
TOTAL	**61.9**	**35**

Rounding of individual values may not sum to actual total.

3. Outdoor Water Use Conservation Potential

Many residential water use studies analyze outdoor water conservation potential by calculating a minimum amount of water necessary to sustain any given piece of property based on its landscaping, plants present in the environment, and climate conditions in the region. These calculations often involve the use of a GIS and remotely sensed data (e.g., LIDAR). Such a methodological approach was not within the scope of this study. Instead, percentages of outdoor water use reduction were calculated by first identifying relevant outdoor watering restrictions and ordinances in each region of study. Then the potential for reduction was analyzed if these restrictions and ordinances were to become more restrictive. The top 27 water service providers in Regions C and K were identified along with any outdoor watering restrictions and ordinances. These top 27 water service providers (Table III.8) account for roughly 85% of 2014 water system input volume in Regions C and K (Loftus *forthcoming*). And of these 27 water service providers, only the City of Austin is in Region K.

Table III.8. Outdoor watering ordinances/rules for top 27 water utilities in Regions C and K, tabulated from largest to smallest.

Public Water System Provider	Outdoor Watering Ordinance	Source
Dallas Water Utility	Maximum 2 days per week allowed for automatic irrigation or hose-end sprinklers; No watering from 10am-6pm between April 1 to October 31, and no watering on Monday, Tuesdays, or Fridays. Drip irrigation, soaker hoses, and hand watering are allowed any day and any time.	http://savedallaswater.com/twice-weekly-watering-schedule/
City of Fort Worth	Maximum 2 days per week; No watering from 10am-6pm for irrigation systems or sprinklers, year-round; No watering on Mondays; Hand-held hose, drip irrigation, or soaker hose are allowed at any time.	fortworthtexas.gov/savefwwater/irrigation/twice-per-week/
City of Austin Water and Wastewater	Automatic irrigation allowed 1 day per week for residential customers; Watering only allowed from 7pm-10am, year-round; Hose-end sprinklers allowed 2 days per week; Hand-held hose, soaker hose, and drip irrigation are allowed at any time.	http://www.austintexas.gov/department/watering-restrictions
City of Arlington	No watering 10am-6pm, year-round; Hand watering and soaker hoses are allowed at any time.	http://www.arlington-tx.gov/water/water-conservation/watering-nixed/
City of Plano	For irrigation systems and sprinklers, April-October: 2 days per week; November-March: 1 day per week; Low-flow drip irrigation allowed at any time; Hand-held hose is allowed 2 hours any day.	https://www.plano.gov/220/Water-Conservation-Restrictions-Home
City of Irving	Maximum 2 days per week; No watering 10 am-6 pm from April 1 to October 31; Irrigation systems are not allowed on Monday, Thursday, or Friday.	http://cityofirving.org/AlertCenter.aspx?AID=216
City of Garland	For irrigation systems and sprinklers, April 1 to October 31: max 2 days per week and November 1 to March 31: max one day a week; No watering between 10 am and 6 pm; Hand watering with an automatic shutoff nozzle, soaker hoses, and drip irrigation are allowed at any time.	http://www.garlandwater.com/civicax/filebank/blobdload.aspx?blobid=26152
City of McKinney	Maximum 2 days per week; No watering 10 am-6 pm from April 1-October 31 for automatic irrigation systems. Irrigation systems with registered and programmed ET (evapotranspiration) controllers are allowed at any time.	https://www.mckinneytexas.org/511/Outdoor-Water-Use
City of Grand Prairie	Maximum 2 days per week, year-round; No watering 10 am-6 pm; No watering on Wednesday, Saturday, or Sunday; Hand-held and soaker hoses are allowed at any time.	https://www.gptx.org/city-government/city-departments/public-works/water-utilities/current-water-restrictions

City of Frisco	Maximum one day per week during spring and summer unless weather station data supports 2 days; No watering 10 am-6 pm during Daylight Saving Time; Hand-held hoses, soaker hoses, drip irrigation, and bubbler systems are allowed for 2 hours any day.	http://friscotexas.gov/445/Water-Efficiency-Plan
City of Richardson	From April 1 to October 31: max 2 days per week; No watering between 10 am to 6 pm; hand-held hoses with a shut-off spray nozzle are allowed anytime.	https://www.cor.net/departments/public-services/water/water-conservation
City of Carrollton	No watering 10 am-6 pm for permanently installed automatic irrigation systems from April 1-October 31.	http://www.cityofcarrollton.com/departments/departments-g-p/public-works/water-conservation
City of Mesquite	Maximum 2 days per week; No watering between 10 am and 6 pm from April 1 to October 31 for sprinklers and irrigation systems; If necessary, additional watering allowed with hand-held hoses, irrigation drip systems, or soaker hoses at any time if no runoff occurs.	https://www.cityofmesquite.com/1747/Current-Water-Restrictions
Town of Flower Mound	No watering 10 am-6 pm from April 1 to October 31 for irrigation; Watering with hand-held hoses, buckets, or drip irrigation is allowed anytime.	https://www.flower-mound.com/599/Water-Conservation
City of Grapevine	No watering is allowed from 10 am to 6 pm for any type of watering or irrigation systems.	http://www.grapevinetexas.gov/525/Water-Conservation-Watering-Restrictions
City of Lewisville	Maximum 2 days per week year-round; No watering 10 am to 6 pm May-September with automatic irrigation systems or hose-end sprinklers.	https://www.cityoflewisville.com/about-us/city-services/sustainability/water-conservation/outdoor-watering-restrictions
City of Allen	Maximum 2 days per week with sprinklers; No watering 10 am-6 pm from April 1 to October 31	https://www.cityofallen.org/929/Water-Conservation
City of North Richland Hills	Maximum 2 days per week with sprinklers or irrigation systems year-round; no watering 10 am-6 pm; No irrigation allowed on Mondays.	https://www.nrhtx.com/543/Water-Conservation
City of Southlake	Maximum 2 days per week; no watering 10 am-6 pm year-round; No irrigation allowed on Mondays; Hand-held hoses are allowed anytime.	https://www.cityofsouthlake.com/289/Water-Smart-Outside
City of Coppell	No watering 10 am-6 pm year-round; Hand-held hoses and non-spray irrigation systems are allowed anytime.	http://www.coppelltx.gov/residents/water-conservation-plan
City of Sherman	No restrictions	n/a
City of Keller	Maximum 2 days per week; No watering 10 am-6 pm; Hand-held hoses, soaker hoses, or drip irrigation are allowed 2 hours any day.	https://www.cityofkeller.com/services/public-works/environmental-services/water-restrictions

City of Farmers Branch	No restrictions	https://www.farmersbranchtx.gov/faq.aspx?qid=110
City of Euless	No watering 10 am-6 pm year-round with hose-end sprinklers and automatic and non-automatic irrigation systems; Hand-held hoses, drip irrigation, and soaker hoses are allowed anytime.	http://www.eulesstx.gov/environment/waterconservation.htm
City of Bedford	No watering 10 am-6 pm year-round.	https://www.bedfordtx.gov/faq.aspx?qid=64
City of Desoto	No restrictions	http://www.ci.desoto.tx.us/573/General-Watering
City of Colleyville	Maximum 2 days per week; No watering 10 am-6 pm; No watering on Mondays; Hand watering and soaker hoses are allowed anytime.	https://library.municode.com/TX/colleyville/codes/code_of_ordinances?nodeId=PTIICOOR_CH98UT_ARTIIWASE_DIV1GE

Table III.9 below offers a tally of outdoor water rules that are found among the top 27 water utilities that are listed in Table III.8.

Table III.9. Summary of outdoor watering rules for top 27 utilities in Regions C and K, Texas.

Type of Restriction	Number of Utilities
Time of day restrictions	23
1 day/week auto irrigation restrictions	2[a]
1 day/week watering restrictions	4[b]
2 day/week watering restrictions	16[c]
Hose-end sprinkler restrictions	10
Handheld watering restrictions	3

[a] Frisco: only applicable during the spring and summer; [b] Austin: only applicable to auto irrigation; Garland: only applicable November through March; Plano: auto irrigation and sprinkler systems November-March; Frisco: only applicable Spring and Summer; [c] City of Richardson: only applicable Spring and Summer; Garland: only applicable April through October; Plano: only applicable April-October; Austin: if 1 day is auto irrigation then one additional day allowed for hose-end sprinklers.

Twenty-three of these 27 water service providers restrict watering between the hours of 10 am and 6 pm, but not at any other time. Watering by any means is often allowed without restriction at other times of day, with the exception of Frisco, Plano, and Keller that restrict hand-held hoses to two hours per day. Assuming use of automatic irrigation systems, this lack of restriction allows large volumes of water use to occur on a daily basis and until a drought might be well underway at which time drought-related restrictions might be triggered. Furthermore, even in utilities that restrict automatic irrigation systems, there is often no restriction on hand-held watering of which customers can use even in the hottest and driest times when watering is the least effective.

To estimate water conservation potential, this study lays out a hypothetical conservation scenario in which all water service providers adjust their ordinances to restrict outdoor water use by automatic irrigation systems and hose-end sprinklers to just one day per week. In such a scenario, it can be assumed that there would be variable levels of water use reduction. This is due to the fact that day of the week watering restrictions are only in place for automatic irrigation systems, not hand watering. Residential water users could continue to hand water as much as desired and might even increase hand watering if their automatic irrigation systems were restricted. However, it is likely that overall outdoor residential water use would decrease given the reduction of automatic irrigation system use by one half or more. Limiting use of automatic irrigation systems and hose-end sprinklers to one day per week could also result in residents discovering that their landscapes require less water than they have been using. For the purposes of this study, two levels of water reduction are assumed: 25 and 40 percent. Results of this analysis are presented in Table III.10.

Table III.10. Outdoor water use and conservation potential estimates: Regions C and K, 2014.

Outdoor Water Use Volume	Water Savings - 24% Reduction	Water Savings - 40% Reduction
Gallons	**Gallons**	**Gallons**
61,859,165,925	14,846,199,822	24,743,666,370
Acre-feet	**Acre-feet**	**Acre-feet**
189,839	45,561	75,936

H. Discussion

This study finds that if Texas Water Planning Regions C and K had implemented fully efficient residential indoor water fixtures in 2014, water use could have been reduced by 44 percent, from 61.9 gallons per capita per day to 35 gallons per capita per day.[24] By extension and given the 2014 indoor water use figure of 488,157 acre-feet in Regions C and K, implementation of fully-efficient indoor water use fixtures could have saved a total of 214,789 acre-feet of water.

This amount of estimated water savings potential from fully utilizing current high-efficiency fixtures – 214,789 acre-feet – exceeds the 86,901 acre-feet[25] expected from municipal conservation water management strategies in 2020, per the most recent regional plans. This expected supply from implementation of municipal strategies undoubtedly comes from a more comprehensive suite of conservation measures and incentives than fixture replacements alone. Thus, the two regional plans appear to be underestimating the amount of water that could be saved/generated from a more robust suite of utility conservation programs that includes an

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[24] This finding also presumes water-use behaviors as outlined in Table 6.

[25] Again, this figure includes additional savings from water loss control strategies in Region K.

emphasis on proactive fixture replacements. Findings here are complementary to those found by DeOreo et al. (2016) where just 37 and 46 percent of homes they surveyed employ toilets and clothes washers, respectively, that met their fixture-efficiency criteria.[26]

Analysis of outdoor water use found that Regions C and K could have saved between 45,561 and 75,936 acre-feet of water in the year 2014 assuming water savings of 24 to 40 percent that are attributed to limiting outdoor water use with automatic irrigation systems to one day per week. Common-sense restrictions on outdoor water use are not novel. The City of Austin in Region K (i.e., Austin Water) is a case in point where a growing and thriving city made a decision, following the most recent drought, to limit outdoor water use with automatic irrigation systems to one day per week. Frisco, Texas in Region C is another example of a growing city that limits outdoor water use to one day per week.[27] Other water utilities could follow Austin and Frisco's leads and implement similar outdoor watering rules. In doing so, cities will have more water on hand when the next drought occurs and as a result, have more time to prepare for an unknown degree of pending scarcity.

Estimated potential for outdoor and indoor water savings combined come to a total of between 260,350 acre-feet (lower assumption of outdoor savings) and 290,725 (higher assumption of outdoor savings) acre-feet. These numbers are clearly significant, particularly in the context of the projected water shortages in Regions C and K by the year 2020. Assuming a recurrence of the drought of record, these two regions combined are expected to experience water needs/potential shortages of 498,600 acre-feet per year (2020) across all water-use sectors of which 23 percent or 114,599 acre-feet per year are within the municipal sector (LCRWPG 2015; TWDB 2016). The potential water savings calculated in this study could account for approximately 52 to 58 percent of the potential shortages across all sectors. More importantly, the estimated savings are greater than the potential shortages expected within the municipal sector. The savings estimated here are achievable without the magnitude of public investment that is typical of traditional supply-side augmentation projects that are also found in the state water plan.

I. Conclusions/Recommendations

Considerable water savings from greater use of high-efficiency fixtures and implementation of sensible outdoor water-use restrictions across a larger number of communities have been identified in this study. And these estimated savings are usually available at relatively low costs as compared to other water management strategies, particularly the more traditional supply-side augmentation strategies (TWDB 2016, Richter 2014).

Older and more wasteful water-use fixtures are slowly replaced over time with the current technology of high-efficiency fixtures, most of which are WaterSense-labeled. With a potential shortage looming now, however, should the next record drought be underway or soon to occur,

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[26] These percentages were improvements from the Mayer et al. (1999) study that found just 5 and 6 percent of homes employed toilets and clothes washers that met their fixture-efficiency criteria.

[27] Frisco's outdoor water restriction is limited to the spring and summer seasons unlike Austin where rules are in effect year-round. Austin allows the use of hose-end sprinklers an additional day per week.

there is little reason to wait on natural fixture replacement rates (e.g., 20 years for toilets) when tangible water savings can be had almost immediately with utility-driven, targeted programs for proactive fixture replacement. Savings estimated here greatly exceed those expected in 2020 from a more comprehensive suite of conservation programs as documented in the two regional plans. If greater savings from municipal conservation is to be taken advantage of, then more emphasis can be placed on fixture updates with a particular focus on toilets and clothes washers. Fixture-rebate programs have proven to be successful incentives for replacing older fixtures when accompanied by a thoughtful public information campaign (Syme, Nancarrow, and Seligman 2000).

As for outdoor water use, conservation in many places (the top 27 utilities studied here) appears to be practiced only as a drought restriction which is not the same as proactive conservation as it could be practiced. To take advantage of the water conservation savings estimated here, a number of factors will need to be addressed. First, water rates and rate structures will have to be reviewed to ensure that, at a minimum, they cover the cost of service expected, if not the full cost of service provided. A rate study can help determine such utility costs and help a utility to avoid the so-called conservation conundrum[28]. Secondly, political will is needed to acknowledge the unsustainability attached to minimal or no outdoor water restrictions and the typically nonnative and overly thirsty turf grasses that continue to be installed throughout a rapidly growing Texas. A concerted public information campaign to support both nods towards more locally appropriate and sustainable water use will be a critical component for achieving the conservation-derived water supplies estimated here.

Data on multi-family residential water use, including a breakdown of indoor and outdoor use (or methodology for estimating such), are insufficient and forced us to make assumptions in this study. More work needs to be done to develop reliable estimates of multi-family use. Partnering with utilities and apartment complex management companies and/or condominium associations will likely be required to make progress in this area.

One aspect of this type of work that was beyond the scope of this project is to conduct a cost analysis of the fixture upgrades that lead to the estimated savings potential. The cost on a unit of water saved basis can then be compared to a unit value of water saved to generate a benefit/cost ratio of sorts. For now, it is hypothesized that a positive benefit/cost ratio will emerge from this additional research recommendation.

As a last recommendation, it will be useful for all planning regions in Texas to parse out water loss control strategies and their associated annual water supply estimates and costs from other municipal conservation strategies and estimated supply volumes/costs much as is currently done in Region C. The greater level of detail that this separation affords, will help planners, researchers, and policy-makers in understanding where and how water savings and associated costs are to be attributed and where additional conservation potential can be had.

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[28] The conservation conundrum occurs when conservation results in lower water use and thus, sales revenue for the water service provider. Water rates/rate structures need to be carefully designed to maintain revenue stability and fiscal solvency at the utility as a conservation program succeeds in lowering water use/sales.

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IV. Estimating the Conservation Potential of the Commercial, Institutional, and Industrial Water-Use Sectors in Texas Water Supply Planning Regions C and K: Executive Summary

A. Summary of Lacey Smith's Directed Research Report

This study focuses on the water conservation potential in the commercial, institutional, and industrial (CII) water uses in Texas Water Planning Regions C and K. Region C includes the Dallas and Fort Worth-Arlington metropolitan areas and 16 counties (Freese & Nichols et al. 2015). Although this region only consumes 8.3 percent of the state's total water use, its large population and high percentage of its water use for municipal purposes, results in an expected shortage of 1.2 million acre-feet for year 2070 (Freese & Nichols et al. 2015). Water conservation and efficiency are important strategies proposed by this region's Water Planning Group to address this shortage and meet their goal of 1.16 million acre-feet of water saved/produced through conservation measures by 2070 (Freese & Nichols et al. 2015).

Region K is largely located within the Lower Colorado River Basin and its largest city is Austin (LCRWPG 2015). Region K is also expected to face water shortages, estimated at 512,000 acre-feet by 2070 (LCRWPG 2015). With water conservation and efficiency strategies to combat this shortage, region K Water Planning Group aims to save 20,000 acre-feet by 2070 by implementing and improving water conservation measures (Freese & Nichols et al. 2015).

A shortcoming of these goals is the lack of specification of how to achieve conservation and efficiency in the commercial, institutional, and industrial (CII) sectors. To put efforts and money to the best use, it is imperative to understand which economic subsectors make up CII water use and which of these have the greatest potential for decreasing water use. To breakdown water use by subsector within the CII sectors, categories were created by using the classifications that were previously determined in a similar water conservation potential study by Gleick et al. (2003). Thus, Table IV.1 illustrates the economic subsectors that were identified and analyzed in this study:

Table IV.1: CII Subsectors

Commercial/Institutional	Industrial
Restaurants	Meat Processing
Hotels	Dairy Processing
Hospitals	Fruit and Vegetable
Grocery	Beverages
Misc. Retail	Textiles
Schools	Paper & Pulp
Office Buildings	Fabricated Metals
Laundry	High Tech

After identifying the economic subsectors for analysis, employment was determined in each of these subsectors, and then an established water use metric was applied to estimate water use in each subsector. Each economic subsector in both regions was matched to North American Industry Classification System (NAICS) codes with as much precision as possible using a NAICS conversion document (NAICS Association 2017)[29]. With the assigned NAICS codes, the United States Census Bureau's County Business Patterns database (United States Census Bureau 2017) was queried to determine employment in each NAICS code for each county examined in the year of study: 2014. Once employment by NAICS code was established, an equation to determine water use by NAICS code was set up using the metric of gallons (of water used) per employee per day (GED). The GED metric, multiplied by the number of employees working in each subsector, leads to the overall estimate of water use by the subsector and by county. Subsector totals are useful for comparison and determination of the relatively high/low water using subsectors. While this methodology is an appropriate way to find water use for commercial and institutional subsectors, it is less dependable for the industrial sector since water use in this latter sector varies with the type of manufacturing process involved.

Estimates of the amount of potential water that could be saved for each sector were then determined by assuming different levels of high-efficiency fixture installations and their associated percentages of reduction in total water use remaining. All of the commercial and institutional subsectors' water conservation potential is estimated at 25 percent and 50 percent of actual use to indicate a range of possibilities. The United States Environmental Protection Agency's WaterSense program labels consumer products that have increased levels of water efficiency and effectiveness than existing models. The 25 percent potential figure represents the conservative assumption that 75 percent of the fixtures have already been upgraded to high-efficiency/WaterSense-labeled products. The industrial subsector's water conservation potential is estimated at 24 and 36 percent. These percentages were chosen by finding the average of the potential percentages for each subsector from Gleick et al. (2003) which was 30 percent and then by calculating 20 percent above and below that average to account for uncertainties. This process yielded the percentages of 24 and 36.

Since conservation is the primary strategy behind water demand management in the 2017 State Water Plan (TWDB 2016), this research will allow water managers and policymakers to better understand potential savings available in the CII sector and, therefore, make more informed decisions regarding water savings feasibility in different economic sectors.

The data from 2014 to perform this project was acquired from the Texas Water Development Board and other sources. Water-use data were then disaggregated and sorted so only the greatest combined CII volumes and top users were identified. For the sake of efficiency, two groups of Water Service Providers (WSP) were the focus of this study: one group includes the top 50 WSPs of Region C that account for 95 percent of its CII water consumption, and the second group includes the top 20 WSPs of Region K that account for over 94 percent of Region

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[29] The NAICS codes were converted from Standard Industrial Classification (SIC) codes used by the Pacific Institute study.

K’s CII water consumption. The counties for each WSP included in these two groups were identified and selected from the larger list for each planning region to become the focus of this study. Tables with the included counties can be found in Appendix A.

The results of this study indicate that 2014 CII water use estimates for Region C was 239,074 acre-feet and for Region K, 49,353 acre-feet. This project estimates the conservation potential of each subsector based on a breakdown of use as presented in the Tables IV.2 and IV.3 and use-reduction percentages based on estimates of the currently installed base of water-efficient-fixtures. The 2014 water use data reported to the Texas Water Development Board for Region K was only one percent higher than this study’s estimate; the data reported to TWDB for Region C was about 35 percent higher than this study’s estimate of 322,611 acre-feet (Table IV.4). This discrepancy is possibly explained by the larger number of counties in Region C or from a potential water use subsector that was not represented in the categories of this study. Since this study’s CII water use results in Region C are lower than the sum of CII data reported to the TWDB, it is suggested that the conservation potential identified here is a conservative estimate.

Table IV.2 2014 Commercial and institutional water-use estimates by subsector (acre-feet) for Regions C and K, Texas.

Region C	Acre-feet
Restaurants	68,979
Hotels	5,532
Hospitals	7,624
Grocery	5,728
Misc. Retail	25,566
Schools	6,160
Office Buildings	83,570
Laundry	4,684
TOTAL	**207,843**

Region K	Acre-feet
Restaurants	14,799
Hotels	2,383
Hospitals	2,213
Grocery	2,687
Misc. Retail	8,358
Schools	2,043
Office Buildings	9,532
Laundry	1,078
TOTAL	**43,093**

Table IV.3 2014 Industrial water-use estimates by subsector (acre-feet) for Regions C and K, Texas

Region C	Acre-feet
Meat Processing	3,804
Dairy Products	2,604
Preserved Fruits and Vegetables	6,654
Beverage Manufacturing	6,490
Textile Manufacturing	614
Paper and Pulp	1,180
Fabricated Metals	5,024
High Tech	4,761
TOTAL	**31,230**

Region K	Acre-feet
Meat Processing	411
Dairy Products	433
Preserved Fruits and Vegetables	1,152

Beverage Manufacturing	1,209
Textile Manufacturing	91
Paper and Pulp	0
Fabricated Metals	657
High Tech	2,306
TOTAL	**6,260**

Table IV.4 Total water-use comparison between TWDB data and estimates from this study's methodology

	TWDB data	This study's estimate	Percent Difference
Region C	322,611	239,074	35
Region K	49,746	49,353	1

Region C's commercial and institutional sectors yield a potential savings of 51,961 to 103,922 acre-feet with 25 percent and 50 percent water reduction scenarios, respectively (Table IV.5). Region K's commercial and institutional sectors yield a potential savings of 10,642 to 21,283 acre-feet given 25 and 50 percent reductions in water use, respectively (Table IV.6). Both regions' combined potential water savings in the combined commercial and institutional sectors range from 62,603 to 125,205 acre-feet.

Table IV.5 Commercial and Institutional Water Savings by Subsector (acre-feet) (Region C)

Subsector	Water Saved with a 25% Reduction	Water Saved with a 50% Reduction
Offices	20,893	41,785
Restaurants	17,245	34,490
Hotels	1,383	2,766
Hospitals	1,906	3,812
Laundry	1,171	2,342
Misc. Retail	6,392	12,783
Schools	1,540	3,080
Grocery	1,432	2,864
TOTAL	**51,961**	**103,922**

Table IV.6 Commercial and Institutional Water Savings by Subsector (acre-feet) (Region K)

Subsector	Water Saved with a 25% Reduction	Water Saved with a 50% Reduction
Offices	2,252	4,503
Restaurants	3,700	7,400
Hotels	596	1,192
Hospitals	553	1,107

Laundry	270	539
Misc. Retail	2,090	4,179
Schools	511	1,021
Grocery	672	1,344
TOTAL	**10,642**	**21,283**

Industrial water-use conservation potential is smaller than the other two sectors given the methodology employed here. Given a 24 and 36 percent reduction in water use, Region C's industrial sector is estimated to have saved 6,703 to 10,055 acre-feet of water in 2014 (Table IV.7). Region K's industrial sector savings is estimated at 1,356 to 2,035 acre-feet (Table IV.8). Since both Region C and K are expected to have annual needs (potential shortages) by the year 2020, implementing fixture upgrades will help to use less water through efficiency gains.[30]

The results of this study show that combined CII water conservation potential through efficient fixtures for Region C ranges from a low of 58,664 acre-feet to a high of 113,976 acre-feet. This volume of estimated water savings will account for 54 to 104 percent of the region's expected municipal and manufacturing[31] water needs/potential shortages of 109,367 acre-feet per year during the decade beginning in 2020 according to the 2017 State Water Plan (TWDB 2016). The combined CII water conservation potential through efficient fixture upgrades in Region K ranges from a low of 11,998 acre-feet to a high of 23,318 acre-feet. These volumes account for 3 to 6 percent of Region K's expected demand from both municipal and manufacturing sectors combined in 2020 of 362,579 acre-feet (TWDB 2016; LCRWPG 2015). Estimated savings for Region K are greater than the expected needs/potential shortage of 8,451 acre-feet per year during the upcoming decade.

Table IV.7 Industrial Water Savings by Subsector (acre-feet) (Region C)

Subsector	Water Saved with a 24% Reduction	Water Saved with a 36% Reduction
Meat Processing	904	1,356
Dairy Products	606	909
Preserved Fruits and	1,549	2,324
Beverage	841	1,262
Textile	147	221
Paper and Pulp	307	461

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[30] Within the Industrial sector, greater or similar water savings are likely to come from changes in the particular manufacturing process as opposed to upgrades to high-efficiency fixtures. Furthermore, Region K's annual needs (potential shortages) in the municipal and manufacturing sectors are expected to be relatively minimal in 2020 (7,881 acre-feet/year and 570 acre-feet/year respectively), but will grow consistently and considerably by 2070.

[31] Some percentage of water use in the manufacturing sector is sourced from private wells or permitted surface withdrawals rather than being purchased from a municipal water service provider.

Fabricated Metals	1,206	1,808
High Tech	1,143	1,714
TOTAL	**6,703**	**10,055**

Table IV.8: Industrial Water Savings by Subsector (acre-feet) (Region K)

Subsector	Water Saved with a 24% Reduction	Water Saved with a 36% Reduction
Meat Processing	98	146
Dairy Products	101	151
Preserved Fruits and	268	402
Beverage	157	235
Textile	22	33
Paper and Pulp	0	0
Fabricated Metals	158	236
High Tech	553	830
TOTAL	**1,356**	**2,035**

Texas' water demand is expected to soon exceed its water supply by year 2020, assuming recurrence of record drought conditions and lack of implementation of the water management strategies that are recommended in the State Water Plan. This study provides plausible evidence that there is potential for substantial quantities of water to be saved through reduction of water use from proactive installation of upgrades to high-efficiency fixtures. The quantity of water estimated to be available, ranging from 70,662 to 137,294 acre-feet, will help to reduce the expected water supply shortages that will be facing Regions C and K in just a couple of years should a record drought be underway. Region C's potential water savings is especially notable where the upper end of identified savings potential is as much as 104 percent of the region's expected needs/potential shortages in 2020.

This study also provides a framework and methodology for future studies. Using NAICS codes and county employment data to breakdown commercial, institutional, and industrial water-use sectors into specific economic subsectors is necessary for targeting conservation programs that aim to lower water use where it is highest. Furthermore, the knowledge of water use by economic subsector (e.g., hotels vs. restaurants, etc.) allows a conservation program to be nuanced with elements that are tailored to a particular type of commercial and/or institutional activity. The relative water-use accuracy of this methodology when compared to the data reported to the TWDB indicates a promising level of efficacy that with additional work, can likely be improved on.

Future research to build on this study can determine the cost of implementing water-efficient fixtures. The economic feasibility of water conservation measures and operating funds that are estimated to be saved by fixture-upgrade implementation will inform the decisions of those seeking to reduce their water use and/or operating expenses. Additionally, performing audits that use different water metrics such as gallons/hotel guest/day will further improve on this study's methodology and its yield of water conservation potential. With the potential for Texas' water demand to exceed water supply, it is imperative for all economic sectors to reduce their water consumption. This study has aimed to give water managers a more detailed picture of water conservation potential and a hint at benefits. Implementing water efficiency and conservation measures now will help to minimize costly and, in some cases, controversial public investment in water infrastructure going forward.

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C. Appendix A

Region C:

Table App-1: 2014 Commercial and Institutional Water Use by County (acre-feet)

County	Acre-feet
Collin	55,660
Dallas	85,473
Denton	12,969
Ellis	2,035
Grayson	2,362
Tarrant	49,344
TOTAL	**207,843**

Table App-2: 2014 Industrial Water Use by County (acre-feet)

County	Acre-feet
Collin	2,491
Dallas	16,043
Denton	514
Ellis	586
Grayson	2,560
Tarrant	9,037
TOTAL	**31,230**

Table App-3: Commercial and Institutional Water Savings by County (acre-feet)

County	Water Saved with a 25% Reduction	Water Saved with a 50% Reduction
Collin	13,915	27,830
Dallas	21,368	42,737
Denton	3,242	6,485
Ellis	509	1,018
Grayson	591	1,181
Tarrant	12,336	24,672
TOTAL	**51,961**	**103,922**

Table App-4: Industrial Water Savings by County (acre-feet)

County	Water Saved with a 24% Reduction	Water Saved with a 36% Reduction
Collin	586	878
Dallas	3,410	5,115
Denton	116	175
Ellis	139	208
Grayson	593	890
Tarrant	1,859	2,788
TOTAL	**6,703**	**10,055**

Region K:

Table C App-5: 2014 Commercial and Institutional Water Use by County (acre-feet)

County	Acre-feet
Bastrop	910
Burnet	740
Colorado	317
Fayette	518
Gillespie	687
Hays	3,669
Llano	348
Matagorda	497
Travis	24,182
Wharton	581
Williamsonnn	10,644
TOTAL	**43,0933**

Table App-6: 2014 Industrial Water Use by County (acre-feet)

County	Acre-feet
Bastrop	132
Burnet	62
Colorado	105
Fayette	399
Gillespie	258
Hays	669
Llano	3
Matagorda	40
Travis	3,850
Wharton	62
Williamsonon	680
TOTAL	**6,2600**

Table App-7: Commercial and Institutional Water Savings by County (acre-feet)

County	Water Saved with a 25% Reduction	Water Saved with a 50% Reduction
Bastrop	228	455
Burnet	185	370
Colorado	79	159
Fayette	130	259
Gillespie	172	344
Hays	917	1,835
Llano	87	174
Matagorda	124	248
Travis	6,046	12,091
Wharton	145	291
Williamson	2,530	5,059
TOTAL	**10,642**	**21,283**

Table App-8: Industrial Water Savings by County (acre-feet)

County	Water Saved with a 24% Reduction	Water Saved with a 36% Reduction
Bastrop	30	45
Burnet	13	20
Colorado	23	35
Fayette	92	137
Gillespie	38	58
Hays	130	196
Llano	1	1
Matagorda	9	14
Travis	843	1,265
Wharton	15	22
Williamson	161	242
TOTAL	**1,356**	**2,035**

V. Summary and Conclusions

Each component of this project resulted in estimated water savings potential from proactive water-use conservation (Table V.1). Table V.2 provides context – municipal demand, supplies, and needs expected during the next decade – within which the total savings from conservation can be compared. Given the assumptions made in this study and without calculating costs, conservation alone can meet the expected annual needs during the next decade.

Table V.1. Summary of water conservation potential across all three study components for Regions C and K, Texas.

Water Planning Region	Economically-recoverable water (acre-feet / year)	Residential Water Conservation (acre-feet / year)	CII Water Conservation (acre-feet / year)	Total Savings Potential (acre-feet / year)
Region C	---	---	51,961 – 103,922[b]	---
Region K	---	---	10,642 – 21,283[b]	---
Regions C & K	65,032	260,350 - 290,725[a]	58,664 – 113,976[b]	384,046 – 469,733

[a] Given the lower assumption (24 percent) and higher assumption (40 percent) of outdoor savings

[b] Given the lower assumption (25 percent) and higher assumption (50 percent) of water use reduction in the commercial and institutional sectors. And given the lower assumption (24 percent) and higher assumption (36 percent) of water use reduction in the industrial sector.

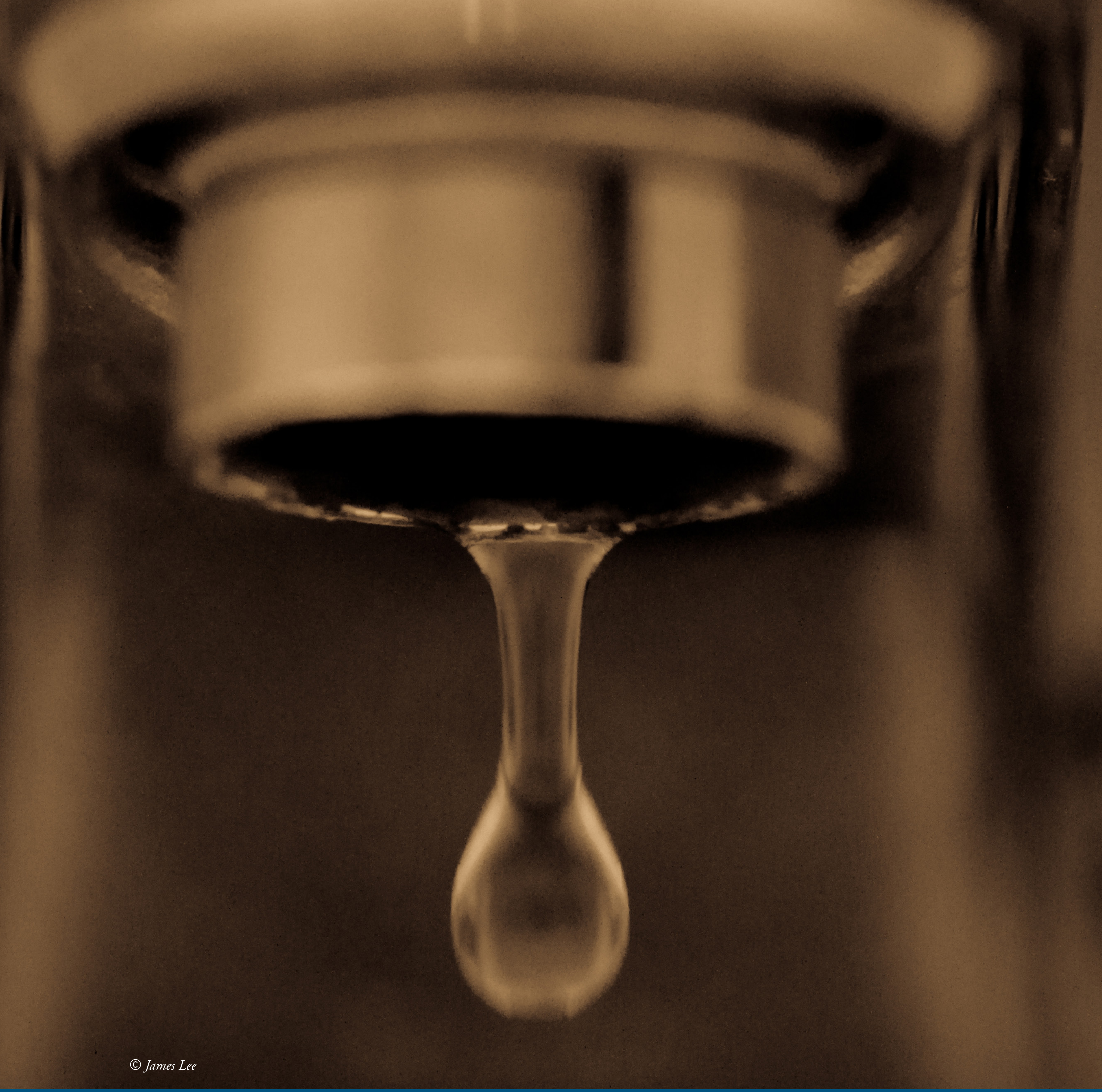
Table V.2. 2020 Municipal Water Demand/Supplies/Needs, Regions C and K, Texas (from TWDB 2017 Interactive State Water Plan).

Water Planning Region	2020 Municipal Demand (acre-feet / year)	2020 Municipal Existing Supplies (acre-feet / year)	2020 Municipal Needs (Potential Shortages) (acre-feet / year)
Region C	1,481,530	1,390,169	106,718
Region K	306,560	457,961	7,881
Regions C & K	1,788,090	1,848,130	114,599

As suggested, the costs associated with implementing the conservation activities that were assumed in this study were not determined. Cost identification was beyond the scope of this pilot project. Calculating costs for comparison to benefits (e.g., value of water saved) will be especially useful for the residential, commercial, and institutional sectors. As noted above, industrial water use is likely to become more efficient through process changes rather than through fixture upgrades. Thus, savings estimated for industrial use can be considered a minimum volume of potential.

It should also be noted that savings from outdoor watering rules suggested here are optimistic, given that there are no communities that currently limit outdoor watering to just one time per week year-round. An outdoor watering regime as suggested in this study is more typical of a Stage 2 or 3 drought restriction. Despite the relatively aggressive nature of the assumption made in this study, savings estimated here offer a glimpse of the potential, nonetheless, should conservation become a way of life for Texans. To further enable the potential savings from a once-per-week outdoor watering regime, changes will be necessary in landscaping choices (i.e., to a more native palette of plants). Here, builders and developers have a key role to play as do community ordinances and building codes that provide developers with guidance. Widespread adoption of rainwater harvesting for outdoor use will further enable such a shift. In any event, the topic of watering less outdoors will require behavior change, if not cultural change, rather than any technology-driven efficiency gains alone.

The final thought that we are left with is that water-use conservation and efficiency can go further than it is currently relied on to achieve long-term water-use reductions. Perhaps with new conservation planning tools, new conservation coordinators designated at water service providers, and a new emphasis on more sophisticated water loss audit reporting, Texans will achieve greater reductions in every-day water use before the next record drought forces us to do so.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The Meadows Center
for Water and the Environment
TEXAS STATE UNIVERSITY

601 University Drive, San Marcos TX 78666
512.245.9200 | MeadowsCenter@txstate.edu | www.MeadowsWater.org