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The Grass Is Always Greener… Outdoor Residential Water Use in Texas

by

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Summary

As Texas' demand for water rises with increasing population, expanding our awareness of the ways we consume water becomes essential, especially as we seek to reduce consumption through conservation. Numerous detailed studies of single-family residential water use have been conducted nationally over the past three decades; however, no such research has been done in Texas. A study published in 2010 compared winter to summer municipal use within the state, but to date, there is no evaluation specific to annual single-family residential water use.

In this study we analyzed annual seasonal single-family residential water usage in cities across Texas using monthly data provided to the Texas Water Development Board either as part of its annual Water Use Survey or upon request. We evaluated indoor and outdoor consumption patterns for 259 Texas cities from 2004 through 2008 and for 17 Texas cities from 2004 through 2011. Our analysis shows that about 31 percent of single-family residential annual water consumption is dedicated to outdoor purposes. Broadly, drier parts of the state use a greater proportion of water for outdoor purposes than wetter areas, but there can be a great deal of variability within a particular region. Among individual cities, we did not find a strong correlation between monthly outdoor water use and precipitation, though the lack of association may be due to issues with the temporal resolution of the data. However, we did see evidence of greater outdoor water use in 2011, one of the driest years on record, and during the 2009 to 2011 study period, a recognized time of low precipitation for the state. Further study is needed to determine the factors that drive single-family residential consumption patterns across the state.

Introduction

Texas is growing rapidly. We are projected to add more new residents by 2030 than any other state except California (U.S. Census Bureau 2005). By 2060 the state's population is expected to surpass 46 million (TWDB 2012). Such rapid population growth will lead to significant growth of the municipal water sector, in part to serve the rising number of single-family residences. While consumption by this sector accounted for 26.9 percent of statewide water use in 2010 (4.9 million acre-feet), this figure is expected to increase to 38.3 percent (8.4 million acre-feet) by 2060 (TWDB 2012). This projected 73 percent increase in municipal water demand over the coming decades represents the fastest growing sector among all water user categories in the state. As Texas grows, so do our water needs.

As our demand for water increases, developing an awareness of the ways in which we use our water becomes essential. For example, this awareness can be used to guide water conservation efforts, anticipated to provide 24 percent of our new supplies by 2060, and the development of drought management plans. With this broad purpose in mind, the goal of this study is to further our understanding of how single-family residences in Texas distribute their water use between indoor and outdoor purposes. Gaining a sense of the variability and scale of this division will allow for more effective planning and targeted conservation efforts as Texas prepares for the future.

Background

From showers to lawn watering, single-family residences use water both indoors and outdoors for a variety of reasons and in varying amounts. Generally speaking, quantities consumed indoors do not vary significantly by region whereas outdoor amounts can and often do (Vickers 2001). Arid, hot parts of the country, such as Texas, typically consume higher quantities of water per person for outdoor uses than regions with cooler, wetter climates, and this consumption often exceeds local rainfall by a significant amount (Vickers 2001). Of the water that is used outdoors, between 80 and 90 percent is dedicated to maintaining lawns, gardens, and plants. Landscape irrigation behavior, in turn, is affected by numerous factors, including water cost, household income, age of the home, extent of landscaped area, type of grass, whether or not an automatic irrigation system is used, precipitation, climate, and local aesthetic landscape preferences (Vickers 2001). Understanding how these variables influence consumption is a critical step in developing awareness of seasonal water use patterns.

Numerous studies of residential water use patterns have been carried out nationally over the past three decades. The Denver Water Department and U.S. Geological Survey conducted one of the earliest such analyses from 1980 to 1987 in Denver, Colorado (Litke and Kauffman 1993). In the study, researchers used in-line flow meters to evaluate water use patterns at 16 sites in the Denver, Colorado area. Weekly and hourly flow data were combined with water company billing records, census block data, and county tax assessor information to evaluate residential water use patterns with regard to billing type, size of household, lot size, assessed value, and other factors. The study differentiated between temperature-independent (base) and temperature-dependent (seasonal) water use using 60°F as a cut line. All consumption during weeks with an average maximum weekly temperature below 60°F was considered indoor use, and consumption in excess of average indoor use during weeks with an average maximum temperature above 60°F was considered seasonal use.

The study found average base usage (that is, indoor usage) to be 81 gallons per capita daily at sites where consumption was measured by a meter and billed accordingly and 89 gallons per capita daily at sites where users paid a flat rate regardless of consumption. Seasonal usage ranged from 25 to 575 gallons per housing unit per day with billing type (flat rate or metered) and lot size being the best predictors of outdoor water use. Additionally, the study concluded that most variability in results between study years was due to seasonal, temperature-dependent use rather than base use. Within seasonal use, variability was as likely to have been caused by billing type, differences in lawn or lot size, or institutional constraints (that is, mandatory lawn watering restrictions) as it was by weather differences.

In 1999, the American Water Works Association Research Foundation, in conjunction with 22 additional entities, released an in-depth study of indoor and outdoor water use entitled *The Residential End Uses of Water* (Mayer and others 1999). The study measured and analyzed flow meter data at 10-second intervals[1] to monitor consumption at 1,188 residences spread across 12 North American study locations. Water use was measured during two, two-week intervals, with one monitoring period occurring during summer months and a second period occurring during winter months. Additional data on roughly 1,000 randomly selected single-family residences at each study site were gathered from billing information, surveys, city data, and climate data. Consumption patterns were then analyzed in relation to income, lot size, property value, number of persons per household, type of sprinkler system, types of appliances found in the household, and other factors.

Seasonal water use was calculated using billing data. Average monthly indoor use was assumed to be equivalent to use during the month of the year with the lowest total consumption. This approach assumes that no water is being used for outdoor purposes during that month, though the study authors acknowledge that this assumption does not necessarily hold true, particularly in hot, arid climates where some irrigation takes place year-round. Annual indoor use was calculated as the minimum monthly use times 12, and annual outdoor use was calculated by subtracting annual indoor consumption from total annual consumption.

The study found average total daily per capita residential water use across all study sites to be 172 gallons per capita with 69.3 gallons attributable to indoor use, 101 gallons attributable to outdoor uses, and 1.7 gallons not clearly attributable to either. On average, 58 percent of water consumption was for outdoor purposes and 42 percent was for indoor uses, although these figures varied significantly by the city and its associated weather patterns. Cities characterized by lower levels of precipitation and higher average annual temperatures dedicated a higher percentage of consumption to outdoor purposes than those with lower temperatures and higher rainfall, with figures ranging from 22 to 67 percent.

Additionally, the study demonstrated a strong positive relationship between outdoor use and home square footage, a measure widely considered a proxy for standard of living. Outdoor usage and lot size, another possible standard-of-living proxy, were also positively related, and outdoor use showed sensitivity to the marginal price of water. In terms of irrigation practices, homes with installed, in-ground systems on average used 35 percent more water than homes without installed irrigation systems. This series of findings generally suggests that a greater ability to pay allows for more seasonal, discretionary use.

This report (Mayer and others 1999) sparked a series of residential water use studies conducted by cities, counties, and states across the country. The Utah Division of Water Resources conducted multiple

[1] Data is measured and recorded with such precision that patterns emerge and can be used to determine what type of fixture is being used (such as shower head, toilet, or clothes washer). The stream of data can then be broken into separate events, attributable to specific end uses.

such investigations, the most recent of which was released in 2009 (Hasenyager and Klotz 2009). In this study, 17 communities in Utah were evaluated using a total of over 1,800 household surveys and water billing records. The analysis included number of persons per household, income, lot size, livable floor space, method of irrigation, and numerous other measures as variables.

All water consumption between the months of December and February was assumed to be entirely for indoor purposes, a determination that was made based on an internal evaluation of water use records and on the state's seasonal climate. For each household, the number of gallons consumed per day during this time frame was determined using billing data, and this figure was then divided by the number of persons per household to determine a per person daily figure. Outdoor water use was then calculated as water use from April to October in excess of average indoor use.

Average indoor water use across all study cities was 62 gallons per capita daily. This figure was analyzed using multiple regression analysis to estimate a statewide indoor average of 60 gallons per capita daily, a 14 percent reduction from a 2001 statewide average of 70 gallons per capita daily (UDWR 2001). Also, as seen in other work (Litke and Kauffman 1993), this study found that there was a higher degree of variability in outdoor use figures than in indoor use numbers. Annual outdoor water consumption ranged from 69 to 414 gallons per capita daily or 228 to 1,169 gallons per household per day, and outdoor use during summer months alone averaged 249 gallons per capita daily, or 729 gallons per household. Averaged out over the full year, this figure drops to 134 gallons per capita daily, resulting in 68 percent of residential water use occurring outdoors. Lastly, the study found that automatic sprinkler systems resulted in overwatering by an average of 30 percent.

Authors of the 1999 study sponsored by the American Water Works Association Research Foundation and others (Mayer and others 1999) have themselves conducted follow-up work to their initial project, most notably with the release of two studies in 2011. Their *California Single-Family Water Use Efficiency Study* (DeOreo and others 2011), conducted between 2005 and 2010 in conjunction with the California Department of Water Resources and numerous California water agencies, used the same methods employed in Mayer and others (1999). Additional information on the 10 California study sites was gathered through surveys, billing information, aerial photography, and weather data.

In this study, non-seasonal use was determined using billing data by averaging total single-family residential use for the months of December through February and then multiplying this figure by 12 to come up with an annual non-seasonal use figure. Seasonal use is then calculated as total annual use minus this non-seasonal use figure. The researchers note, however, that this method of calculating non-seasonal use generally overestimates indoor consumption as some irrigation typically takes place during the winter months, particularly in warmer areas of California. Data from the subset of study homes with flow monitors installed were also used to disaggregate indoor and outdoor water consumption.

The study found that the average single-family household used 361 gallons per day, a figure that equated to an average of 123 gallons per capita daily based on local occupancy rates. The seasonal breakdown of these figures showed that 190 gallons per household daily, or 53 percent of single-family water use by study participants, was for outdoor, seasonal purposes while 171 gallons per household per day or 47 percent was for indoor, non-seasonal uses. Average annual indoor use per household was 62,000 gallons while outdoor use was 70,000 gallons. Again, outdoor use was found to be much more variable than indoor use.

The second major study released in 2011 was entitled *Analysis of Water Use in New Single-Family Homes* (DeOreo 2011). This study analyzed water consumption patterns in standard new homes and in high-efficiency new homes that were built after 2001, and it compared these outcomes to the findings in Mayer and others (1999). The study involved nine sites spread across the country and utilized surveys, flow trace data, billing information, weather data, lot size information, tax assessor data, and home value in developing study models.

Multiple methodologies were used to calculate seasonal water consumption. In one part of the study, detailed flow measurements taken during two, two-week periods were used to estimate annual indoor use[2], and in a second part of the study billing data were used. When billing data were used for areas with monthly billing information and a low probability of outdoor water use during winter months, indoor use was calculated by averaging consumption during the three coldest months of the year and multiplying this figure by 12. In areas with monthly billing and a higher probability of outdoor use across all seasons, the single month with the lowest consumption was used to estimate indoor use. For sites with bi-monthly billing, figures for the two-month period with the lowest demand were used regardless of climate. In all cases, the calculated value for indoor use was subtracted from total use to determine outdoor use.

The study found a significant improvement in indoor water use efficiency between the Mayer and others (1999) study and the homes included in the 2011 study. In the 1999 study, households averaged 177 gallons of indoor water consumption per day. In the 2011 study, the standard new home built after 2001 averaged 140 gallons per household per day and high-efficiency new homes averaged 110 gallons per household per day.

Outdoor use, on the other hand, increased. When comparing the 2011 study with Mayer and others' (1999) findings, only new standard homes monitored with detailed flow measurements were included[3]. When the associated flow projections for both groups were evaluated, annual outdoor use increased from 84,000 to 90,300 gallons per home. When billing data for survey respondents to the 2011 study alone were considered, homes constructed prior to 2001 averaged 76,100 gallons of water consumption for outdoor purposes annually whereas post-2001 homes averaged 84,000 gallons. Both sets of data suggest that newer homes use more water for outdoor purposes. Though no specific explanation for this phenomenon is given, eight factors were found to be helpful in generating outdoor use predictions:

[2] In cases where figures estimated using detailed flow measurements were not realistic, billing data were used to estimate indoor use.

[3] Data for the high-efficiency new homes were insufficient for comparison.

income, number of individuals in the home, total irrigated area, landscape ratio, the presence of individuals in the home during the day, excessive irrigation use, presence of a water feature or spa, and whether occupants reported having a leak in their swimming pool.

Although numerous studies of residential water use have been conducted across the country, no similar large-scale investigation has been undertaken in Texas to date. However, multiple small studies related to seasonal water use have been conducted. Two such reports, conducted at the city level, were published in 2004 and a third, state-level analysis was released in 2010. The first city report focuses on water consumption patterns in El Paso and the second analyzes watering needs of residential landscapes in College Station.

Researchers at The University of Texas at El Paso conducted an in-depth statistical analysis of short-term water consumption patterns for the period from January 1994 to December 2002 (Fullerton and Elías 2004). In the study, municipal revenue and water consumption data, weather information, and nonagricultural employment data were gathered at monthly intervals to develop price, weather, and employment variables. Although the study included all municipal water uses and did not focus specifically on seasonal usage patterns, it did evaluate the impact of study variables on short-term consumption patterns. The results ultimately indicated that consumption declines shortly after increases in price, drops within 30 days of rainfall, increases shortly after increases in temperatures, and increases months after improvements in economic conditions.

Though not focused explicitly on residential water consumption patterns, research conducted from 2000 to 2002 in College Station, Texas, is relevant to the current project as it evaluates the amount of water used for residential landscape irrigation with regards to actual landscape water needs (White and others 2004). Citing inefficient operation of landscape irrigation systems as the leading cause of surplus water consumption for outdoor purposes, the researchers developed “water budgets” for 800 residences in the College Station area using potential evapotranspiration, a landscape coefficient specific to local environments with multiple plant species, and landscape size. Two water budget values were developed per residence, one representing 100 percent replacement of potential evapotranspiration with an associated landscape coefficient of 1.0 and one representing 70 percent replacement of potential water loss via evapotranspiration with an associated landscape coefficient of 0.7. The landscape coefficient represents the percentage of the estimated evapotranspiration that should be replaced through irrigation to meet the needs of all plants in a particular landscape rather than focusing on a single plant type (White, 2012). Both landscape coefficients were calculated using a multiple plant species landscape that included plant varieties commonly found throughout Texas. The water budgets were then used to evaluate the amount of water required to maintain acceptable quality and health of each residence’s landscape, and predicted consumption needs were compared to actual consumption using billing information. In all cases, monthly consumption above 7,000 gallons per residence was assumed to be used for irrigation purposes[4].

[4] Consumption from December to February for all study homes for all years was averaged, resulting in a figure of roughly 7,000 gallons. This amount is assumed to represent indoor consumption.

A primary goal of the study was to determine whether summer increases in water demand are appropriate for meeting landscape irrigation needs. The researchers found that a landscape coefficient of 0.7 was higher than needed to maintain acceptable landscape quality and health. They also determined that in all study years a significant portion of residences irrigated in excess of potential evapotranspiration, ranging from 347 homes (43 percent) in 2000 to 476 (60 percent) in 2002. Using the higher landscape coefficient of 1.0, this represents 24,113,006; 33,888,548; and 27,697,371 gallons of excess water application among the 800 homes studied in 2000, 2001, and 2002, respectively. Using the lower landscape coefficient, these figures jump to 29,978,331; 36,169,508; and 32,585,143 gallons annually. Had all consumers watered based on potential evapotranspiration, the more generous of the two water budget figures, between 24 and 34 million gallons of water would have been saved annually.

To date, the only work at the state level that directly analyzes seasonal water use in Texas is a joint study released in 2010 by the Lone Star Chapter of the Sierra Club and the National Wildlife Federation (McCormick and Walker 2010). In the report, data from utility profiles submitted to the Texas Water Development Board (TWDB) and the Texas Commission on Environmental Quality as part of water conservation plans were used to evaluate municipal[5] water consumption in 18 Texas cities[6] for five of the six years between 2004 and 2009. Water use from December through February was equated to winter use, and consumption from July through September constituted summer use. Winter consumption was considered a proxy for indoor consumption, and summer use in excess of winter use was assumed to be for outdoor purposes.

Using these metrics, summer monthly municipal water consumption in Texas increased by 58 percent when compared to winter monthly municipal consumption. According to the study, increases ranged from lows of 14 percent in Beaumont, Brownsville, and Houston to a high of 103 percent in Plano.

The above studies present significant variation in consumption patterns by geographic region, although they also demonstrate broad trends toward declining per capita indoor consumption and increasing per household outdoor consumption. Additionally, these studies show that there is typically more variability for outdoor consumption than in indoor consumption. Though there is clearly a growing body of single-family residential water use research, no work specific to Texas has been conducted to date.

Methodology

We conducted our study of seasonal single-family residential water use in Texas in two distinct phases. For Phase I, we analyzed seasonal single-family residential water usage in cities across Texas from 2004 through 2008. In Phase II, we examined a 17-city subset of Phase I cities from 2004 to 2011. We conducted this second round of analysis to evaluate seasonal water use patterns over a longer and more

[5] Municipal water consumption includes commercial, industrial, multi-family residential, and single-family residential consumption.
[6] The following cities are analyzed in the report: Arlington, Austin, Beaumont, Brownsville, College Station, Corpus Christi, Dallas, El Paso, Fort Worth, Garland, Houston, Katy, Laredo, Lubbock, Pflugerville, Plano, San Antonio, and Tyler.

recent time horizon, to find out whether the historic drought of 2011 affected consumption patterns, and to determine if water use among this limited subset is comparable to the larger Phase I population.

We gathered most data used in the study from the TWDB's annual Water Use Survey. This survey is an annual assessment of municipal and industrial users of both ground and surface water that has evolved since 1955, when it was initially conducted as a voluntary survey of major groundwater users within the state. Since that time, the survey has grown to include more water users and more data, a process that culminated in 2001 with the passage of Senate Bill 2 by the 77th Legislature. As directed by this legislation, nearly all municipal and large industrial water users are mandated to submit information as requested by the TWDB each year, including data on volumes of water used, sources of water, water sales, and other data as specified by this agency. Thus, all data in the survey are self-reported, and individual utilities are responsible for their accuracy and completeness.

While data is reported by individual utilities rather than the municipalities or cities they are associated with, we have chosen to use the term *city* to refer to locations across the state that have provided data. In all cases, water utilities included in this report are associated with a specific city, town, or village, and we have used the name of that entity as the city name (Appendix A). However, many cities across the state work with multiple water utilities to meet the needs of residents, and our study reflects only those providers that supplied adequate data as part of the TWDB Water Use Survey[7]. Thus, reference to a particular city does not mean that data are inclusive of all associated water providers.

Though many Water Use Survey items are identical from year to year, other items are included or excluded depending on the data and planning needs of TWDB. One such figure is single-family residential water consumption by month. The annual Water Use Survey has not historically included this material, but TWDB collected this information between 2004 and 2008.

Information provided to the TWDB as a part of this annual Water Use Survey forms the basis of Phase I of this study in virtually all cases[8]. For Phase II of the report, cities provided monthly single-family residential usage volumes for the period from 2009 to 2011 directly to us upon request[9] as the Water Use Survey did not include these figures for this time frame. Cities also provided an annual average number of single-family residential connections, a proxy for single-family residential households, as a part of the annual Water Use Survey. In cases where a city did not include these figures when completing the survey, we requested them directly[10] from the city's staff.

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[7] In only one case, that of the City of Falfurrias, did more than one utility for a given city provide sufficient data for inclusion in the study.
[8] The following cities provided data directly to TWDB staff for the purposes of this study: City of El Paso (2005, May 2007–December 2007), City of Laredo (2004), and City of Fort Worth (2004–2005, 2007–2008).
[9] In two cases, Amarillo and Garland, cities provided separate monthly residential usage figures and residential irrigation figures as some of their customers have two separate systems and meters. We opted to pool both numbers to create a single set of monthly residential usage figures in order to maintain a consistent methodology between cities and individual users of varying socio-economic status.
[10] Laredo did not provide a figure for single-family residential connections for 2004, and El Paso did not provide a number of connections for 2005. We used the methodology described in footnote 12 to generate figures for these two years.

Phase I

Initially, we included all cities coded as municipally-owned in the Water Use Survey database in the study. We then checked the data for validity and completeness. If figures were identical from month to month or year to year, we considered them invalid and excluded all time periods involving the identical information. Additionally, we eliminated any survey year in which the city did not provide data and figures in the survey were carried over from the previous survey year[11]. We also discarded survey years that were missing data or that contained data that varied by orders of magnitude throughout. Following this culling process, we eliminated any locale with less than four years of valid data remaining for the five-year period from 2004 to 2008. Of the over 900 cities initially included in this round of evaluation, the remaining 259 form the basis of the Phase I analysis[12].

We used monthly single-family residential water use volumes to calculate annual totals as well as seasonal usage figures for each city, and in calculating these figures we used the methodology for determining outdoor use most commonly employed in hot, dry regions. Thus, we considered the lowest monthly usage figure for a given calendar year to be the best available basis for estimating annual indoor usage, a metric we calculated for the year by multiplying the lowest monthly usage figure by 12. We considered any usage over this figure to be outdoor usage. Thus, outdoor usage is the difference between indoor and total usage.

As discussed previously, this approach may overestimate indoor use, and thus underestimate outdoor use, if any outdoor water use occurs during the low-use month. During particular years, some households in the Fort Worth area have been observed leaving their automatic sprinkler systems on and watering during the winter months (Andrew Chastain-Howley, personal communication, 2012). However, it should be noted that Texas' summer heat may also lead to minor increases in indoor uses such as bathing and laundering, thus slightly offsetting this effect (Dan Hardin, personal communication, 2012). Additionally, this study's approach also assumes that the number of residential connections remains constant over the year, something that's not the case in fast-growing Texas. Depending on when the lowest month usage occurs (early in the year or later in the year), this could overestimate or underestimate outdoor usage.

When generating statewide averages of outdoor usage, we accounted for variations in size between cities by weighting usage by population. We did so by using the number of single-family connections as a proxy for the number of single-family residences. In other words, the proportion of average statewide outdoor use attributed to a specific city is proportional to the size of that area's population. To perform these calculations, we multiplied *Outdoor use as a percent of total use* by the number of single-family

[11] Fort Worth submitted 2005 data directly to TWDB staff. We used these figures in lieu of 2005 Water Use Survey data which contained a positive (*Y)* value for the *EstFlag* field, the marker for records generated by carrying over data from the previous survey year.

[12] In some cases, we made changes to raw data to correct for data entry errors. The most common alteration we made was adjusting the order of magnitude for either one month or one year to bring figures in line with all other data for a city. We have included a full list of changes made to raw data (Appendix B).

connections for a given city for a given year[13]. We then summed this new figure for all cities for all years and subsequently divided it by the total number of single-family connections for all cities for all years, thus arriving at a weighted statewide average. We subsequently used the figures described here and above to analyze seasonal single-family residential water usage patterns in Texas for the period from 2004 through 2008.

Phase II

For this phase of the study, we selected a subset of Phase I cities. Initially we contacted all cities that were included in McCormick and Walker (2010) that also provided adequate data for inclusion in Phase I of our study. We then sought information from additional cities to improve the geographical diversity of our subset. These outreach efforts ultimately resulted in 17 cities providing adequate data for inclusion in the second phase.

In addition to using the metrics developed in Phase I and conducting a more focused analysis of usage during 2011, Phase II also includes analysis of seasonal water usage as it relates to both precipitation and temperature. We gathered all climate data for this portion of the study from the National Oceanic and Atmospheric Administration's National Climatic Data Center using their Climate Data Online service (NCDC 2012). Specifically, we queried the Global Historical Climatology Network's monthly summaries database for monthly mean temperature and monthly total precipitation figures.

This database provides more than one station location with climate data for most cities, so we chose stations based on historical coverage. For a given city, we first selected the station with the longest range of data available including the years from 2004 to 2011. If that station did not have complete temperature and precipitation figures for that time frame, we selected the station with the next-longest range of data. We used this iterative process to determine stations for most cities.

In a few cases, no station within the city contained complete temperature and/or precipitation data. In these situations, we used the database's proximity function to determine the station closest to the city with complete data (Appendix C). We did so by increasing the radius of the proximity function by one-mile intervals until the resulting sphere yielded a station with complete climate data for the study time frame. In three cases, we located a station with complete precipitation data closer to the city than the first station with complete temperature data. In these cases, we used the closest precipitation station coupled with the closest temperature station, resulting in a pair of two distinct stations for the city. Once we compiled all climate data, we used linear regression analysis and cross plots to evaluate possible trends associated with these climatic factors and seasonal water consumption.

[13] In cases where the number of single-family connections was not provided for a city for a given year, we averaged the number of connections for the years before and after the missing year and used the new figure as an estimate. In cases where the missing year was either the first or last of the survey time frame, we used the adjacent year that fell within the survey period.

Analysis

We conducted our analysis in two phases. The goal of the first phase was to provide the most comprehensive statewide analysis of seasonal single-family residential water use in Texas as possible given currently available data. The purpose of the second phase of analysis was to consider a smaller number of Texas cities over a longer time frame in order to determine if such a subset can be used to accurately generalize to the state more widely. Additionally, the second phase provided an opportunity to consider factors that may influence seasonal residential water consumption.

Phase I

For Phase I of the study we analyzed data from 2004 to 2008 for 259 Texas cities to assess indoor use, outdoor use, and outdoor use as a percentage of total use (Table 1). *Indoor Use* and *Outdoor Use* figures are the average annual total number of gallons used by all single-family residences for indoor or outdoor purposes, respectively. Indoor use ranged from a low of 2,370,168 gallons in Quinlan to a high of 23,129,860,447 in San Antonio. Outdoor use figures ranged from a low of 1,007,707 gallons, again in Quinlan, to a high of 11,533,979,620 in Dallas. *Outdoor Use as a Percentage of Total Use* illustrates the average annual percentage of single-family residential water use that is specifically for outdoor purposes. The percentage of outdoor single-family residential water use ranged from a low of 13 percent in Galena Park to a high of 64 percent in Gail with a weighted average of 31 percent across the state.

Table 1: Annual average water use by city for 2004 through 2008.

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
1	Albany	46,027,200	42,294,800	46
2	Allen	1,703,821,200	1,242,558,800	42
3	Alvarado	53,245,440	18,814,000	26
4	Alvin	314,083,440	57,020,917	15
5	Amarillo	4,230,024,000	2,958,766,000	41
6	Anahuac*	35,694,000	5,745,375	14
7	Andrews	291,885,600	267,550,400	48
8	Arlington	6,656,685,600	3,736,446,400	36
9	Aspermont	25,711,200	11,558,240	31
10	Athens	240,245,040	180,059,320	43
11	Aubrey	37,506,720	18,249,060	32
12	Austin	11,600,174,640	5,299,677,060	31
13	Baird	50,473,764	19,661,867	28
14	Ballinger	124,035,442	45,465,995	27
15	Bastrop	111,549,840	69,319,900	39

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
16	Bay City	437,132,088	115,839,653	21
17	Baytown	919,257,600	297,589,200	24
18	Beckville	19,831,200	6,572,000	25
19	Bellmead*	163,062,900	46,238,125	22
20	Bells	25,738,176	8,125,244	23
21	Bellville	102,554,400	64,494,812	37
22	Boerne	148,560,480	63,787,420	29
23	Bonham	118,938,857	49,871,124	29
24	Borger	464,265,600	225,118,800	33
25	Bovina	44,960,047	27,615,771	38
26	Brazoria	51,120,240	12,811,560	20
27	Breckenridge	102,036,240	66,222,202	40
28	Bremond	17,467,200	9,181,400	35
29	Brenham	266,379,120	131,948,660	33
30	Bridge City	155,462,400	39,049,000	20
31	Bridgeport	120,557,700	45,813,000	27
32	Bronte	22,022,400	12,408,600	36
33	Brownfield	239,504,311	119,736,833	33
34	Brownsboro*	19,683,123	9,504,394	33
35	Brownwood	445,893,790	194,993,994	30
36	Buda	83,023,200	46,573,800	36
37	Buffalo	43,208,400	14,804,480	25
38	Burkburnett	211,885,584	80,788,016	27
39	Callisburg	22,282,536	13,086,560	37
40	Canton	66,657,842	46,413,958	38
41	Canyon	232,260,000	166,502,800	42
42	Carthage	127,342,536	68,790,957	35
43	Castroville*	69,961,509	47,953,675	39
44	Celeste	15,595,440	7,321,220	32
45	Charlotte*	46,443,000	29,488,500	37
46	Chico	18,256,080	6,682,900	27
47	Cibolo	165,559,572	95,013,476	36
48	Cisco	82,891,411	76,799,698	50
49	Clarendon	42,487,200	37,874,800	46
50	Clarksville*	53,546,100	13,907,775	20
51	Coleman	101,613,600	46,992,600	31
52	College Station*	1,714,056,000	846,754,750	33

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
53	Comanche	69,352,080	25,309,307	26
54	Conroe	594,734,400	423,540,620	42
55	Converse	277,615,913	99,952,321	26
56	Corinth	429,802,898	392,687,943	47
57	Corpus Christi	5,040,264,000	1,513,251,600	23
58	Corsicana	330,043,920	246,905,540	43
59	Crawford	19,473,600	14,039,500	42
60	Crosbyton	51,003,233	23,935,083	32
61	Cumby	19,738,320	6,641,420	25
62	Daingerfield	63,480,720	23,655,080	26
63	Daisetta	19,741,726	8,362,784	29
64	Dalhart	259,149,600	292,027,000	53
65	Dallas	16,759,205,760	11,533,979,620	40
66	Darrouzett	7,243,200	6,586,600	46
67	Dell City	6,548,105	2,655,092	28
68	Denton	1,565,212,546	1,070,996,403	40
69	Denver City	107,479,680	83,385,980	44
70	Dimmitt	117,804,000	101,160,000	47
71	Duncanville	742,320,000	380,134,200	33
72	Early*	52,158,000	27,601,675	33
73	Earth	33,375,610	21,914,797	39
74	Edinburg	1,219,984,080	364,681,820	23
75	Edna*	105,435,000	34,505,261	25
76	El Paso	12,594,048,384	6,152,376,225	33
77	Emhouse	12,287,424	5,338,468	30
78	Ennis	292,005,600	134,189,800	31
79	Fairfield*	49,819,500	29,309,175	37
80	Falfurrias-Encino Water System*	5,204,100	2,507,175	32
81	Falfurrias-City Board	157,156,080	77,514,060	32
82	Farmers Branch	517,862,400	347,475,200	39
83	Ferris	39,387,360	16,746,900	29
84	Flatonia	30,801,600	13,900,400	30
85	Flower Mound	1,715,898,581	1,774,098,459	50
86	Fort Worth**	11,658,598,514	6,382,544,622	35
87	Franklin	46,876,553	23,457,586	33
88	Friendswood	600,448,800	551,364,400	48

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
89	Frisco	2,257,116,240	1,912,898,980	46
90	Fritch	72,866,453	48,025,768	40
91	Gail	3,203,976	4,491,872	64
92	Galena Park	151,380,000	23,547,400	13
93	Garland	4,499,095,104	2,249,155,076	33
94	Giddings	103,666,229	52,895,811	33
95	Gladewater*	184,941,000	51,667,393	22
96	Goldthwaite	46,935,600	26,412,140	37
97	Gordon	10,992,000	5,866,480	34
98	Graham	234,666,660	176,484,154	42
99	Granbury	106,353,336	58,573,020	35
100	Grand Saline	52,648,260	24,164,312	31
101	Grapeland	37,435,200	14,357,000	27
102	Grapevine	1,763,701,397	1,333,912,362	43
103	Greenville	419,360,400	176,118,131	29
104	Gunter	19,674,480	9,927,204	33
105	Gustine	11,904,840	10,075,521	45
106	Hallsville	56,982,696	29,040,186	35
107	Hamilton	56,318,880	30,160,150	34
108	Harker Heights	430,470,000	434,614,260	50
109	Hart	28,624,296	18,011,928	39
110	Haslam	4,546,080	1,447,120	24
111	Hedley	7,350,590	4,852,089	39
112	Hemphill	19,891,200	5,178,800	20
113	Hempstead*	109,403,730	47,271,651	30
114	Hico	23,400,624	9,941,368	29
115	Higgins	9,264,000	10,237,800	53
116	Highland Park	548,791,200	438,324,600	45
117	Highland Village	403,256,400	430,377,240	51
118	Holliday	37,850,400	13,005,000	25
119	Honey Grove	45,481,457	26,355,802	36
120	Houston	22,475,018,400	4,909,456,400	18
121	Howe	37,364,856	20,682,180	35
122	Hubbard	26,858,400	12,733,000	32
123	Humble	189,967,200	66,880,600	26
124	Huntington*	43,395,000	7,823,750	15
125	Hurst	736,479,000	614,847,772	44

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
126	Huxley	30,828,000	14,876,182	35
127	Ingleside	155,040,720	31,386,420	17
128	Ingleside On The Bay	14,468,400	4,757,560	25
129	Iowa Park	180,482,544	74,036,820	28
130	Iraan*	54,396,000	53,532,000	50
131	Irving	2,233,022,400	1,814,771,400	45
132	Jacinto City	133,123,440	24,422,686	16
133	Jacksonville	245,763,120	109,917,780	30
134	Joaquin	36,007,680	27,483,220	42
135	Johnson City	29,462,844	13,770,981	31
136	Josephine	27,234,617	14,534,830	34
137	Katy	282,520,800	157,997,400	35
138	Kermit	168,290,400	164,852,600	49
139	Kingsville	433,721,520	135,685,260	23
140	Kirby	125,498,400	56,093,800	30
141	Kountze	38,586,134	10,237,369	20
142	La Porte*	638,647,200	145,508,450	18
143	Ladonia	13,887,360	5,045,500	25
144	Lago Vista	138,962,599	98,078,809	41
145	Lake Worth	99,079,200	46,770,400	32
146	Lampasas*	149,120,100	86,893,378	36
147	Laredo	4,976,160,000	1,816,360,000	26
148	Leander	403,840,013	333,843,319	46
149	Lindale	154,300,440	82,326,160	35
150	Littlefield	141,962,400	79,306,800	35
151	Liverpool	6,069,360	3,628,240	38
152	Longview	1,574,527,680	1,191,265,920	45
153	Lorena*	47,299,200	33,201,500	41
154	Lorenzo	17,738,400	18,937,400	51
155	Lubbock	4,262,169,600	2,434,569,000	37
156	Madisonville	78,461,885	40,146,125	34
157	Malone	4,416,360	1,597,045	26
158	Manor	64,783,200	28,026,600	30
159	Marion	28,130,400	11,006,320	28
160	Mason	90,602,866	69,669,744	43
161	Meadows Place*	109,635,000	44,423,500	28
162	Melissa	55,520,458	62,609,937	53

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
163	Melvin	7,519,884	7,241,165	46
164	Menard	34,487,340	21,508,579	38
165	Meridian	22,072,800	11,368,740	34
166	Mesquite	2,362,765,186	1,050,005,276	31
167	Mexia	115,814,880	39,189,192	25
168	Midway*	9,915,534	3,130,257	20
169	Mineral Wells	263,583,540	168,937,315	39
170	Mobeetie	2,789,520	2,992,460	53
171	Monahans	211,483,200	180,213,000	46
172	Moody	33,588,720	15,686,260	31
173	Morton	50,940,000	30,401,600	37
174	Mount Pleasant	237,614,256	144,590,326	37
175	Murphy	377,042,160	495,088,230	57
176	Navasota	132,110,400	50,797,300	28
177	Needville	55,046,400	15,185,541	22
178	New Braunfels	1,179,664,560	573,045,858	32
179	New London	42,359,760	20,307,780	32
180	New Waverly	15,313,258	3,894,174	20
181	Nixon	52,443,600	23,134,640	30
182	Nocona*	46,992,840	69,235,431	59
183	Odem	66,858,960	21,308,240	24
184	Odessa	2,288,791,200	1,339,531,200	37
185	Olney	75,004,800	40,462,200	34
186	Orange	285,739,200	61,245,600	17
187	Orange Grove	46,335,811	36,228,327	42
188	Orchard*	9,419,700	4,338,790	31
189	Paducah	28,407,600	15,589,180	34
190	Paris	389,254,157	144,707,061	27
191	Pasadena	1,930,578,960	474,770,600	19
192	Pearsall	200,400,000	117,188,200	37
193	Pflugerville	448,143,840	245,745,120	35
194	Pineland	18,668,640	6,050,740	24
195	Plains	35,073,120	29,695,540	46
196	Plainview	427,276,800	229,856,600	35
197	Poteet*	56,859,351	28,550,906	33
198	Quanah	51,060,012	23,215,794	31
199	Quinlan	2,370,168	1,007,707	29

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
200	Richland	6,897,024	3,040,750	30
201	Richland Hills	169,554,216	85,557,492	33
202	Richmond	218,666,160	76,135,600	26
203	River Oaks	130,133,138	64,853,659	33
204	Robinson	214,122,720	149,198,480	40
205	Rockwall	855,511,680	645,870,888	43
206	Rosenberg	379,135,440	82,243,820	18
207	Round Rock	1,763,001,840	1,090,014,520	38
208	Rule	13,608,000	2,911,766	18
209	Sadler	6,580,344	2,654,266	29
210	Saint Jo	23,118,720	10,708,414	32
211	San Antonio	23,129,860,447	7,194,235,494	23
212	San Leanna	11,900,304	10,180,626	45
213	San Marcos	359,395,440	127,192,000	26
214	San Saba	62,235,578	49,243,019	43
215	Schertz	635,740,800	294,455,240	31
216	Sealy	101,160,960	66,818,360	39
217	Seminole*	175,773,000	164,920,250	49
218	Shallowater	49,257,600	28,540,400	37
219	Shenandoah	39,292,800	23,829,800	37
220	Shiner	53,545,200	29,568,680	34
221	Smithville	75,002,400	45,033,600	37
222	Somerville*	37,985,745	14,060,286	27
223	Sonora	96,957,600	64,062,620	39
224	Spearman	80,985,552	80,233,808	49
225	Stinnett	44,517,600	32,179,000	41
226	Stockdale	45,062,179	24,198,253	33
227	Sugar Land	1,801,137,307	879,076,854	33
228	Sundown	34,233,600	26,364,800	43
229	Sunray	38,803,200	53,699,800	58
230	Sweetwater	178,382,400	86,051,600	32
231	Teague*	46,493,700	43,928,000	49
232	Temple	1,199,123,280	748,018,093	38
233	Terrell	218,258,160	106,577,000	33
234	Thorndale	24,050,400	8,705,400	26
235	Timpson	20,961,600	6,207,400	23
236	Tioga	20,117,230	9,307,325	31

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use
237	Tolar	16,268,441	4,471,842	22
238	Tomball	135,904,800	115,586,200	46
239	Troup	33,091,351	11,767,321	26
240	Tyler	1,715,517,600	1,746,380,800	50
241	Universal City	347,520,000	136,615,400	28
242	Uvalde	434,561,760	253,221,460	37
243	Vernon	220,876,800	76,799,700	26
244	Victoria	1,064,280,000	368,301,000	25
245	Waco	2,125,998,960	1,144,253,912	35
246	Wallis	25,023,168	8,862,488	26
247	Waskom	48,936,960	10,010,500	17
248	Waxahachie	412,537,680	273,595,305	39
249	Weatherford	441,386,686	249,872,021	36
250	Webster	22,653,600	6,885,000	23
251	Wellington	91,773,830	38,623,403	30
252	West	67,701,355	23,569,638	26
253	Wharton	152,134,080	47,548,460	24
254	Whitesboro	82,825,680	26,189,288	23
255	Wichita Falls	1,766,179,200	1,197,883,000	40
256	Wilson	9,969,120	7,542,437	43
257	Woodville	38,362,903	31,180,007	44
258	Woodway	235,033,440	383,936,767	62
259	Wylie	550,756,946	379,867,591	40
	City average			*34*
	City median			*33*
	Statewide average			*31*

*Indicates that only four years of valid data were available for the 2004 through 2008 period.

**As a part of their 2007 10-Year Water Conservation Master Plan, the City of Forth Worth reported peak (outdoor) and baseline (indoor) residential water use for the period from 2001 to 2005. The report found that 35.5percent of residential water use during this time frame was peak, or outdoor, water use (Water Prospecting and Resource Consulting 2007). Though the study period from this report only partially overlaps with ours, the consistency between our findings and theirs supports the validity of our calculations.

- *Statewide average,* the best metric of the state as a whole, represents the average of the cities' values after each city is weighted by its population.

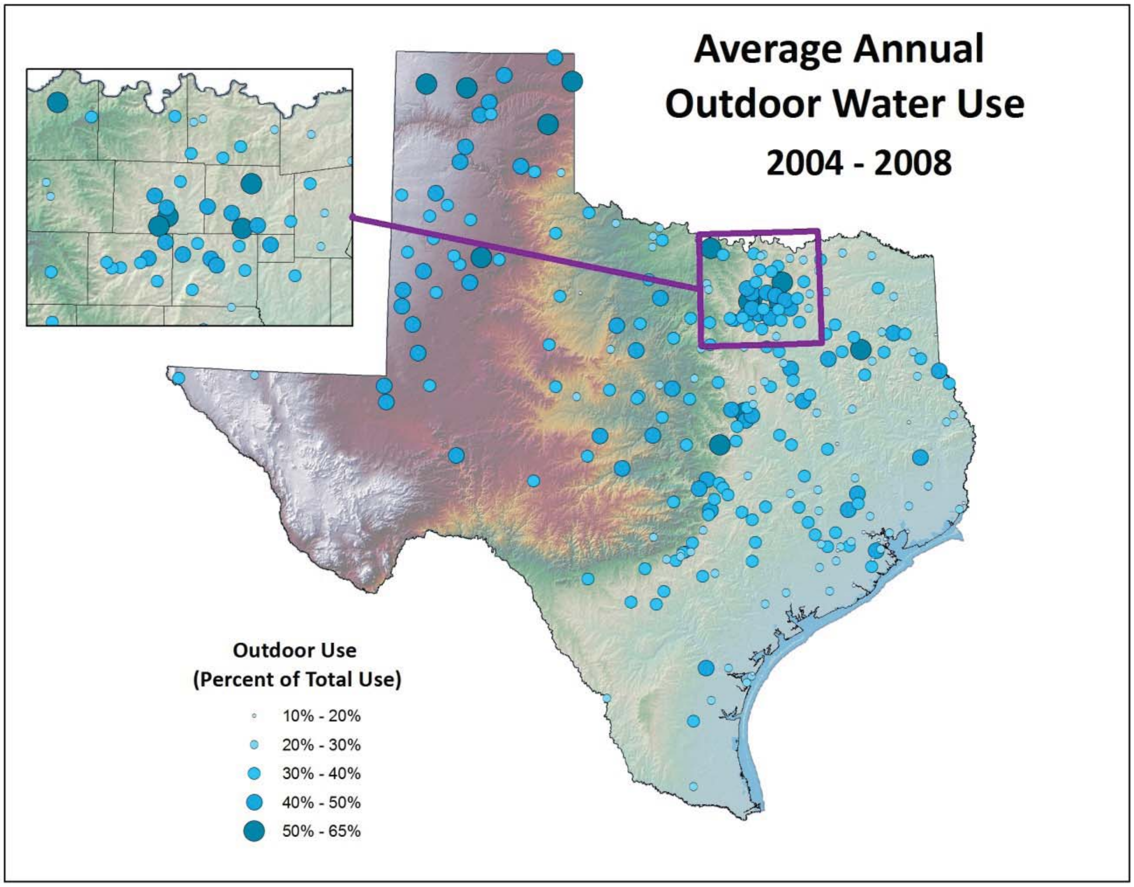
Though the study involves a subset of all Texas cities, and water usage patterns vary among them, the sample is large enough to provide a general indication of seasonal residential water use patterns across the state. Weighted statewide annual averages for outdoor use as a percent of total use range from 26 percent in 2007 to 38 percent in 2005 (Table 2).

Table 2: Statewide weighted values of outdoor use as a percent of total residential use for 2004 through 2008.

Outdoor use as a percentage of total use					
2004	**2005**	**2006**	**2007**	**2008**	***Average***
29	38	32	26	32	*31*

When we mapped the magnitude of outdoor water consumption as a percentage of total use by each city along with its location, a subtle geographic trend emerged. Moving across the state from the Gulf Coast and Texas Louisiana border regions toward West Texas, outdoor use as a percent of total use tends to increase. There is a high degree of variability in consumption across all regions, but residential outdoor water use in West Texas is consistently higher than in any other comparably-sized portion of the state. Generally speaking, annual precipitation decreases moving from east to west across the state, so a trend of higher average outdoor usage in the western, more arid regions is not surprising.

Figure 1: Map of outdoor use as a percent of total use for 2004 through 2008.



*We combined Falfurrias Encino Water System and Falfurrias City Board survey results to create a single entity, *Falfurrias*, for spatial mapping purposes. As both cities averaged 32 percent outdoor residential water use between 2004 and 2008, this change did not alter results.
**Two cities, Gail and Haslam, are not represented due to their small size (less than 250 residents).

Phase I of the study indicates that roughly one-third of all single-family residential water consumption across Texas is for outdoor uses such as irrigation, pool maintenance, and car washing. Though variations exist, average annual outdoor usage constitutes between 25 and 50 percent of total use for 91 percent of all study cities.

Phase II

During Phase II of the study, we analyzed data from 17 cities for the period from 2004 to 2011 to evaluate indoor use, outdoor use, and outdoor use as a percentage of total use (Table 3). Initially we conducted the same analyses undertaken in Phase I, using the same variables. In this more focused assessment in which only urban areas are included, indoor use ranged from a low of 281,554,500 gallons in Katy to a high of 23,242,411,405 in San Antonio. Outdoor use figures ranged from a low of 202,737,375 gallons, again in Katy, to a high of 11,668,235,722 gallons in Dallas.

Outdoor use as a percentage of total use figures ranged from a low of 20 percent in Houston to a high of 53 percent in Tyler, with a weighted average of 31 percent across the state. Though this statewide average value remained the same between Phases I and II of the study, the range of outdoor consumption values shrank by 18 percentage points, indicating less variability among usage patterns. Additionally, 89 percent of cities used between 25 and 50 percent of all water they consumed for outdoor purposes.

In this second phase of the study, we also used figures for single-family residential connections to calculate average daily usage figures per household for each city. G*allons per household per day for indoor use* reflects indoor annual consumption divided by 365 days and then averaged by the number of households (in other words, single-family connections) in the city, and *Gallons per household per day for outdoor use* indicates total annual outdoor usage averaged by household per day. Given that cities vary widely in terms of average size of household, typical climatic conditions, average income levels, and in various other ways, calculations describing each are not meant for comparative purposes. Instead, we provide these figures to give a sense of the range in number of gallons used daily by households for outdoor purposes across the state.

Indoor residential water consumption in Texas on average accounts for 181 gallons per household daily with a median value of 191 gallons per household daily. Figures range from a low of 148 gallons per household per day in Houston to a high of 265 in Laredo. In terms of outdoor consumption, values ranged from a low of 37 gallons per household per day in Houston to a high of 195 in Tyler. On average, Texas households used 86 gallons daily for outdoor purposes with a median usage of 102 gallons daily.

Table 3: Annual average water use by city for 2004 through 2011.

	City	Indoor use (gallons)	Outdoor use (gallons)	Outdoor use as a percentage of total use	Gallons per household per day for indoor use (gallons)	Gallons per household per day for outdoor use (gallons)
1	Amarillo	4,203,333,000	3,110,188,125	42	194	143
2	Arlington	6,579,447,000	3,806,411,375	36	198	114
3	Austin	11,532,894,150	5,879,032,288	33	176	89
4	College Station*	1,510,618,286	922,872,143	38	-	-
5	Corpus Christi	4,983,501,000	1,839,473,375	26	179	66
6	Dallas	16,293,358,200	11,668,235,723	41	173	125
7	El Paso	12,676,702,014	6,231,936,280	33	220	105
8	Fort Worth	11,576,921,511	6,819,864,226	37	166	97
9	Garland	4,398,659,640	2,234,119,198	33	198	100
10	Houston	22,287,783,000	5,629,024,250	20	148	37
11	Katy	281,554,500	202,737,375	40	188	135
12	Laredo	5,013,600,000	1,707,862,500	25	265	93
13	Lubbock	4,332,784,500	2,341,568,000	36	177	96
14	Odessa	2,327,562,000	1,358,331,500	37	205	119
15	Pflugerville	558,544,200	393,038,375	39	219	152
16	San Antonio**	23,242,411,406	7,713,879,696	25	202	67
17	Tyler	1,682,887,500	1,937,568,750	53	171	195
	City average			*35*	*192*	*108*
	City median			*36*	*191*	*102*
	Statewide average			*31*	*181*	*86*

* College Station changed its method of calculating single-family residential connections between 2008 and 2009. Consequently, we omitted gallons per household calculations for this city as the data was inconsistent.

** San Antonio Water System staff indicated that monthly totals for the 2009 through 2011 period have not been adjusted to reflect changes in final billing figures recognized at the end of each calendar year. Adjustments typically result in a 1 to 2 percent change to annual totals and are caused by billing errors, meter reading errors, and adjustments due to leakage.

- *Statewide average,* the best metric of the state as a whole, represents the average of the cities' values after each city is weighted by its population.

Though Phase II of the study involved a limited subset of Texas cities, the statewide annual averages for outdoor use as a percentage of total use were comparable to Phase I averages for the 2004 to 2008 study period (compare Table 4 to Table 2). For three of the five years, the statewide average was 2 percentage points lower in Phase II than in Phase I, and for the remaining two years the reductions in averages were 1 and 3 percentage points. This variation in figures amounted to a 2 percentage point difference between the Phase I (31%) and Phase II (29%) statewide averages for 2004 through 2008.

Table 4: Statewide weighted values of outdoor use as a percentage of total use for 2004 through 2011 for Phase II municipalities.

Outdoor use as a percentage of total use									
2004	**2005**	**2006**	**2007**	**2008**	***2004 through 2008 average***	**2009**	**2010**	**2011**	***2004 through 2011 average***
26	36	30	25	30	*29*	28	35	37	*31*

Additionally, when we compared weighted annual averages for the 17 Phase II municipalities for the 2004 to 2008 time frame with the weighted annual averages for the 2004 through 2011 period, there was again a 2 percentage point difference in annual outdoor use figures (Table 5). The continuity of this pattern suggests that figures for non-Phase II cities would be valid beyond the Phase I study period despite not having enjoyed a longer period of record. Based on these calculations, it seems likely that statewide averages for Phase I municipalities for 2009 through 2011 would fall within 3 percentage points of Phase II state averages as 3 percentage points represents the largest gap between Phase I and Phase II figures.

Table 5: Outdoor use as a percentage of total use for Phase II cities for 2004 through 2008, 2009 through 2011, and 2004 through 2011.

City	2004 through 2008	2009 through 2011	2004 through 2011
Amarillo	41	44	42
Arlington	36	37	36
Austin	31	37	33
College Station	33	45	38
Corpus Christi	23	32	26
Dallas	40	43	41
El Paso	33	33	33
Fort Worth	35	39	37
Garland	33	34	33
Houston	18	24	20
Katy	35	49	40
Laredo	26	23	25
Lubbock	37	33	36
Odessa	37	37	37
Pflugerville	35	45	39
Tyler	50	57	53
San Antonio	23	27	25
City average	*33*	*38*	*35*
City median	*35*	*37*	*36*
Statewide average	*29*	*33*	*31*

- *Statewide average,* the best metric of the state as a whole, represents the average of the cities' values after each city is weighted by its population.

When comparing the Phase I study time frame, 2004-2008, with the years added to generate Phase II of the study, 2009-2011, a pattern emerges. Thirteen out of 17 study cities dedicated a higher percentage of their single-family residential water consumption to outdoor purposes during the later time period. Of the remaining four cities, two used the same percentage of total water use for outdoor purposes during both time frames and two decreased their outdoor water consumption in the later period. Given that both 2009 and 2011 are considered low precipitation years for Texas as a whole, the predominance of increases in outdoor water use as a percentage of total use from 2009 through 2011 as compared to 2004 through 2008 suggests that outdoor consumption may be related to precipitation.

During Phase II of the study, we also attempted to directly analyze the effects of precipitation and temperature on monthly single-family residential consumption patterns during the summer months of

July, August, and September as well as year-round. We considered total monthly precipitation and monthly mean temperature across all 17 cities combined, across Texas' ten climatic zones as determined by the National Oceanic and Atmospheric Administration, and by individual cities. In all cases, the raw data lacked the approximate normal distribution required to conduct regression analysis. Additionally, the statistical transformations required to make the raw data suitable for this type of analysis were extensive and beyond the scope of our analysis. We subsequently created precipitation and consumption cross plots to visually assess the relationship between the two variables, and no clear patterns emerged.

We believe there are three primary reasons that the data do not demonstrate a distinguishable relationship between precipitation and consumption. First, we think that climate information when aggregated to monthly time intervals obscures precipitation events to the point that any association between these events and corresponding changes in consumption is lost. As consumption is also measured in monthly increments, we doubt that the data is detailed enough to capture a relationship between rainfall and outdoor water use.

Second, we believe that lag times associated with billing data may disassociate any relationship between precipitation and consumption. There are typically delays of roughly 15 to 30 days between when water is consumed and when the billing cycle for this consumption takes place (Chastain-Howley 2012). As figures used in this report are typically generated using billing data, this means that the consumption value indicated for a particular month most likely reflects consumption 15 to 30 days prior. Additionally, as billing lag times are not uniform across all study sites, making a universal adjustment to all study data to account for delays is not possible. Thus, we assume that lag times associated with billing data reduce the likelihood of demonstrating a relationship between precipitation and consumption patterns.

Third, we believe that average annual precipitation in much of Texas is not adequate to support many preferred landscapes, particularly given that the summer months are typically part of the driest time of year. For example, the recommended watering amount for the most commonly used grasses in Texas, St. Augustine and Bermuda, is 1 inch of water per week or just over 4 inches of water per month (TCEQ 2012), whereas average July, August, and September rainfall for all Phase II cities from 2004 to 2011 was 3.1, 2.2, and 3.6 inches, respectively. On an annual basis, common Bermuda grass requires 40 inches of water for sufficient development and coloration and St. Augustine grass requires 45 inches to meet the same standards (Duble 2012). However, only the easternmost third of the state receives annual precipitation in large enough quantities to approach or exceed these figures. Furthermore, irrigation applied to most Texas lawns is actually double what is necessary for a healthful appearance (TCEQ 2012). Thus, with landscaping that both requires and inspires irrigation in excess of typical precipitation, watering patterns are less responsive to precipitation events as the need to irrigate is constant.

In addition to considering residential water use in relation to climatic factors, we also evaluated how usage during 2011, the hottest, driest single year in Texas on record, measured up to usage during the remainder of the study period (Table 6). We conducted this analysis using *Outdoor use as a percentage of total use* figures for each city. First, we compared outdoor use during 2011 to the survey year with the highest outdoor use percentage or the survey year with the second highest percentage in cases where the highest use year was 2011. In this scenario, 2011 was the highest usage year for eight of the seventeen cities, with the increase in use during 2011 over the next highest year ranging from 0.8 percent in Corpus Christi and Garland to 9 percent in Katy. For the remaining nine cities, use during 2011 was below use during another survey year, with the differential between 2011 and the highest use year ranging from negative 0.7 percent in San Antonio to negative 21.4 percent in Lubbock. The difference in weighted averages for all cities between 2011 usage and that of the highest or next highest use year was negative 3.3 percent. In other words, outdoor use during 2011 on average did not exceed use during the highest usage years of the 2004 through 2011 study period.

We also evaluated outdoor water use during 2011 in relation to average outdoor water use for 2004 through 2010 by city. When considered using this metric, only Odessa averaged more water use for outdoor purposes from 2004 to 2010 than it did in 2011, and this was by a margin of 0.2 percent. In El Paso, outdoor water use in 2011 equaled average outdoor water use for 2004 through 2010. For the remainder of cities, outdoor consumption in 2011 exceeded average outdoor consumption from 2004 through 2010 by between 0.2 percent and 19.1 percent. When we evaluated all cities collectively, outdoor water use in 2011 exceeded average 2004 through 2010 water use by 8.1 percent.

Though 2011 was a record-breaking year in terms of drought, outdoor water use as a percentage of total use for the year was not consistently higher than in other study years. Nine of the 17 study cities reported higher outdoor use for a year in the 2004 through 2010 time frame, and the average outdoor use during those peak years surpassed that of 2011. One possible explanation for the lack of consistently higher outdoor usage figures for 2011 despite the drought is that measures such as watering restrictions impacted the total amount of water dedicated to outdoor uses across the state. Further research is required to determine if this is the case.

Table 6: Comparison of 2011 outdoor use as a percentage of total use to outdoor use as a percentage of total use in other years.

City	2011 outdoor use as a percentage of total use	Next highest use year	(Next) Highest outdoor use as a percent of total use	2011 outdoor use minus next highest year outdoor use	2011 outdoor use minus 2004-2010 average outdoor use
Amarillo	50.9	2005	49.8	1.1	9.8
Arlington	42.1	2005	46.9	-4.9	6.6
Austin	43.7	2005	39.5	4.2	12.0
College Station	51.1	2010	45.2	5.9	15.5
Corpus Christi	35.2	2009	34.4	0.8	9.9
Dallas	47.0	2008	53.7	-6.8	6.5
El Paso	33.0	2005	38.1	-5.1	0.0
Fort Worth	44.7	2005	51.7	-7.1	9.2
Garland	38.0	2006	37.2	0.8	5.5
Houston	25.0	2010	28.5	-3.6	5.6
Katy	56.8	2005	47.8	9.0	19.1
Laredo	25.4	2006	37.7	-12.4	0.2
Lubbock	38.0	2007	59.4	-21.4	2.7
Odessa	36.7	2010	40.7	-4.0	-0.2
Pflugerville	53.2	2010	44.3	8.9	16.4
Tyler	63.5	2010	57.0	6.5	11.9
San Antonio	31.2	2005	31.9	-0.7	7.5
City average	*42.1*		*43.8*	*-1.7*	*8.1*
City median	*42.1*		*44.3*	*-0.7*	*7.5*
Statewide averages	*36.8*		*40.1*	*-3.3*	*6.8*

- *Statewide average,* the best metric of the state as a whole, represents the average of the cities' values after each city is weighted by its population.

Recommendations for further study

Our study takes the first step in analyzing seasonal single-family residential water use patterns in Texas by estimating how much water is being used indoors and outdoors across the state. However, to gain a more complete understanding of residential water use patterns, additional research is required. Numerous factors need to be considered, including the cost of water, the effect of water pricing structures, income levels, size of homes and their landscaped areas, climatic conditions including evapotranspiration, conservation measures and restrictions, and type of irrigation method. Only once the impacts of these variables on consumption patterns are evaluated can we truly gauge residential water use patterns across the state.

To reach this level of assessment, a more in-depth analysis is required. Ideally, a multi-year study of a geographically diverse subset of Texas cities involving individual residential surveys, billing data, climatic data, and flow trace analysis should be conducted. This type of household-level exploration of single-family residential water consumption specific to Texas would provide more conclusive evidence of how we use our water, thus providing a sound basis for recommendations aimed at meeting the state's future water needs.

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Appendix A: Cities and corresponding Water Use Survey names

	City	Water use survey respondent name
1	Albany	City of Albany
2	Allen	City of Allen
3	Alvarado	City of Alvarado
4	Alvin	City of Alvin
5	Amarillo	Amarillo MWS
6	Anahuac	City of Anahuac
7	Andrews	City of Andrews
8	Arlington	City of Arlington
9	Aspermont	City of Aspermont
10	Athens	City of Athens
11	Aubrey	City of Aubrey
12	Austin	City of Austin-General Distribution System
13	Baird	City of Baird
14	Ballinger	City of Ballinger
15	Bastrop	City of Bastrop
16	Bay City	City of Bay City
17	Baytown	City of Baytown
18	Beckville	City of Beckville
19	Bellmead	City of Bellmead
20	Bells	City of Bells
21	Bellville	City of Bellville
22	Boerne	City of Boerne
23	Bonham	City of Bonham
24	Borger	City of Borger
25	Bovina	City of Bovina
26	Brazoria	City of Brazoria
27	Breckenridge	City of Breckenridge
28	Bremond	City of Bremond
29	Brenham	City of Brenham
30	Bridge City	City of Bridge City
31	Bridgeport	City of Bridgeport
32	Bronte	City of Bronte

	City	Water use survey respondent name
33	Brownfield	City of Brownfield
34	Brownsboro	City of Brownsboro
35	Brownwood	City of Brownwood
36	Buda	City of Buda
37	Buffalo	City of Buffalo
38	Burkburnett	City of Burkburnett
39	Callisburg	City of Callisburg
40	Canton	City of Canton
41	Canyon	City of Canyon
42	Carthage	City of Carthage
43	Castroville	City of Castroville
44	Celeste	City of Celeste
45	Charlotte	City of Charlotte
46	Chico	City of Chico
47	Cibolo	City of Cibolo
48	Cisco	City of Cisco
49	Clarendon	City of Clarendon
50	Clarksville	City of Clarksville
51	Coleman	City of Coleman
52	College Station	City of College Station
53	Comanche	City of Comanche
54	Conroe	City of Conroe
55	Converse	City of Converse
56	Corinth	City of Corinth
57	Corpus Christi	City of Corpus Christi-General Water Distribution System
58	Corsicana	City of Corsicana
59	Crawford	Aqua Texas, Inc-City of Crawford
60	Crosbyton	City of Crosbyton
61	Cumby	City of Cumby
62	Daingerfield	City of Daingerfield
63	Daisetta	City of Daisetta
64	Dalhart	City of Dalhart
65	Dallas	City of Dallas
66	Darrouzett	City of Darrouzett
67	Dell City	City of Dell City
68	Denton	City of Denton
69	Denver City	City of Denver City
70	Dimmitt	City of Dimmitt
71	Duncanville	City of Duncanville

	City	Water use survey respondent name
72	Early	City of Early
73	Earth	City of Earth
74	Edinburg	City of Edinburg
75	Edna	City of Edna
76	El Paso	City of El Paso Water Utilities
77	Emhouse	Community Water Company-City of Emhouse
78	Ennis	City of Ennis
79	Fairfield	City of Fairfield
80	Falfurrias-Encino Water System	City of Falfurrias-Encino Water System
81	Falfurrias-Utility Board	City of Falfurrias-Utility Board
82	Farmers Branch	City of Farmers Branch
83	Ferris	City of Ferris
84	Flatonia	City of Flatonia
85	Flower Mound	City of Flower Mound
86	Fort Worth	City of Fort Worth-General Water Distribution System
87	Franklin	City of Franklin
88	Friendswood	City of Friendswood
89	Frisco	City of Frisco
90	Fritch	City of Fritch
91	Gail	City of Gail
92	Galena Park	City of Galena Park
93	Garland	City of Garland-General Water Distribution System
94	Giddings	City of Giddings
95	Gladewater	City of Gladewater
96	Goldthwaite	City of Goldthwaite
97	Gordon	City of Gordon
98	Graham	City of Graham
99	Granbury	City of Granbury
100	Grand Saline	City of Grand Saline
101	Grapeland	City of Grapeland
102	Grapevine	City of Grapevine
103	Greenville	City of Greenville
104	Gunter	City of Gunter
105	Gustine	City of Gustine
106	Hallsville	City of Hallsville
107	Hamilton	City of Hamilton
108	Harker Heights	City of Harker Heights
109	Hart	City of Hart

	City	Water use survey respondent name
110	Haslam	Haslam Community Water System
111	Hedley	City of Hedley
112	Hemphill	City of Hemphill
113	Hempstead	City of Hempstead
114	Hico	City of Hico
115	Higgins	City of Higgins
116	Highland Park	Town of Highland Park
117	Highland Village	City of Highland Village
118	Holliday	City of Holliday
119	Honey Grove	City of Honey Grove
120	Houston	City of Houston-General Distribution System
121	Howe	City of Howe
122	Hubbard	City of Hubbard
123	Humble	City of Humble
124	Huntington	City of Huntington
125	Hurst	City of Hurst
126	Huxley	City of Huxley
127	Ingleside	City of Ingleside
128	Ingleside On The Bay	City of Ingleside on the Bay
129	Iowa Park	City of Iowa Park
130	Iraan	City of Iraan
131	Irving	City of Irving
132	Jacinto City	City of Jacinto City
133	Jacksonville	City of Jacksonville
134	Joaquin	City of Joaquin
135	Johnson City	City of Johnson City
136	Josephine	City of Josephine
137	Katy	City of Katy
138	Kermit	City of Kermit
139	Kingsville	City of Kingsville
140	Kirby	City of Kirby
141	Kountze	City of Kountze
142	La Porte	City of La Porte
143	Ladonia	City of Ladonia
144	Lago Vista	City of Lago Vista
145	Lake Worth	City of Lake Worth
146	Lampasas	City of Lampasas
147	Laredo	City of Laredo
148	Leander	SWWC-City of Leander Utilities

	City	Water use survey respondent name
149	Lindale	City of Lindale
150	Littlefield	City of Littlefield
151	Liverpool	City of Liverpool
152	Longview	City of Longview-General Water Distribution System
153	Lorena	City of Lorena
154	Lorenzo	City of Lorenzo
155	Lubbock	City of Lubbock-Water Treatment Plant
156	Madisonville	City of Madisonville
157	Malone	City of Malone
158	Manor	City of Manor
159	Marion	City of Marion
160	Mason	City of Mason
161	Meadows Place	City of Meadows Place
162	Melissa	City of Melissa-City Water Department
163	Melvin	City of Melvin
164	Menard	City of Menard
165	Meridian	City of Meridian
166	Mesquite	City of Mesquite
167	Mexia	City of Mexia
168	Midway	City of Midway
169	Mineral Wells	City of Mineral Wells
170	Mobeetie	City of Mobeetie
171	Monahans	City of Monahans
172	Moody	City of Moody
173	Morton	City of Morton
174	Mount Pleasant	City of Mount Pleasant
175	Murphy	City of Murphy
176	Navasota	City of Navasota
177	Needville	City of Needville
178	New Braunfels	City of New Braunfels
179	New London	City of New London
180	New Waverly	City of New Waverly
181	Nixon	City of Nixon
182	Nocona	City of Nocona
183	Odem	City of Odem
184	Odessa	City of Odessa
185	Olney	City of Olney
186	Orange	City of Orange
187	Orange Grove	City of Orange Grove

	City	Water use survey respondent name
188	Orchard	City of Orchard
189	Paducah	City of Paducah
190	Paris	City of Paris
191	Pasadena	City of Pasadena
192	Pearsall	City of Pearsall
193	Pflugerville	City of Pflugerville-General Distribution System
194	Pineland	City of Pineland
195	Plains	City of Plains
196	Plainview	City of Plainview
197	Poteet	City of Poteet
198	Quanah	City of Quanah
199	Quinlan	City of Quinlan-4 R Ranch Water 2
200	Richland	Community Water Company-City of Richland
201	Richland Hills	City of Richland Hills
202	Richmond	City of Richmond
203	River Oaks	City of River Oaks
204	Robinson	City of Robinson
205	Rockwall	City of Rockwall
206	Rosenberg	City of Rosenberg
207	Round Rock	City of Round Rock
208	Rule	City of Rule
209	Sadler	City of Sadler
210	Saint Jo	City of Saint Jo
211	San Antonio	San Antonio Water System-General Distribution System
212	San Leanna	Village of San Leanna
213	San Marcos	City of San Marcos
214	San Saba	City of San Saba
215	Schertz	City of Schertz
216	Sealy	City of Sealy
217	Seminole	City of Seminole
218	Shallowater	City of Shallowater
219	Shenandoah	City of Shenandoah
220	Shiner	City of Shiner
221	Smithville	City of Smithville
222	Somerville	City of Somerville
223	Sonora	City of Sonora
224	Spearman	City of Spearman
225	Stinnett	City of Stinnett
226	Stockdale	City of Stockdale

	City	Water use survey respondent name
227	Sugar Land	City of Sugar Land
228	Sundown	City of Sundown
229	Sunray	City of Sunray
230	Sweetwater	City of Sweetwater
231	Teague	City of Teague
232	Temple	City of Temple
233	Terrell	City of Terrell
234	Thorndale	City of Thorndale
235	Timpson	City of Timpson
236	Tioga	City of Tioga
237	Tolar	City of Tolar
238	Tomball	City of Tomball
239	Troup	City of Troup
240	Tyler	City of Tyler
241	Universal City	City of Universal City
242	Uvalde	City of Uvalde
243	Vernon	City of Vernon
244	Victoria	City of Victoria
245	Waco	City of Waco-General Water Distribution System
246	Wallis	City of Wallis
247	Waskom	City of Waskom
248	Waxahachie	City of Waxahachie
249	Weatherford	City of Weatherford
250	Webster	City of Webster
251	Wellington	City of Wellington
252	West	City of West
253	Wharton	City of Wharton
254	Whitesboro	City of Whitesboro
255	Wichita Falls	City of Wichita Falls
256	Wilson	City of Wilson
257	Woodville	City of Woodville
258	Woodway	City of Woodway-Community Services
259	Wylie	City of Wylie

Appendix B: Changes to 2004 through 2008 Raw Data*

	City	Years omitted	Changes to raw data	Notes on changes to raw data/analysis
1	Anahuac	2004	-	No data provided.
2	Aspermont	-	January 2006 x 10	January 2006 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
3	Baytown	-	2005 through 2008 figures x 1,000	Spoke with superintendent of water city, Steve Fife, to determine what scale of usage (million vs. billion gallons) was appropriate for the city. Adjusted data accordingly. Data entry errors are assumed.
4	Bellmead	2004	2008 figures x 100	2008 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed. 2004 omitted as monthly totals were identical.
5	Bridge City	-	2004 figures x 1000	2004 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
6	Brownsboro	2008	-	2008 figures appear to be estimates to the nearest 100,000 gallons. Gross estimates are excluded due to lack of specificity/to maintain uniform level of analysis.
7	Castroville	2004	-	No data provided.
8	Charlotte	2004	-	Y EstFlag for 2004.**
9	Clarksville	2004	-	Y EstFlag for 2004.**
10	Coleman	-	January through October 2008 x 10	Most 2008 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
11	College Station	2006	-	No data provided.
12	Conroe	-	July 2008/10	July 2008 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
13	Converse	-	October 2007 x 10	October 2007 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
14	Daisetta	-	January 2004 x 10	January 2004 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
15	Dimmitt	-	2004 figures x 10	2004 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
16	Early	2005	-	2005 omitted due to numerous and inconsistent irregularities in monthly figures.
17	Edna	2008	-	2008 omitted due to numerous and inconsistent irregularities in monthly figures.
18	El Paso		2005 & May through December 2007	Data obtained directly from El Paso Water City rather than state water survey.

	City	Years omitted	Changes to raw data	Notes on changes to raw data/analysis
19	Fairfield	2006	-	2006 omitted due to numerous and inconsistent irregularities in monthly figures.
20	Falfurrias-Encino Water System	2004		No data provided.
21	Ft. Worth	-	-	2004, 2005, 2007, and 2008 data obtained directly from City of Ft. Worth Water Utility rather than state water survey.
22	Fritch	-	December 2004/10	December 2004 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
23	Giddings	2004	-	No data provided.
24	Hemphill	2007	-	No data provided.
25	Highland Village	-	December 2004 x 10	December 2004 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
26	Honey Grove	-	2008 figures x 1000	2008 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
27	Humble	2006	2005 & 2007 figures x 1,000	No data for December 2006, so full year eliminated. Figures for 2005 and 2007 were adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
28	Iowa Park	2004	-	2004 omitted due to numerous and inconsistent irregularities in monthly figures.
29	Iraan		2004 figures x 1,000; April 2006 x 10	2004 and April 2006 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
30	Irving	-	April 2007 x 10	April 2007 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
31	Josephine	-	2008 figures x 1,000; 2005 Sf_Con x 10	2008 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed. 2005 sf_con figure adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
32	Kountze	2004	-	Y EstFlag for 2004.**
33	Lake Worth	2007	-	Y EstFlag for 2007.**
34	Laredo	-	December 2004 x 10	December 2004 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
35	Longview	2004	-	Y EstFlag for 2004.**
36	Lorena	-	February & March 2005 x 10	February & March 2005 figures were adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
37	Manor	-	October 2008 x 10	October 2008 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
38	Mason	2004	2005 figures x 1,000	2005 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed. Y EstFlag for 2004.**
39	Mexia	2005	-	2005 omitted due to numerous and inconsistent irregularities in monthly figures.

	City	Years omitted	Changes to raw data	Notes on changes to raw data/analysis
40	New Braunfels	-	2006 figures x 100	2006 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
41	Nixon	2004	Dec 2005 x 10	December 2005 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed. 2004 omitted due to numerous and inconsistent irregularities in monthly figures.
42	Odem	-	2004 figures x 1,000	2004 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
43	Odessa	-	2006 figures x 1,000	2006 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
44	Orange Grove	2004	-	Y EstFlag for 2004.**
45	Paris	-	January 2005 x 10	January 2005 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
46	Plainview	2005	-	2005 omitted due to numerous and inconsistent irregularities in monthly figures.
47	Richland Hills	-	2005 figures x 100	2005 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
48	Robinson		January 2006 & Mar 2007 x 10	January 2006 & March 2007 figures were adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
49	Round Rock	-	2004 figures x 10	2004 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
50	Sealy	2006	-	2006 omitted due to numerous and inconsistent irregularities in monthly figures.
51	Seminole	-	December 2005 /10; 2004 figures x 1,000	December 2005 & 2004 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
52	Smithville	2004	-	No data provided.
53	Sweetwater	2004	-	2004 omitted due to numerous and inconsistent irregularities in monthly figures.
54	Temple	-	2004 figures /10	2004 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
55	Troup	-	2006 through 2008 figures x 1,000	2006 through2008 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
56	Wellington	-	January 2005 x 10; May through December 2007 /10	January 2005 & May through December 2007 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.
57	Whitesboro	-	November & December 2005/10	November & December 2005 figures were adjusted to bring the order of magnitude in line with figures for all other survey years. Data entry error is assumed.

	City	Years omitted	Changes to raw data	Notes on changes to raw data/analysis
58	Woodville	-	April 2007/10	April 2007 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.
59	Woodway	-	August 2006 x 10	August 2006 figure was adjusted to bring the order of magnitude in line with figures for all other survey months and years. Data entry error is assumed.

*Only utilities that we adjusted or excluded a year of survey data from are included in this appendix.

** We eliminated any survey containing a positive (*Y)* value for the *EstFlag* field. This field indicates whether the figures used in the survey are numbers carried over from the previous year because no new information was provided (Y), or whether information was not carried over (N) because new figures were given.

Appendix C:
NOAA Climate Data Stations

	City	Station name	Distance from city	Total precipitation (TPCP), Monthly mean temperature (MNTM), both
1	Amarillo	Canyon	17 miles	Both
2	Arlington	Arlington Municipal Airport	-	Both
3	Austin	Austin Camp Mabry	-	Both
4	College Station	College Station Easterwood Field	-	Both
5	Corpus Christi	Corpus Christi International Airport	-	Both
6	Dallas	Dallas Love Field	-	Both
7	El Paso	El Paso International Airport	-	Both
8	Fort Worth	Fort Worth Meacham Field	-	Both
9	Garland	Richardson	9 miles	TPCP
		Lavon Dam	13 miles	MNTM
10	Houston	Houston William P. Hobby Airport	-	Both
11	Katy	Katy City	-	TPCP
		Houston Sugarland Mem	16 miles	MNTM
12	Laredo	Laredo 2	-	Both
13	Lubbock	Lubbock International Airport	-	Both
14	Odessa	Odessa Schlemeyer Field	-	Both
15	Pflugerville	Round Rock 3 NE	9 miles	TPCP
		Austin Camp Mabry	13 miles	MNTM
16	San Antonio	San Antonio International Airport	-	Both
17	Tyler	Tyler Pounds Field	-	Both