Update to Technical Note 12-01

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Outdoor Residential Water Use in Texas – 2026

by

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SUMMARY

Outdoor residential water use is the most variable component of single-family water demand in Texas. In 2012 the Texas Water Development Board published Technical Note 12-01, the first comprehensive statewide analysis of seasonal single-family residential water use, which found that approximately 31% of single-family annual water consumption goes to outdoor purposes. That analysis covered 259 community water systems from 2004 through 2008 and a subset of 17 systems through 2011. Given the population growth, shifting climate conditions, and changes in conservation policies across Texas since that time, updated estimates are needed to support the state's long term water supply planning.

This study estimates single-family outdoor water use for the period of 2012 through 2023 for approximately 253 community water systems, extending the results available from Technical Note 12-01. Because monthly single-family water use volumes are no longer collected through the Water Use Survey, this study develops and validates two methods to estimate single-family monthly water use distributions from available data. We apply the minimum-month method[1] to these monthly distributions to estimate outdoor use. We find that over this study period single-family outdoor water use has declined to a statewide average of 27%.

Outdoor use is variable across the state, with humid systems in the southeast consistently at the low end of single-family outdoor water use, while drier inland communities are at the high end, a pattern broadly consistent with the Technical Note 12-01 study. Year-to-year variation is pronounced and closely tied to drought cycles; with the highest outdoor use at 32% during the 2012 drought and stabilizing in the 25-28% range through most of the post-2016 period before returning to 30% during renewed drought conditions in 2022-2023. We also find that several systems show sustained declines in outdoor use that are consistent with statewide conservation improvements, while others show increases aligned with rapid suburban growth.

As with the Technical Note 12-01 study, a strong relationship between monthly precipitation and outdoor use could not be mathematically established statewide. However, we observe that regionally wetter months are associated with lower outdoor use in east and central Texas systems, while in the High Plains and Panhandle outdoor use and rainfall tend to peak together in summer months. Temperature remains the stronger and more consistent driver of monthly single-family outdoor water use across the state.

INTRODUCTION

Residential outdoor water use - primarily landscape irrigation - is the largest and most variable component of municipal water demand across Texas. Unlike indoor consumption which tends to be relatively stable across regions and seasons, outdoor water use fluctuates with climate, landscape practices, household characteristics and local conservation polices, making it both a

[1] Indoor use is estimated as the minimum monthly SF volume multiplied by twelve; outdoor use is the total annual SF volume minus this estimated annual indoor volume, and the outdoor use percentage is outdoor use divided by total annual SF volume.

primary driver of seasonal peak demand and a primary focus for conservation strategies (Pannkuk & Wolfskill, 2015; Vickers, 1999). As Texas faces a growing gap between water supply and municipal demand needs, with municipal shortages projected to account for 57% of all statewide water needs by 2080 (2027 State Water Plan - Phase 1), accurately characterizing outdoor residential water use across the state's diverse Community Water Systems (CWS) is essential for effective water supply planning and conservation.

In 2012, the Texas Water Development Board (TWDB) published Technical Note 12-01: *The Grass is Always Greener*… Outdoor Residential Water Use in Texas (Hermitte & Mace, 2012), the first comprehensive statewide analysis of seasonal single-family (SF) residential water use in Texas. The study was conducted in two phases using monthly SF water use volumes reported through the TWDB Water Use Survey. Phase 1 analyzed 259 CWS from 2004 through 2008 and calculated SF outdoor water use by applying the minimum-month method. The minimum month method estimates indoor and outdoor water consumption by assuming the month with the lowest water demand represents indoor consumption and any usage above that baseline is attributed to outdoor use. Findings from this phase revealed that outdoor use accounts for a weighted statewide average of 31 percent of total SF residential consumption, ranging from 12% in Galena Park to 64% in Gail, with a broad east-west gradient reflecting the state's precipitation gradient.

Phase 2 extended the analysis through 2011 for a subset of 17 urban CWSs, with the goals of evaluating seasonal water use patterns over a longer time horizon, determining whether the historic drought of 2011 affected consumption patterns, and assessing whether water use among this smaller subset was representative of the broader Phase 1 population. The statewide weighted average remained consistent at 31% across both phases. The Technical Note 12-01 study also noted that a statistically significant relationship between monthly precipitation and outdoor use could not be established, a limitation the authors attributed to the temporal resolution of the data, possible billing lag times, and the structural irrigation deficit characteristic of much of Texas.

Given the rapid population growth and shifting drought conditions experienced in Texas since the original study, updating these baseline estimates is critical to maintaining the accuracy of the state's long-term water supply projections. Updated indoor and outdoor water use metrics are computed in this study using the minimum-month method consistent with the original study, and the prospective relationship between outdoor water use and climate drivers is explored. These findings are intended to provide updated estimates that reflect contemporary SF outdoor water use conditions and inform regional water demand projections and conservation planning.

A. Background

Nationally, studies of SF residential water use have relied on two primary methodological scales. The most granular approach involves direct end-use measurement, utilizing high-resolution flow-trace analysis and individual data loggers installed at the household level. The American Water Works Association's Residential End Uses of Water studies conducted in 1999 and later updated in 2016 found that average daily indoor household water use declined 22% over that period, from

177 to 138 gallons per household per day, driven by improvements in technology (DeOreo et al., 2016; Mayer et al., 1999).

Outdoor use, by contrast, constituted approximately 50% of annual SF consumption among the study's landscape sample and proved far more difficult to characterize consistently. Primary drivers were determined to be local weather conditions, irrigated area and plant material. A 'heavy-tail' distribution of irrigation behavior where a small fraction of households applying excess water disproportionately influence system-wide peak demand was observed (DeOreo & Mayer, 2012). These studies revealed that indoor consumption has declined over time while outdoor use remains highly variable and climate dependent.

While direct monitoring allows for precise disaggregation of total consumption into specific components, the implementation costs and logistical complexity often limit its application to relatively small scales. For system-level and statewide analyses where direct monitoring is impractical, a billing-based adaptation known as the minimum-month method is often utilized. This approach, which quantifies the climate-dependent volume consumed above a stable indoor baseline by leveraging the seasonal invariance of indoor demand (Mayer et al., 1999) has been well documented. Notable applications of this method include studies conducted by Hasenyager and Klotz (2009) in Utah, as well as a hybrid approach documented in the California Single-Family Water Use Efficiency Study (Mayer et al., 2011). These studies demonstrated that analyses of multi-year billing records could effectively quantify outdoor irrigation across diverse geographies by isolating the 'seasonal residual' – the volume consumed above the stable winter baseline, providing a scalable alternative to household-level instrumentation.

Across the arid and semi-arid regions of the Western United States, outdoor residential water use consistently represents a disproportionately large share of municipal demand (Potter et al., 2022) compared to more humid regions. This regional disparity is reflected in per capita consumption rates, which frequently exceed 159 gallons per day in arid Western counties - nearly double the 92 gallons per day average typical of the humid East (Dieter et al., 2018). Research has established that this variation is driven by the intensive irrigation demands of urban turfgrasses, which can account for 40% to 70% of total residential withdrawals in semi-arid environments (Blount et al., 2021).

In this context, Texas occupies a critical zone of interest. As the state experiences a documented trend toward aridification, its municipal water demand pattern increasingly mirrors the high-consumption rates of the desert Southwest (Nielsen-Gammon et al., 2020). This is most acute along the 100th meridian, a corridor of rapid urbanization where growing residential demand meets increasingly finite water supplies (Potter et al., 2022). Cabrera et al., (2013) estimated the extent of urban landscaped area across the state and confirmed that landscape irrigation constitutes the largest component of urban-municipal water use in Texas. Although indoor use is more stable and declining due to efficiency improvements, the magnitude of the seasonal swing in Texas remains tied to structural and behavioral predictors, such as parcel size and persistent over-irrigation (Lewis Alan C. et al., 2022; Potter et al., 2022).

At the community level, (Pannkuk & Wolfskill, 2015) documented seasonal outdoor residential water use patterns in an East Texas community, finding that outdoor use drove substantial peaks in SF demand consistent with the statewide patterns identified by (Hermitte & Mace, 2012). More recently, (Lewis Alan C. et al., 2022) analyzed billing data for over 14,000 SF customers in College Station from 2015 to 2019 and found that a significant proportion of households consistently applied irrigation in excess of theoretical landscape water requirements, suggesting that overirrigation remains a persistent feature of Texas residential demand even in communities with active conservation programs. However, this behavioral persistence is not universal; Breyer et al. (2018) found that conservation measures implemented during drought in Austin produced sustained reductions in outdoor water use that persisted beyond the drought period itself. This suggests that while structural drivers often push demand upward, drought-induced behavioral changes and policy interventions can result in a permanent downward shift in the consumption baseline.

While localized studies illustrate the diverse spatial, behavioral, and policy drivers of residential demand, the foundational baseline for the geographic and volumetric characterization of these patterns at a statewide scale was established by Hermitte and Mace (2012). Their analysis serves as the primary reference for quantifying outdoor residential water use in Texas, with the study's 31% statewide weighted average estimate embedded in the residential per capita demand calculations that underpin TWDB's regional water planning process.

However, conditions have changed considerably since the original study was completed. The empirical data underlying these state benchmarks concluded in 2008, a pivotal year that also marked a shift in the state's data reporting environment. Following this period, when the Phase 2 study was conducted (2009-2011), the TWDB altered the reporting requirements for its annual Water Use Survey, moving away from the aggregation of monthly residential volumes required to use the minimum month method at a statewide scale. Over the same period, Texas experienced two significant drought periods, widespread conservation program implementation, and continued population growth concentrated in rapidly urbanizing areas. Coupled with documented patterns of persistent overirrigation, these developments suggest that Technical Note 12-01 may no longer capture the current magnitude and volatility of SF outdoor water use.

Collectively, these factors underscore the need for a comprehensive update to the original statewide analysis. This study seeks to address this need and provide the TWDB with SF outdoor water use estimates that reflect contemporary conditions for the 254 CWSs originally evaluated in Technical Note 12-01.

MATERIALS AND METHODS

A. Water Use Survey Data

The primary data source for this study is the Texas Water Development Board's annual Water Use Survey (WUS), a comprehensive assessment of municipal and industrial water use that has been conducted in various forms since 1955 and made mandatory for nearly all CWSs under

Senate Bill 2 of the 77th Legislature (Hermitte & Mace, 2012). The WUS collects self-reported annual water use data from CWSs statewide, including volumes of water produced, sold, and distributed by customer category. For the purposes of this study, four primary data types were extracted from the WUS for approximately 254 CWSs over the study period of 2004 through 2023: annual SF residential volumes, total metered volumes (TMV) by customer category, monthly system intake, and monthly retail sales of treated water.

1. Data Quality Assurance and Quality Control (QA/QC)

A comprehensive quality assessment and correction process was applied to each dataset prior to SF outdoor water use analysis to ensure internal consistency and reliability across CWSs and years.

a. Outlier Assessment

Outlier assessment was applied to three primary datasets: annual SF volumes, monthly system intake, and TMV. Across all three datasets, a common class of data quality issue was identified: values that were implausibly high or low relative to a CWS's own reporting history, inconsistent with expected gradual demand trends, and in many cases attributable to order-of-magnitude data entry errors such as missing or added zeros. Left uncorrected, these anomalies would directly distort monthly SF demand and the resulting outdoor water use estimates.

Annual SF volumes were evaluated using a three-test detection framework implemented in Python:

- The majority scale test compared every pair of system's annual SF values to form a ratio matrix, then took the largest group of years lying within a factor of 2.0 of one another as the system's dominant (majority) reporting scale. A year outside this group was flagged as a magnitude outlier only when its ratio to every majority-scale year exceeded a factor of 2.8. Values falling between these two factors were retained rather than flagged, providing a buffer that kept moderately variable years from being treated as outliers while still capturing definitive magnitude problems such as missing or added zeros.
- The year-over-year percent-jump test measured whether the annual SF Volume changed by more than 50% relative to the prior year, marking sharp discontinuities inconsistent with expected gradual demand trends.
- The log-jump test applied the same idea in log space using a threshold of 0.7 log units (approximately equivalent to a factor-of-five change), isolating order-of-magnitude shifts from smaller year-to-year changes the percent-jump also picks up.

Taken together, the three tests separated genuine magnitude errors from ordinary year-year variations. The majority test determined which years were flagged, while the percent-jump and log-jump measures were recorded alongside each flagged to characterize it, indicating whether an anomaly was an abrupt single-year discontinuity or sustained order of magnitude shift. Each flagged year was carried into the correction process described below, Of the 254 CWSs evaluated, 63 (about 25%) had at least one year flagged, spanning 100 system-years.

For monthly intake, outlier detection was implemented as a pairwise scale-based screen applied to each CWS and month across years. Values mutually within a factor of 2.6 of one another formed the majority scale for that month, and a value was flagged only when its ratio to every majority-scale value exceeded a factor of 3.0, again distinguishing the normal range from definitively anomalous values. The screen was applied to systems with a complete monthly record, since a system with gaps may have too few same-month observations to establish a reliable majority scale. 213 candidate month-values across 41 systems were flagged at this stage.

Monthly retail sales volumes were screened with a median-based test suited to their shorter but mostly complete records (starting 2014 and ending before 2023 for many CWSs). For each CWS, years with all 12 months reported were used to establish a typical value for each calendar month, and every reported month was compared against it. A value of more than five times or less than one-fifth of its own month's median was flagged as a magnitude-error candidate. This screen flagged 525 candidate month-values across 21 CWSs. As with intake, these ranged from isolated months to the same month recurring years to multi-year spans reported at the wrong scale, which for retail was the dominant scale errors. For example, 2014-2020 being off by two or more orders of magnitude to the rest of the record, which is why a small number of systems account for most of the 525 flagged months.

Total Metered Volume (TMV) was not subjected to an automated magnitude detection screen. TMV feeds only the retail-based outdoor use method, which applies to a small subset of systems, so the small number of TMV magnitude errors (30 system-years across 16 systems) were identified manually carried into the pipeline as a documented correction checkpoint.

Beyond magnitude errors, TMV data exhibited two additional classes of structural reporting issues that required targeted assessment. First, in several cases, TMV was not reported in the designated field but instead entered under the "Other Volume" category of the WUS. This resulted in TMV appearing as zero despite the presence of valid TMV. These cases were identified by comparing the "Other Volume" field against the sum of all other metered customer categories, with a relative tolerance applied to account for minor rounding differences. In other cases, individual customer category volumes (e.g., residential, commercial, industrial) were reported, but the TMV field was either left blank or did not reflect the sum of those categories. To identify these cases, a sum of metered volumes was computed for each system-year and compared to the reported TMV. Records where TMV was zero or inconsistent with the component sum were flagged as candidates for reconstruction.

The detection thresholds applied across all annual SF, monthly intake and monthly retail frameworks were not derived from formal statistical tests but were selected iteratively, based on domain knowledge of the data and refined through manual validation. Multiple threshold values were evaluated, and the final values were chosen to maximize detection of confirmed errors while minimizing false positives.

The systematic detection frameworks described most magnitude anomalies in the annual SF, intake and retail datasets, with manual preview applied afterward to resolve ambiguous cases and any residual errors the automated rules did not reach. in the annual SF and monthly intake datasets. TMV issues proved more resistant to automated screening and were addressed largely through manual review.

b. Outlier Corrections

Following the identification of outliers, corrections were applied to flagged values across all datasets. Adjustments were applied automatically only where the internal consistency of a system's surrounding years clearly supported a single, specific adjustment; ambiguous values were routed to manual review rather than corrected to avoid introducing new errors, so that being flagged as unusual never by itself forced a change.

For annual SF volumes, correction proceeded in two steps. First, the verified 12-month totals from the Technical Note 12-01 (Phase 1, 2004-2008; Phase 2, 2009-2011) study was used to fill early years that had no recorded value; where a Phase 1/2 total was available for a year that did carry a value, the verified total took precedence. Remaining confirmed magnitude errors were then auto-corrected by rescaling flagged years (applying a power of ten adjustment) to align with the dominant reporting scale identified across the CWS's history, but only where exactly one such adjustments brought the value within tolerance of the order of magnitude of the system's other years. Where more than one adjustment was plausible, or none brought the value cleanly into line, the year was carried to manual review.

For monthly intake, flagged candidates were auto-corrected with a power-of-ten adjustment only where it was confirmed on two fronts: the corrected value had to match the cross-reference for that calendar month, and it had to remain consistent with the surrounding months of its own year, preserving month-to-month orderings that hold reliably across the system's clean years and not spiking above neighboring months. No corrections were applied to months where the source of anomaly was ambiguous, these were retained for review and were manually corrected or left unchanged as deemed fit.

For monthly retail sales, flagged values were similarly auto-corrected with a power-of-ten adjustment where it clearly matched the calendar month's median. For a small number of systems (8: City of Allen, City of Corpus Christi, City of Dallas, City of Mesquite, City of Odessa, City of Tomball, City of Wylie, and Lubbock Public Water System), a magnitude error spanned most of that system's own recorded history rather than a single isolated year. In these cases, the median used as a reference point for detecting and correcting an error is itself built from that system's own years, so when most of those years are at the wrong scale, the reference becomes unreliable, and no automatic adjustment can be trusted to move a flagged value toward the correct scale rather than the dominant but wrong one.

These systems were therefore excluded from automatic correction and handled manually, using external context (e.g. TMV, which should sit within a plausible range relative to retail sales for a given system-year) to determine the correct scale independently of the system's contaminated history. Of 525 flagged candidates (system-year-months), 75 were corrected automatically; the remainder, including all months from the 8 excluded systems were handled manually.

For TMV, corrections were applied based on the classification of identified issues. In cases where TMV was misreported under the “Other Volume” category, the value was reassigned to the TMV field where component totals and internal consistency supported this interpretation; this was predominantly the case for 85 CWS between 2004 and 2011, and occasionally for later years. For system-years where TMV was missing but individual customer category volumes were available, TMV was reconstructed as the sum of metered categories. For magnitude anomalies, adjustments were made only where the discrepancy clearly reflected a power-of-ten error (e.g., missing or added zeros), and corrected values were rescaled accordingly for the 30 affected system-years. As with other datasets, records with ambiguous discrepancies or insufficient supporting information were left unchanged.

c. Incomplete Monthly Intake Assessment

Prior to gap-filling, a preliminary statistical screening was conducted to characterize the nature and extent of incomplete monthly intake records across the dataset. For CWSs reporting fewer than 12 months of intake data in a given year two complementary analyses were applied. First, the partial-year total was expressed as a percentage of each system's median annual intake across complete years, providing an intuitive benchmark for whether the reported partial-year volume was plausible given the number of months present. For example, a system reporting six months of data would be expected to show approximately 40–60% of its typical annual total.

Second, a Z-score was computed for each incomplete system-year relative to the system's own complete-year mean and standard deviation, identifying system-years that deviated substantially from typical annual patterns. The strong positive correlation between the two measures ($r = 0.796$) confirms that both independently identify the same problematic system-years (**Figure 1**).

The majority of systems with incomplete data reported partial-year totals close to their expected values given the months present. A smaller subset showed extreme negative deviations (partial-year totals far below what the number of reported months would suggest) and were flagged as likely severe underreporting. These findings confirmed that the majority of incomplete system-years reflected genuinely missing months rather than systematic underreporting, supporting the application of gap-filling procedures described below rather than wholesale exclusion of affected system-years from further analysis.

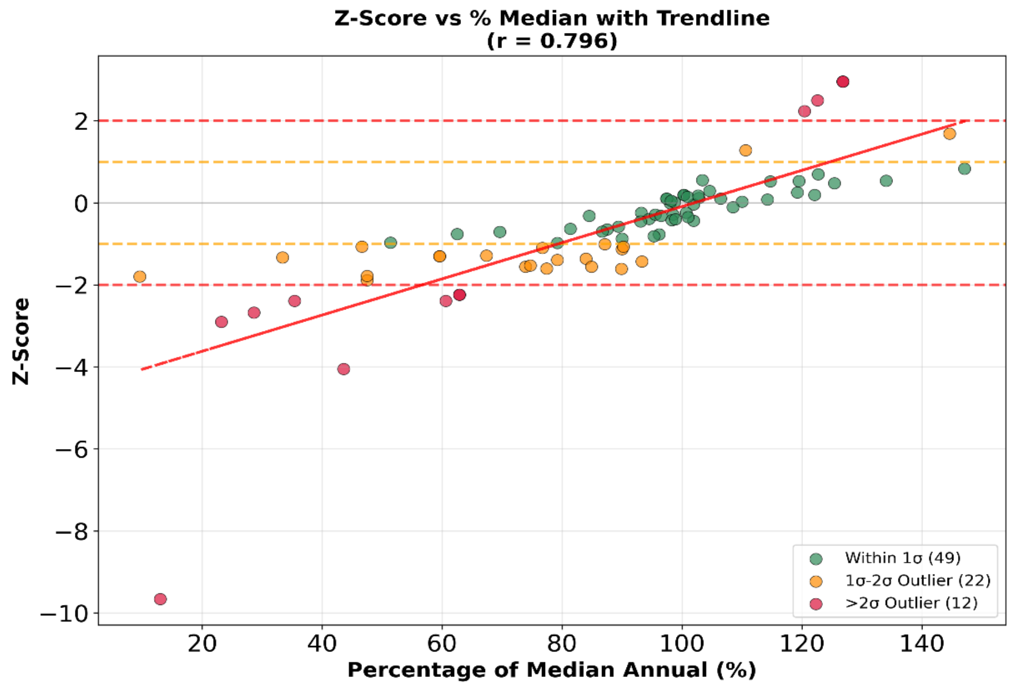

Figure 1. Relationship between the two independent measures of data completeness. The x-axis shows the partial-year intake total expressed as a percentage of each system's median annual intake across complete years, and the y-axis shows the corresponding Z-score relative to the system's own complete-year mean and standard deviation. Green points indicate system-years falling within one standard deviation of the system mean, clustering around 80–120% of median intake with Z-scores near zero, consistent with genuinely missing months. Red points indicate system-years exceeding two standard deviations from the system mean, showing either extreme negative deviations at 15–25% of median intake, or values above 120%.

d. Lump-Sum Disaggregation and Redistribution

A recurring reporting pattern was identified in monthly CWS intake data where the full annual volume for a given year appeared to have been reported as December's intake rather than distributed across all twelve months, likely reflecting an annual total entered in the wrong field rather than a genuine monthly consumption volume. System-years were flagged as potential lump-sums if December intake exceeded 50% of the annual total and all or most other months were missing or zero. This threshold was chosen because a legitimate December value would rarely account for more than half of a system's annual intake given the seasonal nature of water use in Texas, where peak demand typically coincides with summer months.

Confirmed lump-sum years (58 candidates) were redistributed across all 12 months using seasonal fractions derived from the nearest clean reference years, defined as years with complete 12-month records and no lump-sum pattern. Seasonal fractions were computed as each month's share of the annual total, averaged across the selected reference years, and normalized to sum to 1. Up to 2 years before and 2 years after the flagged year were used as references to capture the system's seasonal pattern closest in time to the gap period. The method also allows for a manually confirmed override of the standard reference selection, for cases where another year can be individually verified to share a flagged year's true annual total.

e. Gap Filling

For annual SF volumes, gaps were first classified by position to guide the appropriate filling method. Leading gaps were defined as missing years before the first observed value, middle gaps as missing years between two valid observations, trailing gaps as missing years after the last observed value, and mixed gaps as combinations of the above. To assess directional consistency in each system's annual SF record prior to gap filling, a non-parametric Mann-Kendall trend test and Sen's Slope estimator were applied. The Mann-Kendall test determined whether a statistically significant monotonic trend existed in the time series ($p < 0.05$) without assuming normality, classifying each system as having an increasing, decreasing, or no trend in SF volumes over time. Where a significant trend was identified, Sen's Slope quantified the magnitude of change in volume per year and provided the directional percent rate of change used to guide projections and interpolations.

For middle gaps, missing values were filled by interpolation adjusted upward or downward according to the direction and magnitude of Sen's Slope where a significant trend was detected, and by standard linear interpolation between boundary years where no significant trend existed. Leading and trailing gaps were treated similarly. Where a significant trend was detected, missing edge years were projected forward or backward using Sen's Slope to maintain the historical rate of change. Where no significant trend existed, the nearest observed value was carried forward or backward to preserve stability without introducing artificial growth or decline. For mixed gaps, the same logic was applied segment by segment. In rare cases where trailing gaps exceeded three consecutive years, systems were flagged for manual review.

For monthly intake, a hybrid gap-filling approach was applied to system-years identified as having genuine missing months based on the screening process described above. A system-year was considered complete if all 12 months were non-zero and non-null. For incomplete system-years, seasonal fractions were derived from the nearest two complete reference on either side of the gap, so the shape reflects the system's behavior closest in time to the gap itself. An annual intake baseline was estimated by interpolating between the nearest complete year before and after the gap; where only one side had a complete year available, that year's total was used with a modest adjustment (95% looking backward, 90% looking forward) to avoid assuming unchanged demand, and where neither side was available, the system's own historical average annual total was used instead.

Gaps of three or fewer months were filled using the historical median for that specific calendar month, drawn from a window of the two years before or after. Larger gaps used a ratio-scaled approach, the baseline's share attributable to the missing months was distributed across them according to their relative seasonal weight. In both cases, all filled values were constrained to within 50-200% of that month's historical median from the same window, to prevent unrealistic estimates.

For single-family connections, gaps were classified by position: leading, middle, trailing, or mixed. Of the 101 systems with gaps, the majority (66) had middle gaps of typically one to two years, well suited to linear interpolation between surrounding known values. Edge gaps: leading, trailing, and mixed accounted for 35 systems. Given that connection counts change slowly and monotonically over time, simple positional fills were applied to edge gaps rather than trend-based approaches to avoid introducing additional uncertainty. Leading gaps were backfilled from the earliest available value and trailing gaps were forward-filled from the most recent available value, based on the assumption that connection counts in adjacent years are the most reliable and stable reference available.

B. Climate Data

Two climate datasets were used to support the climate driver assessment component of this study. Monthly precipitation totals were derived from PRISM daily precipitation data (PRISM Group, Oregon State University). Daily maximum and minimum near-surface air temperature data were obtained from gridMET, a gridded meteorological dataset produced by the University of Idaho Climatology Lab (Abatzoglou, 2013) at approximately 4-kilometer spatial resolution. Annual gridMET files for daily maximum (tmmx) and minimum (tmmn) temperatures were collected for the 2012-2023 study period. For each CWS, climate values were extracted from climate datasets at the centroid of each CWS service area polygon, derived from the Water Service Boundary Viewer shapefile hosted by the TWDB.

C. Outdoor Use Methodology

As noted above, monthly SF volumes are no longer collected through the WUS, precluding direct application of the minimum-month method to the current study period. To address this, two proxy methods were developed to derive monthly SF distributions from available annual and monthly CWS data. Each method leverages a different data source as the seasonal proportioning key and was designed to address varying data availability scenarios across CWSs and study years.

Intake Method: Monthly SF from CWS Monthly Intake Proportion

The Intake method uses monthly system intake as a proxy for the seasonal distribution of SF demand. For each CWS-year, the ratio of monthly intake to the annual intake is computed to derive a set of monthly proportions that are then applied to the annual SF volume to produce monthly SF estimates:

$$Monthly\ SF = \left(\frac{Monthly\ Intake}{Annual\ Intake}\right) * Annual\ SF\ Volume$$

This method assumes that the monthly pattern of total system intake is sufficiently representative of monthly SF demand patterns to serve as a reliable proportioning key.

Retail Method: Monthly SF from Monthly Retail Sales

The Retail method uses actual monthly treated water retail sales data to derive monthly SF consumption patterns. For systems reporting retail sales by customer category, the monthly distribution of retail sales is scaled to the annual SF volume using the ratio of annual SF volume to total metered volume (TMV):

$$Monthly\ SF = \left(\frac{Annual\ SF\ Volume}{Total\ Metered\ Volume}\right) * Monthly\ Retail\ Sales$$

This method more directly reflects SF billing patterns and is less susceptible to distortion from non-SF operational factors that may influence the aggregate intake signal. However, it requires monthly retail sales, which is not consistently reported across all CWS and years, limiting its availability to approximately 150 CWs within the study dataset, with most CWS having retail data available from 2014 onward and a median coverage of 10 years within the 2012–2023 study period.

1. Implementation

Prior to applying the Intake method, monthly intake data were aggregated to a single total system intake value for each CWS-year. As reported in the WUS, monthly intake is recorded by water intake type (i.e., groundwater, surface water, reuse), source, and seller. In this way a CWS purchasing from multiple sellers or drawing from multiple sources may have several records for a given month and year. Because the Intake method relies on the proportional distribution of total system intake across months, all disaggregated records were summed to produce a single monthly total for each CWS-year prior to QA/QC screening and method application. All outlier detection and correction procedures described above were applied to this aggregated intake series, rather than to individual intake records broken down by water source, type or seller. This addresses the fact that a CWS may routinely shift water purchasing across sources or sellers within a year for operational reasons, making individual records appear inconsistent even when total system intake is normal. Therefore, anomalies that persist after aggregation into a monthly time series per year reflect genuine inconsistencies in reporting rather than artifacts of how intake is internally disaggregated.

To facilitate comparison of seasonal distributions across CWSs and between methods independent of absolute volume, monthly SF estimates were normalized for each CWS-year by dividing each month's value by the minimum monthly SF value observed across all twelve months of that year:

$$SF_{norm(m)} = \frac{SF_m}{\min\{SF(Jan), SF(Feb), \ldots, SF(Dec)\}}$$

where $SF_{(m)}$ is the monthly SF volume for month m and the denominator is the lowest monthly SF value recorded for that CWS-year. This transformation sets the minimum month to a value of 1.0, with all other months expressed as multiples thereof. This isolates the SF shape of the seasonal curve from differences in system size. Normalized SF volumes are used in the seasonal profile comparisons described below but are not used in the derivation of outdoor use estimates.

2. Validation

The Technical Note 12-01 study applied monthly SF volumes reported directly by the CWSs. For Phase 1 (2004–2008) those volumes were collected through the TWDB WUS while for Phase 2 (2009–2011) monthly SF data were provided directly by the 17-CWS subset upon request. In both cases, the reported volumes represented the best available observed record of monthly SF demand for Texas CWSs. Therefore, the proxy methods for estimating monthly SF volumes developed in this study were validated against the Technical Note 12-01 study data.

Validation of the proxy methods differed by data availability. The Intake method, as the most comprehensive dataset spanning all study CWSs and years, was validated against the original study benchmark using quantitative error metrics. Because monthly retail sales data are not available for the Phase 1 and Phase 2 study years or systems, an equivalent direct validation of the Retail method was not possible. Retail method performance is instead evaluated through normalized seasonal profile comparisons with the Intake method across CWSs and years where both datasets are available.

a. Intake Validation

Intake-derived monthly SF estimates derived from Intake in this study were compared against monthly SF volumes used in the Technical Note 12-01 study (Phase 1) for 239 CWSs using root mean square error (RMSE) and mean absolute error (MAE), both expressed as a percentage of each CWS's mean monthly SF volume. RMSE was selected for its sensitivity to larger month-to-month deviations, while MAE provides a more directly interpretable measure of average error magnitude; together they offer complementary perspectives on method performance. Prior to QA/QC corrections, 64% of CWSs had RMSE values at or below 25% and 81% had MAE values at or below 25%, with 5% of CWSs exceeding 75% RMSE (**Figures A1** and **A2** in the Appendix show systems with highest RMSE and MAE prior to corrections for the Technical Note 12-01 Phase 1 and Phase 2 study periods). Following corrections, the share of CWSs at or below 25% RMSE increased to 81% and the share at or below 25% MAE increased to 95%, with no CWS exceeding 75% RMSE, indicating that severe estimation errors were substantially reduced across the dataset (**Figure 2**).

RMSE/MAE improvements were most pronounced for CWSs that originally exhibited the largest errors. RMSE and MAE reductions exceeded 60% for previously high-error CWSs including City of Terrell, City of Huntington, City of Tyler, and City of Schertz, and City of Bronte – with City of Terrell reduced from over 400% to under 25% and City of Schertz from 135% to 12% - reflecting corrections to previously severe magnitude anomalies in annual SF volumes and monthly intake data (**Figure 2**). Moderate reductions of 30-45% were observed for CWSs such as City of Katy, City of Rule, City of New London, City of Olney and City of Odessa. CWSs with smaller initial errors showed correspondingly modest gains, consistent with the fact that their data required minimal correction. A small number of CWSs including City of Bronte, City of Nocona, and City of Goldthwaite continued to show limited agreement with the benchmark even after corrections, indicating that the underlying intake data for those CWSs could not fully recover the seasonal pattern of SF monthly volumes. (*See* the Appendix for a complete list of per-system RMSE and MAE percentage changes after corrections provided in **Table A1**).

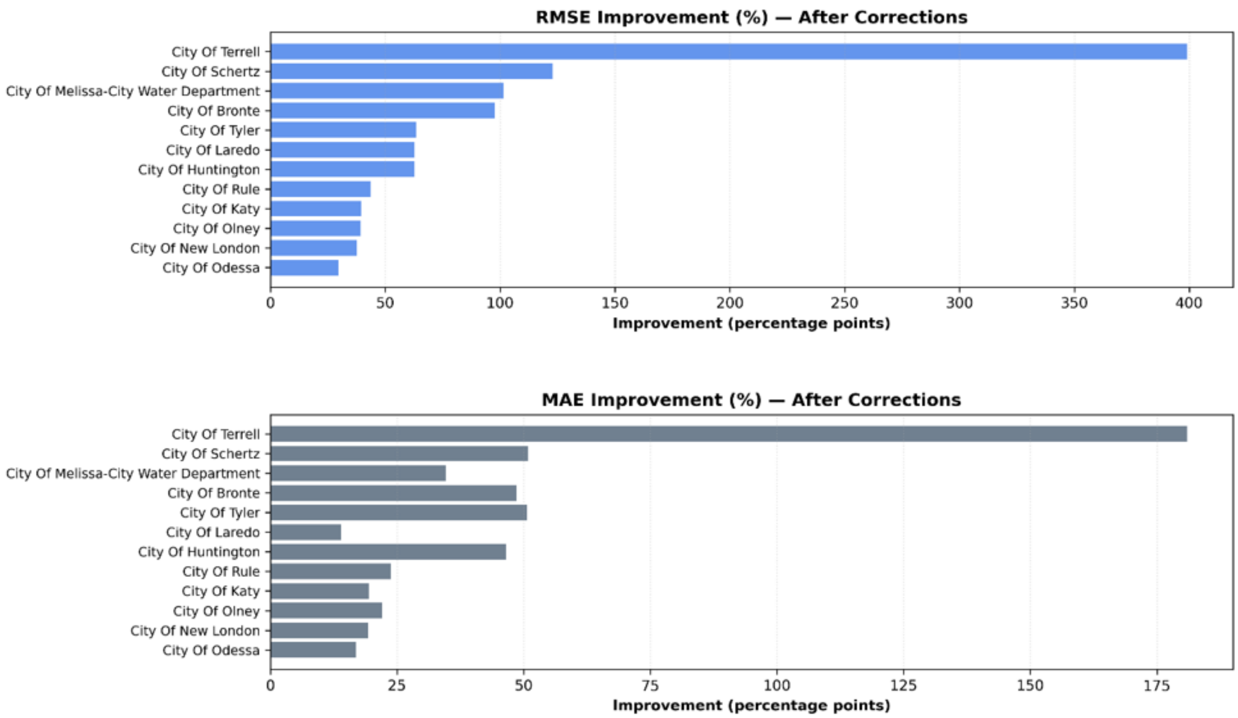

Figure 2. Percentage improvements in RMSE (top) and MAE (bottom) for the systems that previously had the highest errors. Improvement is computed as the reduction in RMSE or MAE expressed as percentage of each CWS's mean monthly SF volume, that is, the difference between the pre- and post-correction error values, both of which are already normalized by mean monthly SF volume. Bars indicate how much error was reduced after data improvements. The longer bars represent larger improvements, i.e., greater reductions in RMSE or MAE (%) after gap-filling and outlier correction.

For the 2012-2023 period no directly reported monthly SF data are available against which to evaluate absolute error. Pearson and Spearman correlation coefficients were instead computed between each CWS's 2012–2023 Intake method results and its 2004–2008 seasonal pattern as a proxy for expected seasonal behavior. Correlation measures the degree to which the seasonal shape (the relative rise and fall of monthly SF demand across the year) of the intake-derived estimates tracks the same pattern as the Technical Note 12-01 study, independent of differences in absolute volume. Both Pearson and Spearman correlation coefficients were computed, where Pearson quantifies linear agreement between the two seasonal curves and is the preferred metric for interpretation, while Spearman provides a rank-based check that is less sensitive to the influence of any single month.

Across 245 CWSs, the mean Pearson correlation was 0.83 and the mean Spearman correlation was 0.82, with 80% of CWSs achieving Pearson coefficients at or above 0.75. Data corrections raised the share of CWSs in strong seasonal agreement (Pearson ≥ 0.85) from 46% to 64%, while the share in poor agreement (Pearson < 0.70) fell from 35% to 14%. Systems that previously showed the weakest seasonal agreement such as City of Needville, City of Ferris, City of Ballinger, and City of Schertz showed the most substantial improvements (**Figure 3**). (*See* **Figures A3** and **A4** in the Appendix for the systems with the highest and lowest correlations prior to data corrections).

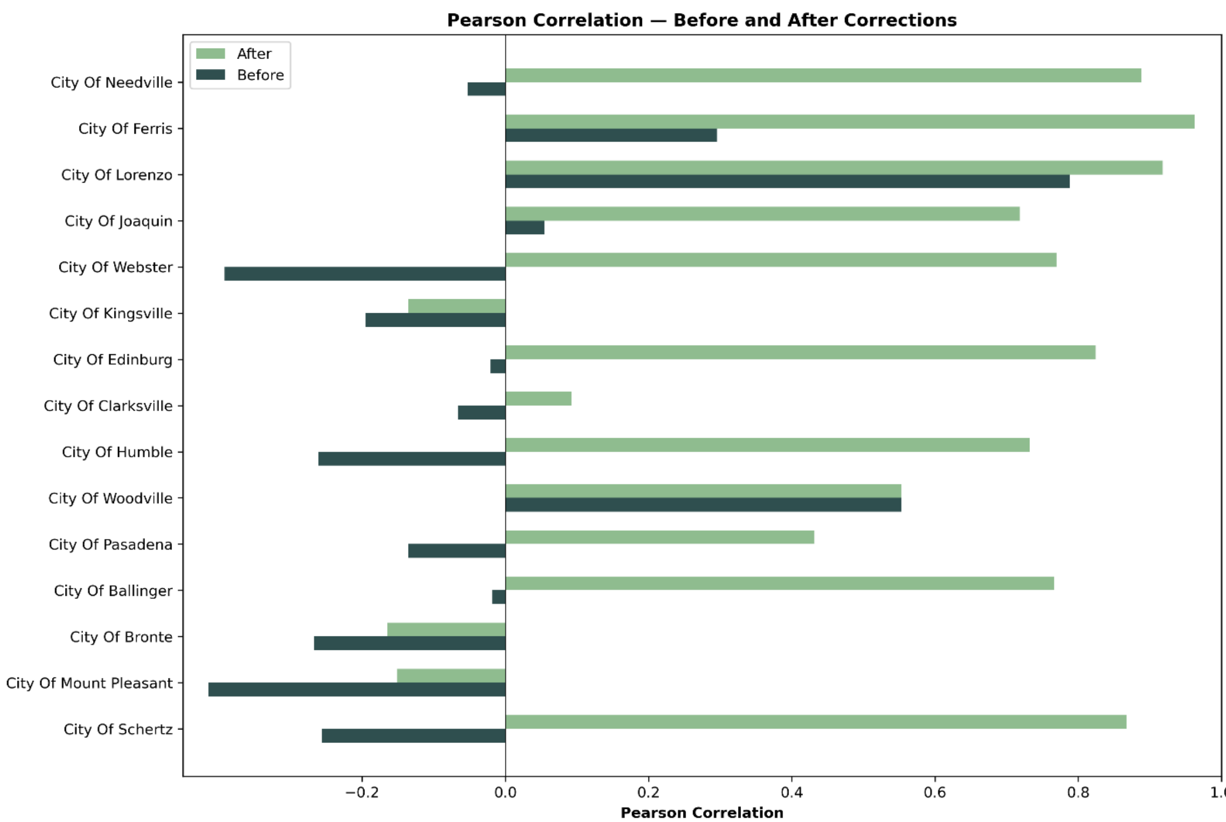

Figure 3. Pearson correlation between the updated monthly SF estimates and the benchmark dataset, shown before and after corrections. Higher values indicate stronger agreement in seasonal pattern; most systems show substantial improvement after corrections.

Furthermore, to confirm that the QA/QC improvements translated into better agreement not only in monthly SF volume estimates but also in the outdoor use estimates that are the ultimate objective of this study, preliminary outdoor use metrics were computed for the 2004-2008 period and compared against the Technical Note 12-01 study baseline for the ten CWS with the highest total intake volumes. The year-by-year deviation of this study's estimates from the Technical Note 12-01 (Phase 1) baseline, both before and after data corrections is shown in **Figure 4**.

Across most CWSs, corrections substantially reduced deviations from the Technical Note 12-01 (Phase 1) baseline, most visibly in CWSs where major data issues were identified and corrected. Laredo (2004) and El Paso (2005) had the largest pre-correction deviations due to extensive missing intake records and show the most substantial improvements. However, in some cases gap-filled winter intake was higher than the Technical Note 12-01 (Phase 1) winter SF volumes. This elevated the indoor baseline and reduced estimated outdoor use relative to the Technical Note 12-01 study; as seen in Fort Worth (2005). Systems such as Arlington, where no corrections or gap-filling were applied, show no before/after difference, as expected.

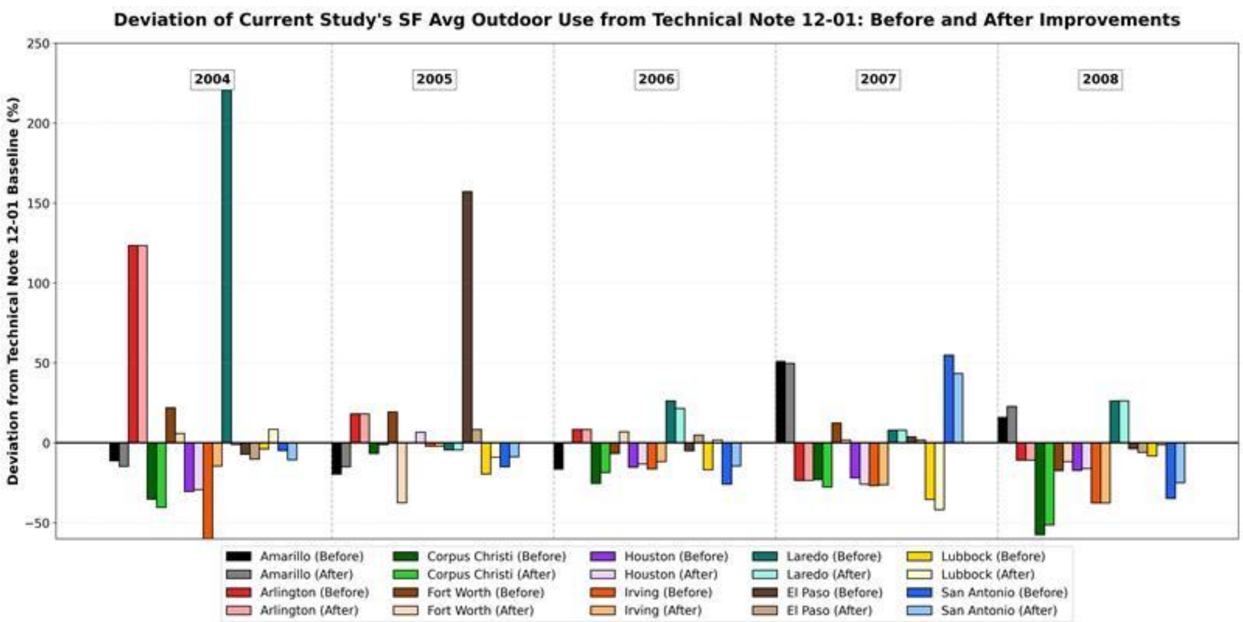

Figure 4. Year-by-year differences between the SF outdoor use estimates generated in this study and those from the Technical Note 12-01 (Phase 1) study for the ten largest CWSs. For each year (2004-2008), paired bars show the deviation before improvements and after improvements, illustrating how these changed the magnitude of outdoor use estimates. Systems with bars closer to zero reflect closer agreement with the Technical Note 12-01 (Phase 1) baseline, while positive or negative deviations indicate an over or under-estimation relative to the original study.

Some variation in the results of this study and the Technical Note 12-01 study should be expected, regardless of data quality, as the two studies are operating with fundamentally different input data. The Technical Note 12-01 study derived outdoor use from directly reported monthly SF volumes whereas this study must estimate monthly SF volumes from intake-derived distributions. The comparison presented here nonetheless provides evidence that the corrections improved the consistency between proxy-derived and directly-reported seasonal patterns, supporting the application of the Intake method for outdoor use estimation across the full 2004–2023 period.

b. Retail Validation

Monthly retail sales data are not available for the 2004–2011 period, precluding direct comparison of Retail method estimates generated in this study against the Technical Note 12-01 monthly SF benchmark used to evaluate the Intake method. Retail method performance is therefore assessed through normalized seasonal profile comparisons with the Intake method across CWSs and years where both datasets are available, as described in the following section. Where the two methods produce consistent seasonal curves with a small amplitude swing, and where the Intake method has been independently validated against the Technical Note 12-01 study benchmark, that agreement provides indirect support for the reliability of the Retail method estimate. Where the methods diverge, the nature and consistency of the divergence inform method selection.

3. Seasonal Profile Comparison

Normalized monthly SF volumes were compared across methods and against the Technical Note 12-01 study benchmark to assess how well each method captures the seasonal shape of SF monthly demand. Two comparisons are presented: (1) the Intake method against the Retail method for the 2012–2023 period and (2) the Intake method against the Technical Note 12-01 study for the 2004–2011 period (where Technical Note 12-01 data are available). All comparisons use the normalized SF volumes described above, isolating seasonal shape from differences in absolute volume.

a. Intake Proxy vs Retail Proxy

For several CWSs, the Intake and Retail methods produce nearly identical seasonal curves across most examined years, agreeing on both peak timing and amplitude. Irving, El Paso and Laredo demonstrate this most clearly with Intake and Retail curves nearly overlapping in most years, such as between 2015 and 2023, and tracing comparable amplitude swings (**Figure 5**). Laredo (2018, 2020, 2023), Lubbock (2020) and Austin (2015) show similarly close peak timing and amplitude agreement, though Laredo shows a sharper Retail peak than Intake in 2018 (**Figure 5**), and Austin shows a wider retail amplitude swing in 2021 (**Figure 6**) driven by an unusually elevated January retail value that distorts the normalization anchor for that year. These CWSs have SF shares of metered volume above 45% and an intake to metering ratio above 0.85, meaning SF residential customers dominate what is billed and most of what enters the system reaches metered customers. Under these conditions the aggregate intake signal closely mirrors SF seasonal demand.

Where the two proxies diverge, the divergence takes different forms depending on CWS demand composition. Houston shows the most persistent amplitude divergence, with the Intake method consistently producing a lower summer peak relative to the Retail method across some years, reflecting an SF share below 15% of metered volume where non-SF demand dominates and dilutes the aggregate intake signal (**Figure 6**). This divergence is further compounded in 2023 by an unusually low January intake value that distorts the normalization anchor. Corpus Christi presents a different and more variable pattern: in some years the two curves track similar

seasonal shapes but with intake running higher in amplitude for much of the year, while in others intake shows abrupt mid-season shifts. On the other hand, Lubbock (2015, 2018) shows the retail curve peaking higher than the intake curve, yet still maintaining the same seasonal shape (**Figure 6**).
San Antonio, Fort Worth, Arlington (**Figure 6**), and Brenham (**Figure 7**) show a different character of divergence where the two curves broadly follow similar shapes but intake consistently peaks earlier than retail across most examined years. This timing offset is driven by a substantial non-SF (multifamily, commercial, industrial and reuse demand) pulling the aggregate intake ramp earlier into summer in these systems. In San Antonio and Fort Worth this is most pronounced in 2015, 2017 and 2022, while Arlington shows the pattern across 2015-2021 and Brenham in 2020 and 2023 as shown in **Figures 6 and 7**.

Gordon and Hico also show notable amplitude divergence in a few years, with retail curves reaching several multiples of the minimum in some years while intake remains comparatively flat, consistent with their low metering rates and diverse customer mix (**Figure 7**). Taken together, the degree of agreement between the two methods is primarily driven by how much of a system's metered volume is attributable to SF residential customers and how much of total intake reaches metered customers.

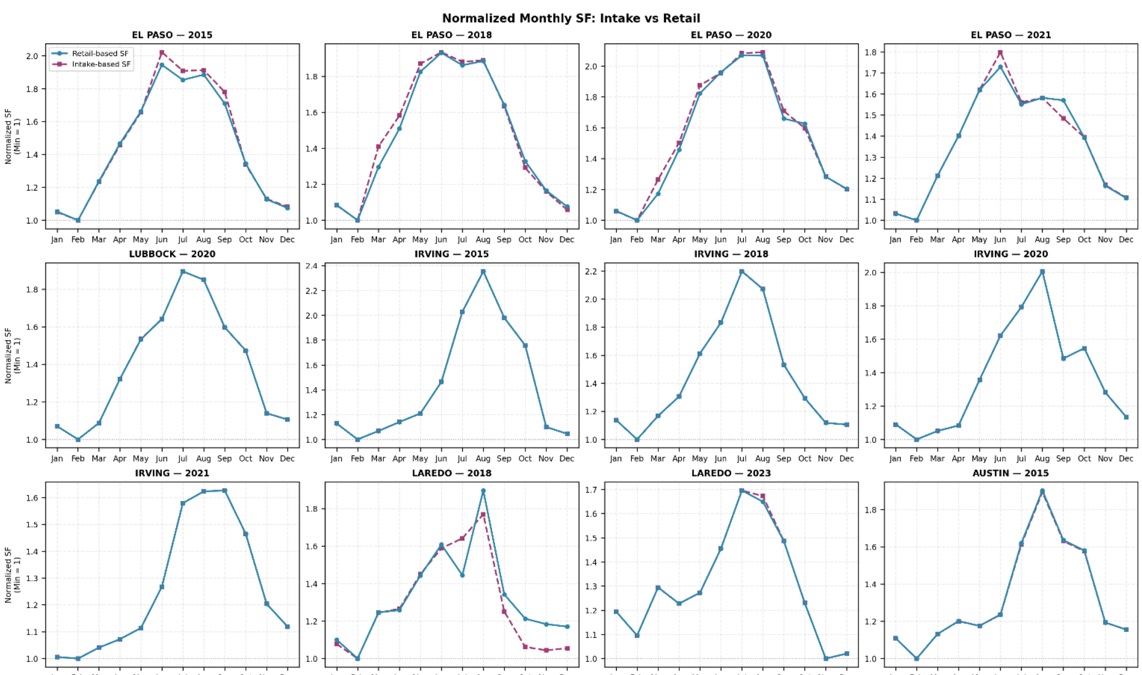

Figure 5. Normalized seasonal curves derived from the Intake and Retail methods plotted against each other SF for El Paso, Lubbock and Irving. The blue line represents the Retail-derived SF while the pink line represents the Intake-derived SF.

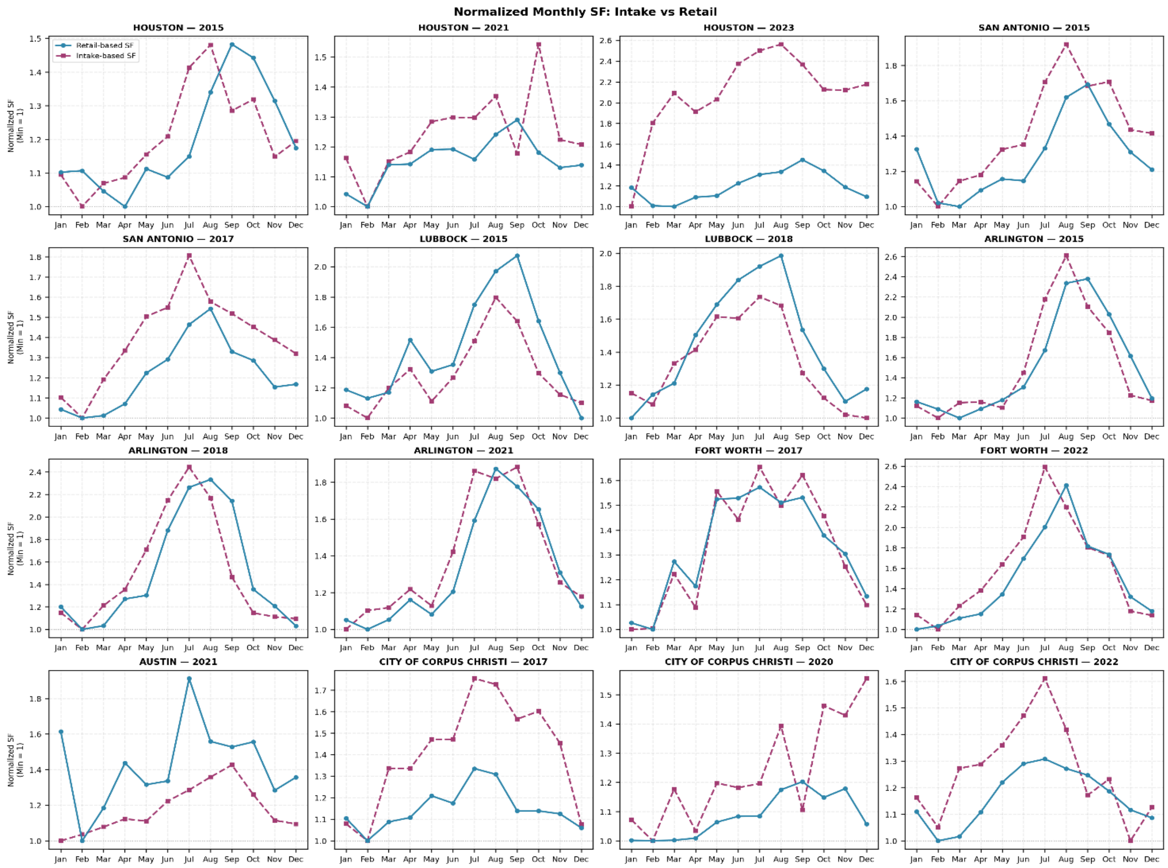

Figure 6. Normalized seasonal curves derived from the Intake and Retail methods plotted against each other for Houston, San Antonio, Lubbock, Arlington, Fort Worth, Austin and Corpus Christi. The blue line represents the Retail-derived SF while the pink line represents the Intake-derived SF.

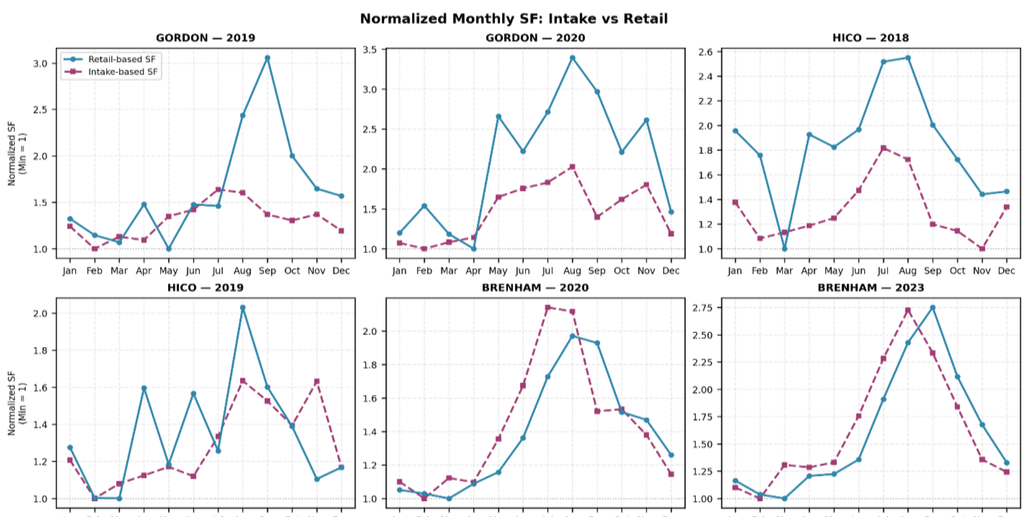

Figure 7. Normalized seasonal curves derived from the Intake and Retail methods plotted against each other for Gordon, Hico and Brenham plotted. The blue line represents the Retail-derived SF while the pink line represents the Intake-derived SF.

b. Intake Method vs Technical Note 12-01

To assess how well the Intake method reproduces the seasonal shape of monthly SF volumes, we compared normalized intake-derived curves against the Technical Note 12-01 study benchmark for systems with overlapping data. Patterns are broadly consistent with those observed in the intake-retail comparison, reinforcing that the drivers of method agreement and divergence are structural rather than period-specific. As shown in **Figure 8**, summer peak agreement is strong across this group: El Paso and Arlington show timing agreement in nearly all Technical Note 12-01 (Phase 1) years, while Irving, Lubbock and Laredo show a few years of small to moderate timing disagreement. Amplitude differences are the more common source of divergence, though the direction varies by year, with intake running above Technical Note 12-01 (Phase 1) benchmark in some years and below it in others; while timing offsets are more limited and year-specific.

El Paso shows the closest overall agreement with a mean amplitude difference of 7.5% and consistent peak timing throughout. Laredo and Lubbock show moderate mean amplitude differences of 17% each, though with notable year-specific spikes: Laredo in 2006 and Lubbock in 2007 where the amplitude gap widens considerably. Irving shows a progressive widening of the amplitude gap across 2006-2008, with the original study producing increasingly higher peaks. Arlington's mean Technical Note 12-01 (Phase 1) amplitude difference is elevated by the large 2004 anomaly; in the remaining Technical Note 12-01 (Phase 1 years), differences are moderate. Among the systems shown, 2007 tends to show the largest differences, though the seasonal shape remains broadly consistent throughout.

Houston and Corpus Christi show the same persistent amplitude divergence observed in the intake-retail comparison. Houston's intake-derived SF volumes consistently lower in magnitude than the Technical Note 12-01 study benchmark across all five Phase 1 years, with a mean amplitude difference of 26% and strong (80%) peak timing agreement. The fact that this pattern is present in both the 2004-2011 benchmark period and the post 2012 intake-retail comparison confirms that it reflects a persistent structural characteristic of these systems rather than an artifact of this study's methods or data quality issues introduced after 2011. Austin also shows intake consistently lower than the Technical Note 12-01 (Phase 1) years, with the largest gap in 2008, alongside one year of timing disagreement in 2005 (**Figure 9**).

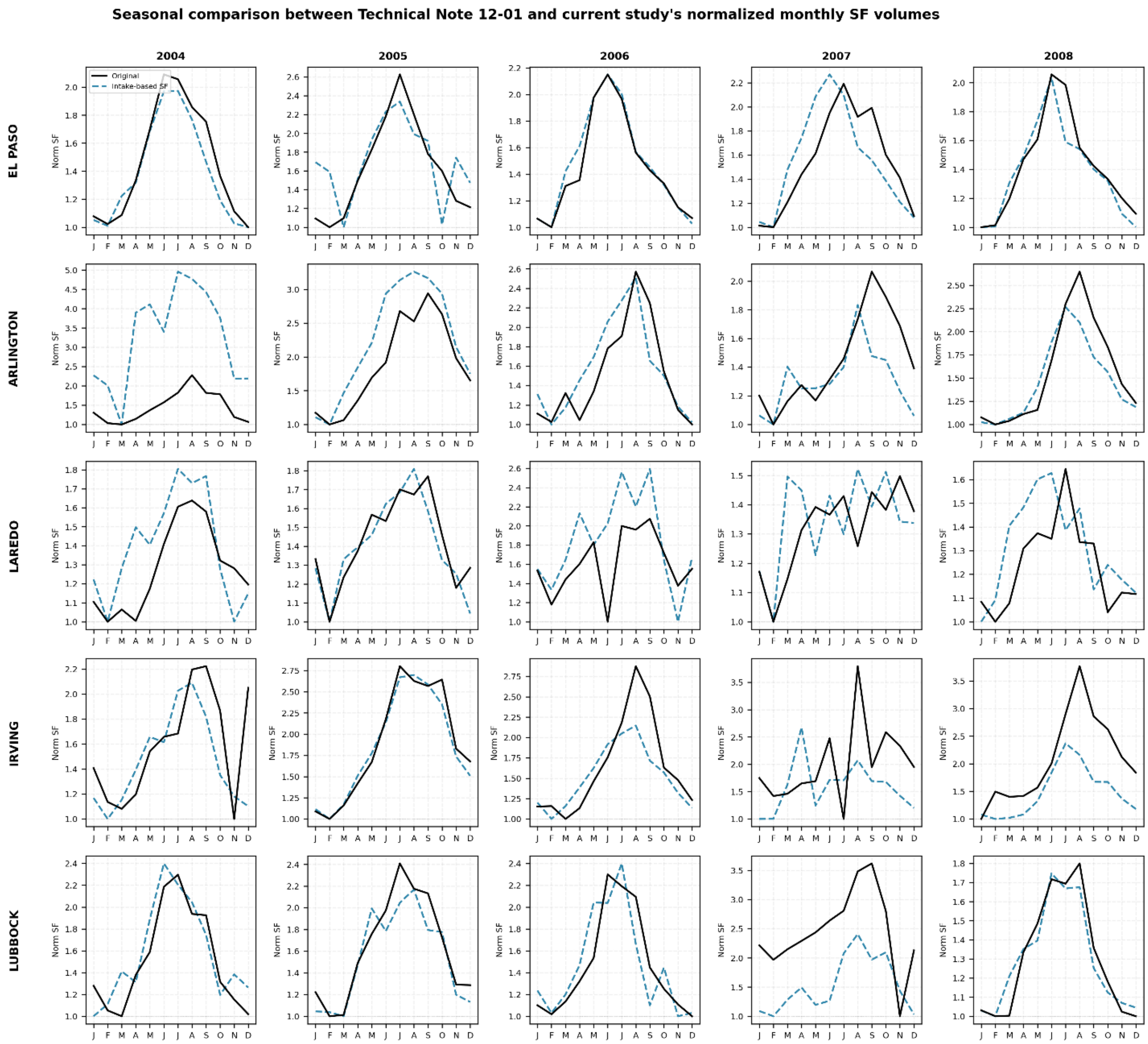

Figure 8. Subplots of select CWS showing the normalized SF curves derived from the intake proxy and the Technical Note 12-01 study's Phase 1 monthly SF, overlain against each other.

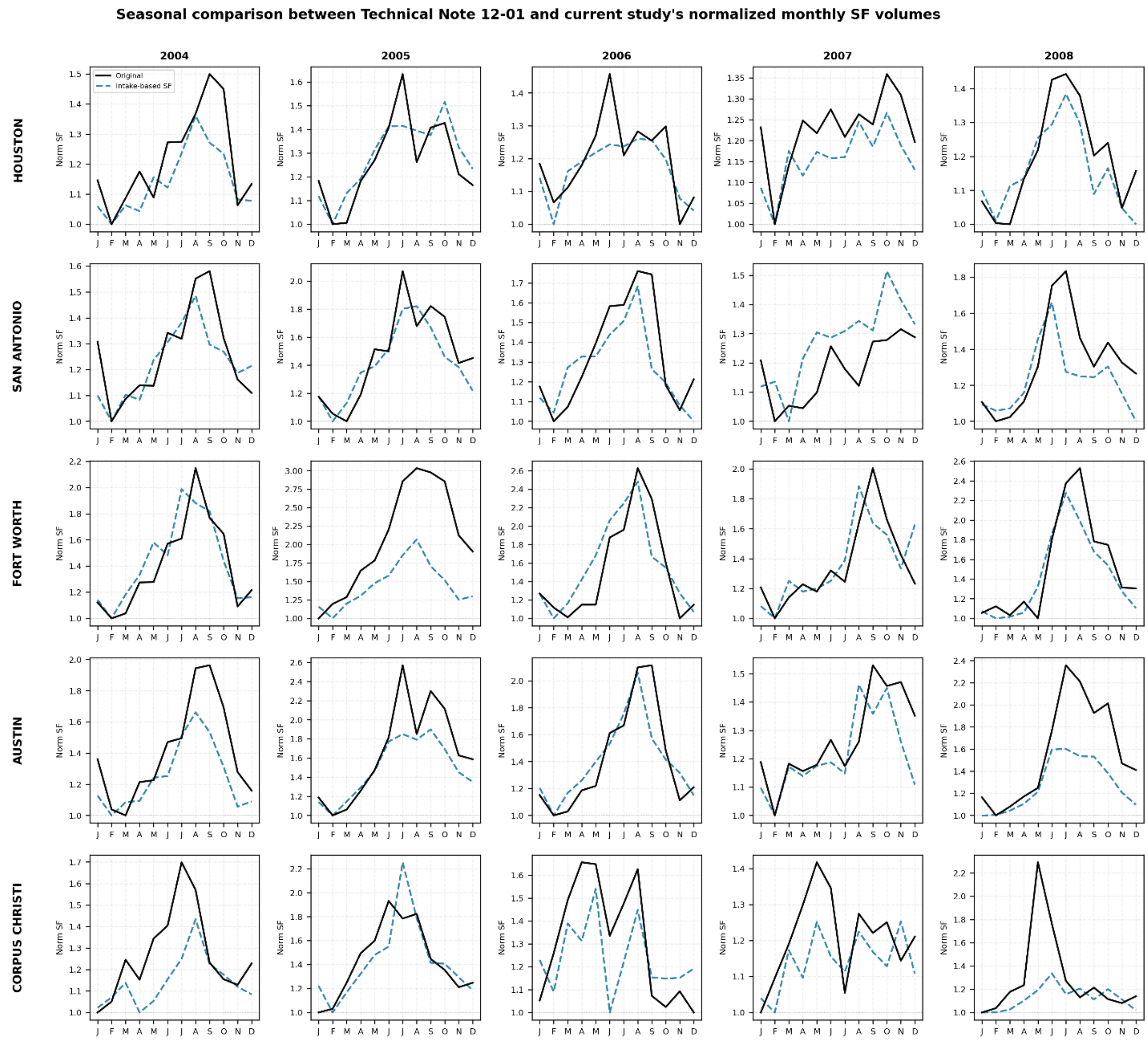

Figure 9. Subplots of select CWS showing the normalized SF curves derived from the Intake method and the Technical Note 12-01 study's Phase 1 monthly SF, overlain against each other.

Corpus Christi shows a more variable pattern, with a mean amplitude difference of 41% and intake running below the Technical Note 12-01 study in most years but above it in 2005, with the direction and magnitude of the difference shifting considerably from year to year. San Antonio and Fort Worth show broadly consistent seasonal shapes and perfect peak timing agreement across all Technical Note 12-01 (Phase 1) years, with intake generally running below the Technical Note 12-01 study (**Figure 9**). San Antonio shows a notable 2007 anomaly where intake swings substantially above the original, while Fort Worth shows its largest amplitude gap in 2005 also shown in **Figure 9**. For systems where the intake signal reliably tracks the original study benchmark in timing and amplitude, that agreement provides additional confidence that the Intake method captures true SF seasonal demand across the full study period.

For Technical Note 12-01 Phase 2 system-years (2009-2011), the dominant pattern across most systems is consistent seasonal shape with moderate amplitude differences, with intake generally running below the original study benchmark in most years. This is broadly similar to Technical Note 12-01 Phase 1 but with generally stronger timing agreement. El Paso and Amarillo show the closest overall agreement, with mean Technical Note 12-01 Phase 2 amplitude differences of 8% and 10% respectively and perfect timing throughout. Fort Worth, Katy, Lubbock, Arlington, and Austin all show broadly consistent seasonal shapes across most Technical Note 12-01 Phase 2 years, with intake running below Technical Note 12-01 in most years, and moderate amplitude differences (**Figures 10 and 11**). Although Arlington shows similarly consistent seasonal shapes, intake is consistently peaking slightly earlier than in Technical Note 12-01 (**Figure 10**) which is the same timing characteristic observed in the intake-retail comparison. Austin's timing agreement also improves to 100% (**Figure 11**) in Technical Note 12-01 Phase 2 compared to 80% in Technical Note 12-01 Phase 1, further supporting the consistency of the seasonal shape in more recent years.

Where amplitude differences persist in other systems, they are generally comparable to or smaller than in Technical Note 12-01 Phase 1. For instance, Houston's amplitude gap narrows from 26% in Technical Note 12-01 Phase 1 to 18% in Technical Note 12-01 Phase 2, with the two curves converging most closely in 2011 (**Figure 11**). Also, Laredo, Austin and San Antonio both show larger amplitude gaps in 2011, but these are isolated rather than persistent across the Technical Note 12-01 Phase 2 period because the gaps are smaller in 2009 and 2010 (**Figure 11**). Taken together, the stronger timing agreement and broadly consistent seasonal shapes observed across these large and customer-diverse systems in Technical Note 12-01 Phase 2 provide additional confidence in the Intake method's reliability in years closer to the current study period.

Furthermore, to better understand the customer composition driving these observed patterns, each CWS was characterized by its SF share of metered volume and intake metering rate. The resulting classification framework (*see* Appendix for summary in **Figure A5**) was developed as an analytical tool to interpret system composition using the underlying WUS data. This framework does not constitute a formal system classification or directly inform the method selection process of this study.

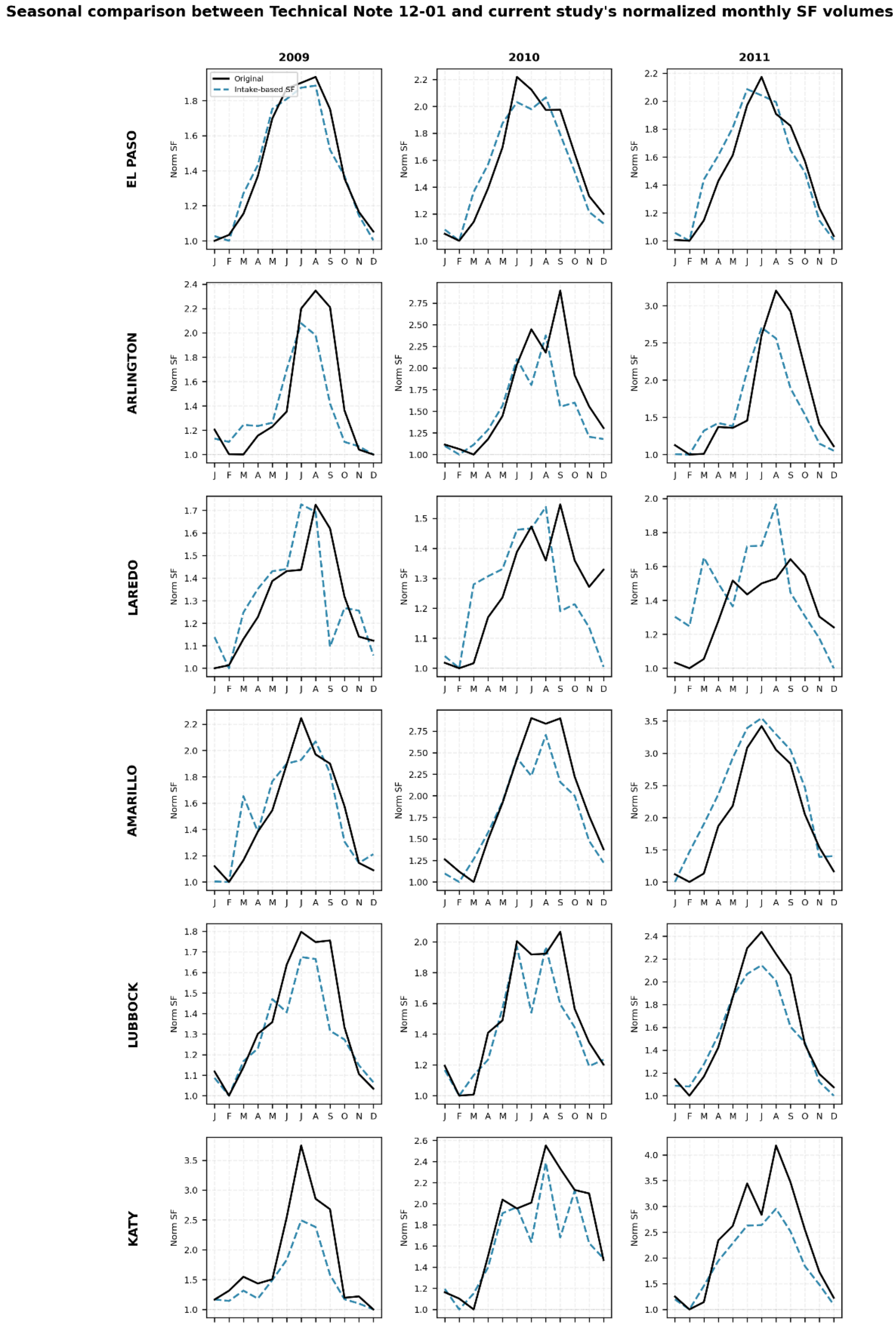

Figure 10. Subplots of select CWS showing the normalized SF curves derived from the Intake method and the Technical Note 12-01 study's Phase 2 monthly SF, overlain against each other.

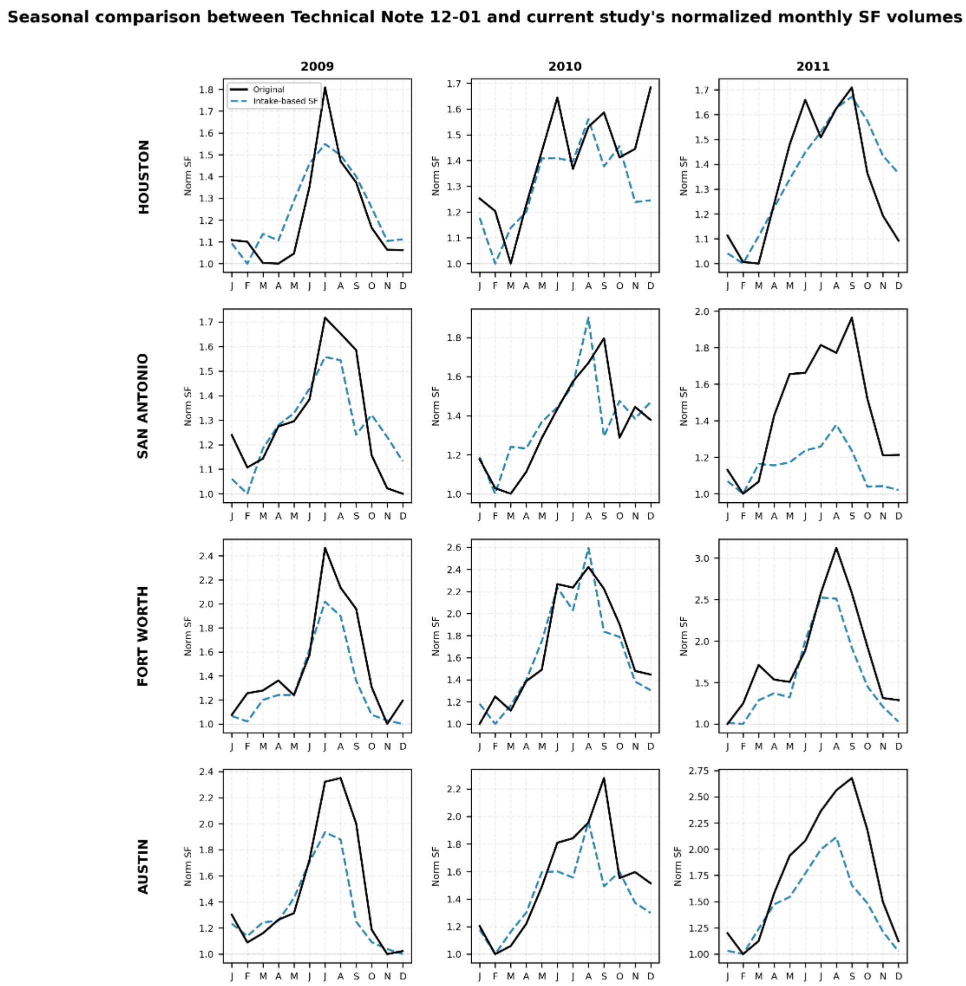

Figure 11. Subplots of select CWS showing the normalized SF curves derived from the Intake method and the Technical Note 12-01 study's Phase 2 monthly SF, overlain against each other.

4. Method Selection

Following the seasonal profile comparisons, either the Intake or Retail method was assigned to each CWS for the derivation of monthly SF estimates across the full 2012-2023 study period. The selection framework evaluates two tracks of evidence where available. Track 1 compares the amplitude and peak timing of intake-derived and retail-derived normalized seasonal curves for the 149 CWSs where both datasets are available. Track 2 compares the intake-derived curve against the original study benchmark for the 241 CWSs with overlapping 2004–2011 data. Amplitude difference is expressed as the percentage difference between the intake and comparison seasonal swings, where swing is the difference between the peak normalized value and the baseline of 1.0, and peak timing agreement is assessed at the season level, with peaks falling in the same season or within one month of each other considered agreeing. A single method was assigned per CWS across the full study period.

Across all 149 CWSs with Track 1 data, the system-level mean absolute amplitude difference has a median of 12%, with 91% of system-years showing peak timing agreement, indicating that the two methods produce broadly consistent monthly SF breakdowns for the large majority of CWSs where retail data are available. However, the distribution has a long right tail: the standard deviation of 29% reflects a subset of systems where intake-retail divergence is substantially larger than the central tendency, and it is these systems that the selection thresholds are designed to identify.

Retail is recommended where: (a) the mean absolute Track 1 amplitude difference exceeds 60% (near the 95^{th} percentile of the system-level distribution) regardless of timing, (b) amplitude differences exceed 30% and peak timing agreement falls below 60% of available years, or (c) where a CWS has a low SF share of metered volume and a low intake to metering ratio (conditions under which the Retail method is expected to provide a more reliable representation of SF seasonal demand). The Intake method is assigned to all remaining CWSs where these conditions are not met. Across the 253 CWSs with sufficient data, 239 were assigned the Intake method and 14 the Retail method. (*See* **Figure A6** in the Appendix for the full decision framework used to assign each system to either method).

5. Confidence Assessment

a. Method Confidence

While the validation established overall method performance across the study dataset, the reliability of the monthly SF breakdown varies from system to system depending on data availability, data quality, and the degree of agreement between the available validation signals. Method confidence was therefore assessed at the system level to reflect the degree of trust in each assigned method's monthly SF breakdowns based on the evidence available for that specific CWS.

For Intake-assigned systems, confidence is derived from Track 1 and Track 2 amplitude and timing agreement. The Track 2 system-level amplitude differences are wider on average than Track 1, with a median of 32% and 75th percentile at 44%, reflecting both the longer time horizon and the structural differences between the intake proxy and the directly reported monthly SF volumes in the Technical Note 12-01 study. High confidence requires Track 1 amplitude differences at or below 15% and peak timing agreement in at least 60% of years, alongside Track 2 amplitude differences at or below 50% (near the 75th percentile of the Track 2 distribution). Moderate confidence applies where Track 1 amplitude differences remain below 30% with reasonable timing agreement. Low confidence is assigned where amplitude or timing divergence exceeds these thresholds, or where more than 30% of a system's years are flagged for data quality concerns.

For Retail-assigned systems, confidence is assessed on the internal consistency of the retail data itself: the number of clean years available, the stability of seasonal amplitude across years, and the consistency of peak timing, since Track 1 agreement cannot serve as a validation signal for systems where that divergence drove the Retail recommendation. Across all CWSs with sufficient data, 102 were assigned High confidence, 110 Moderate, and 41 Low confidence.

b. Outdoor Use Confidence

While method confidence reflects trust in the monthly SF breakdown, it does not directly assess whether the minimum month (the foundation of the indoor/outdoor split under the minimum-month method) is reliably identified for each system and year. Outdoor use confidence was therefore assessed separately at the system-year level to reflect the degree of trust in the indoor/outdoor split itself. The assessment follows the same Track 1 and Track 2 framework used for method confidence, but is applied to trough month agreement rather than peak month. A system-level trough agreement rate is computed as the proportion of clean years where the minimum month agrees between methods, with Track 1 preferred where available and Track 2 used as a fallback. Systems with a trough agreement rate at or above 80% are rated High outdoor use confidence, meaning that the indoor baseline is considered reliably established. Those between 60% and 79% are rated Moderate, and those below 60% or with no validation data are rated Low. Across all CWSs, 164 systems were rated High outdoor use confidence, 57 Moderate, and 32 Low. A complete list of method and outdoor use confidence for each CWS is provided in **Table A2** in the Appendix.

6. Climate Driver Analysis

To characterize the relationship between SF residential outdoor water use and prevailing climate conditions, Pearson correlation coefficients were computed for both temperature and precipitation for each CWS with sufficient data across the 2012-2023 study period. This analysis assesses climate sensitivity at the system level and is intended to provide directional insight into which systems exhibit stronger or weaker outdoor water use responses to climate driver variability. It is not a predictive or causal model of SF residential outdoor water use and demand. The monthly SF volumes used in the correlation analysis correspond to the method-assigned estimates described above.

The Pearson correlation coefficient measures the strength and direction of the linear relationship between monthly SF residential water use and each climate driver by evaluating how consistently the two move together across all months in the study period. A coefficient near +1 indicates that months with higher temperatures consistently coincide with higher SF residential water use across the record (i.e., positive correlation). A coefficient near -1 indicates that months with higher precipitation consistently coincide with lower SF residential water use (i.e., negative correlation). The coefficients were computed separately for temperature and precipitation against monthly SF residential use volumes for each CWS using the full twelve-month, twelve-year record. CWSs were included in the climate analysis if at least 24 consecutive SF residential monthly demand observations and climate values were available, ensuring a minimum basis for meaningful correlation estimation. Statistical significance was assessed at the conventional $p < 0.05$ threshold.

For temperature, monthly aggregates were constructed as the sum of daily mean temperature values across all calendar days within each month, where daily mean temperature was computed as the average of the coincident daily maximum and minimum values. The aggregate sum of daily mean temperature was preferred over a conventional monthly mean because it preserves sensitivity to within-month heat accumulation: months with sustained high temperatures produce larger sums than months with equivalent average temperatures but greater day-to-day variability, providing a more physically meaningful measure of the cumulative thermal load that drives irrigation demand. Monthly precipitation totals were used directly as the climate input for the precipitation correlation, as accumulated monthly rainfall is the physically appropriate aggregation for assessing the relationship between rainfall and residential irrigation behavior.

7. Assumptions and Limitations

The primary limitation of this study is inherent to its data foundation: the WUS is a self-reported instrument collected annually across hundreds of utilities over a 20-year period. The quality and completeness of reported data vary considerably across systems and years. Two distinct but related challenges emerge from this. The first is data availability. Monthly SF volumes were not collected through the WUS after 2008, necessitating the estimation methods developed in this study, and monthly retail sales data are unavailable for most systems before 2014. The second is reporting inconsistencies across both monthly and annual datasets.

The QA/QC procedures described in this report were designed to identify and correct these issues where the evidence supports a defensible correction. Where anomalies were ambiguous or insufficiently supported by surrounding data, values were deliberately left uncorrected to avoid manufacturing estimates. These residual inconsistencies propagate into monthly SF estimates, contributing to magnitude and timing divergences between methods, and ultimately into uncertainty in the derived outdoor use estimates.

Furthermore, both estimation methods make assumptions about the relationship between their input data and SF seasonal demand; that total system intake and monthly retail sales tracks SF seasonal water use patterns. These assumptions hold well for most systems, as demonstrated by the validation results, but are less reliable where non-SF customer demand is substantial or where a meaningful share of system intake is delivered to customers through non-metered pathways. The method selection framework and confidence ratings were developed to account for this uncertainty, but they do not eliminate it.

Validation of the estimation methods is also constrained by data availability. For the 2012-2023 study period, no directly reported monthly SF data exist and therefore it is not possible to evaluate estimation method accuracy. Alignment with the Technical Note 12-01 study results provides evidence of seasonal shape consistency but not a direct accuracy test. For the Retail method, no equivalent benchmark comparison is possible for any part of the study period and therefore performance can only be assessed indirectly by consistency with Intake method results. Additionally, a single method is assigned to each CWS across the full study period, meaning year-specific variation in method performance is not captured.

Finally, the minimum-month method assumes that the lowest monthly SF volume in a year represents baseline indoor demand, an assumption the Technical Note 12-01 study also noted as a simplification. This is particularly relevant for systems with low seasonal amplitude where the distinction between indoor and outdoor demand is less pronounced and where the minimum month may not reliably isolate true indoor consumption. Outdoor use confidence ratings address this uncertainty by assessing trough timing consistency across methods and the Technical Note 12-01 study benchmark, with thresholds established to be consistent with the peak timing thresholds used in method confidence. Systems where a consistent but potentially misleading minimum month arises from operational patterns, shared data characteristics, or low seasonal amplitude represent a residual source of uncertainty in the indoor/outdoor split that confidence ratings cannot fully capture.

RESULTS AND DISCUSSION

Outdoor and indoor SF residential water use estimates are derived for 253 CWSs across the 2012-2023 study period using the minimum-month method. Outdoor use in gallons and as a percentage of total SF consumption is computed for each system and year. Per-household daily indoor and outdoor use, expressed in gallons per connection per day, is derived by dividing the respective annual volumes by the number of SF connections and dividing by 365 days.

System-level average outdoor use percentages are derived two ways: (1) by taking the mean of each system's annual outdoor use percentages across all available years, consistent with the approach used in the Technical Note 12-01 study, and (2) by computing the ratio of average outdoor use volume to average total SF volume. Unlike the mean of annual percentages, which treats each year equally regardless of total SF volume, the second approach weights years with higher total volumes more heavily. The two approaches produce similar results for most systems but slightly differ for others. The outdoor use percentages reported here (**Table 1**, **Figure 12**) are generated using the second approach.

Table 1: Average SF residential outdoor water use by CWS for the 2012-2023 period.

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
AMARILLO MUNICIPAL WATER SYSTEM	6,621,503,240	4,055,732,697	2,565,770,543	39
AQUA WSC	1,911,508,163	1,436,062,884	475,445,280	25
BASTROP COUNTY WCID 2	115,520,159	76,407,725	39,112,434	34
BORDEN COUNTY WATER SYSTEM	8,111,008	4,729,332	3,381,675	42
BORGER MUNICIPAL WATER SYSTEM	520,368,167	366,509,430	153,858,737	30
CITY OF ALBANY	64,076,000	43,664,813	20,411,187	32
CITY OF ALLEN	3,285,432,782	1,934,809,858	1,350,622,924	41
CITY OF ALVARADO	86,330,728	66,671,642	19,659,086	23
CITY OF ALVIN	388,902,148	329,441,966	59,460,182	15
CITY OF ANAHUAC	36,519,805	30,144,774	6,375,031	17
CITY OF ANDREWS	547,069,500	318,068,028	229,001,472	42

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
CITY OF ARLINGTON	9,412,759,417	6,471,419,753	2,941,339,664	31
CITY OF ASPERMONT	40,511,609	28,040,159	12,471,451	31
CITY OF ATHENS	309,742,517	204,581,121	105,161,395	34
CITY OF AUBREY	66,237,168	49,112,836	17,124,331	26
CITY OF AUSTIN-GENERAL DISTRIBUTION SYSTEM	15,035,144,017	11,745,818,356	3,289,325,661	22
CITY OF BAIRD	55,907,928	34,621,271	21,286,656	38
CITY OF BALLINGER	97,586,720	76,154,729	21,431,991	22
CITY OF BAY CITY	364,616,952	298,363,425	66,253,527	18
CITY OF BECKVILLE	17,660,722	12,187,837	5,472,885	31
CITY OF BELLMEAD	213,280,750	163,786,622	49,494,128	23
CITY OF BELLS	31,433,848	23,504,100	7,929,747	25
CITY OF BELLVILLE	174,087,938	100,452,158	73,635,779	42
CITY OF BOERNE	393,609,966	276,031,538	117,578,428	30
CITY OF BONHAM	158,430,593	126,718,227	31,712,366	20
CITY OF BOVINA	62,261,485	34,537,290	27,724,195	45
CITY OF BRAZORIA	65,362,150	55,043,497	10,318,653	16
CITY OF BRECKENRIDGE	115,794,679	74,625,490	41,169,189	36
CITY OF BREMOND	23,447,583	16,114,989	7,332,595	31
CITY OF BRENHAM	398,991,758	273,001,304	125,990,454	32
CITY OF BRIDGE CITY	166,258,167	136,850,615	29,407,552	18
CITY OF BRIDGEPORT	120,466,650	89,241,156	31,225,494	26
CITY OF BRONTE	30,549,262	16,417,161	14,132,101	46
CITY OF BROWNFIELD	327,455,416	225,500,898	101,954,517	31
CITY OF BROWNSBORO	28,956,873	20,408,168	8,548,705	30
CITY OF BROWNWOOD	501,950,994	342,129,129	159,821,865	32
CITY OF BUDA	276,390,327	194,844,043	81,546,284	30
CITY OF BUFFALO	50,376,042	39,679,510	10,696,533	21
CITY OF BURKBURNETT	216,713,000	182,959,562	33,753,438	16
CITY OF CALLISBURG	39,461,335	28,087,272	11,374,063	29
CITY OF CANTON	109,484,914	77,689,422	31,795,492	29
CITY OF CANYON	433,391,583	237,042,724	196,348,860	45
CITY OF CARTHAGE	193,594,621	147,281,997	46,312,624	24
CITY OF CASTROVILLE	90,649,750	57,819,573	32,830,177	36
CITY OF CELESTE	16,222,568	11,797,298	4,425,270	27
CITY OF CHARLOTTE	100,352,534	72,593,301	27,759,233	28
CITY OF CHICO	22,891,883	18,348,872	4,543,012	20
CITY OF CIBOLO	446,369,735	294,755,735	151,614,000	34
CITY OF CISCO	69,920,115	45,303,931	24,616,184	35
CITY OF CLARENDON	41,681,083	28,188,038	13,493,046	32

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
CITY OF CLARKSVILLE	55,628,587	41,311,033	14,317,554	26
CITY OF COLEMAN	98,206,083	70,123,267	28,082,816	29
CITY OF COLLEGE STATION	2,214,199,750	1,428,076,396	786,123,354	36
CITY OF COMANCHE	71,581,473	54,737,708	16,843,765	24
CITY OF CONROE	1,535,237,855	1,069,011,658	466,226,197	30
CITY OF CONVERSE	463,060,116	376,001,902	87,058,214	19
CITY OF CORINTH	761,388,908	396,493,894	364,895,014	48
CITY OF CORPUS CHRISTI	5,923,613,376	5,041,092,779	882,520,597	15
CITY OF CORSICANA	515,126,000	375,482,938	139,643,062	27
CITY OF CROSBYTON	40,959,000	26,441,566	14,517,434	35
CITY OF CUMBY	23,967,445	15,417,840	8,549,605	36
CITY OF DAINGERFIELD	72,327,587	57,773,391	14,554,196	20
CITY OF DAISETTA	24,583,059	18,176,060	6,406,999	26
CITY OF DALLAS	24,877,302,225	17,340,608,373	7,536,693,851	30
CITY OF DARROUZETT	11,007,053	5,158,237	5,848,815	53
CITY OF DELL	14,049,360	10,726,281	3,323,079	24
CITY OF DENTON	3,074,514,830	2,071,832,888	1,002,681,942	33
CITY OF DENVER CITY	204,217,067	123,055,626	81,161,440	40
CITY OF DIMMITT	191,921,167	106,587,998	85,333,168	44
CITY OF DUNCANVILLE	999,331,000	735,694,877	263,636,123	26
CITY OF EARLY	64,871,260	49,004,783	15,866,478	24
CITY OF EARTH	41,039,967	21,454,658	19,585,309	48
CITY OF EDINBURG	2,224,111,872	1,842,852,076	381,259,797	17
CITY OF EDNA	127,419,154	89,914,985	37,504,169	29
CITY OF EMHOUSE	19,531,976	14,415,072	5,116,904	26
CITY OF ENNIS	427,407,833	336,172,568	91,235,265	21
CITY OF FAIRFIELD	88,211,808	68,476,085	19,735,723	22
CITY OF FALFURRIAS-ENCINO WATER SYSTEM	7,501,582	4,498,574	3,003,008	40
CITY OF FALFURRIAS-UTILITY BOARD	195,901,617	146,790,406	49,111,211	25
CITY OF FARMERS BRANCH	758,855,917	491,427,824	267,428,093	35
CITY OF FERRIS	74,821,764	52,078,815	22,742,948	30
CITY OF FLATONIA	42,878,917	31,947,636	10,931,281	25
CITY OF FORT WORTH	19,610,186,810	13,268,273,938	6,341,912,872	32
CITY OF FRIENDSWOOD	1,299,048,083	851,281,004	447,767,080	34
CITY OF FRISCO	6,384,745,958	3,603,252,865	2,781,493,093	44
CITY OF FRITCH	186,817,405	113,336,974	73,480,430	39
CITY OF GALENA PARK	147,670,216	129,357,853	18,312,364	12
CITY OF GARLAND	5,190,613,133	3,547,414,154	1,643,198,979	32
CITY OF GIDDINGS	152,756,025	109,387,611	43,368,413	28

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
CITY OF GLADEWATER	163,411,733	130,154,790	33,256,942	20
CITY OF GOLDTHWAITE	57,163,175	29,115,963	28,047,212	49
CITY OF GORDON	13,438,205	6,994,395	6,443,809	48
CITY OF GRAHAM	386,483,829	254,213,568	132,270,261	34
CITY OF GRANBURY	317,176,618	222,179,396	94,997,223	30
CITY OF GRAND SALINE	65,967,161	57,374,071	8,593,091	13
CITY OF GRAPELAND	38,437,889	29,919,422	8,518,467	22
CITY OF GRAPEVINE	2,193,989,647	1,383,438,704	810,550,943	37
CITY OF GREENVILLE	592,883,699	414,693,827	178,189,872	30
CITY OF GUNTER	49,988,534	28,063,652	21,924,882	44
CITY OF HALLSVILLE	87,337,400	60,255,643	27,081,757	31
CITY OF HAMILTON	72,765,223	53,731,229	19,033,994	26
CITY OF HARKER HEIGHTS	1,154,024,785	669,037,211	484,987,574	42
CITY OF HEDLEY	5,658,186	3,719,001	1,939,184	34
CITY OF HEMPHILL	22,572,433	17,579,019	4,993,414	22
CITY OF HEMPSTEAD	132,941,341	98,018,293	34,923,048	26
CITY OF HICO	29,077,398	22,642,776	6,434,622	22
CITY OF HIGGINS	17,925,417	11,357,246	6,568,171	37
CITY OF HIGHLAND VILLAGE	820,687,933	375,592,567	445,095,366	54
CITY OF HOLLIDAY	36,829,167	26,877,619	9,951,547	27
CITY OF HONEY GROVE	34,670,834	24,725,786	9,945,049	29
CITY OF HOUSTON	23,129,599,872	19,297,193,083	3,832,406,789	17
CITY OF HOWE	49,013,730	40,154,911	8,858,819	18
CITY OF HUBBARD	39,910,189	28,574,430	11,335,759	28
CITY OF HUMBLE	268,787,662	208,226,786	60,560,877	23
CITY OF HUNTINGTON	45,587,318	38,647,349	6,939,969	15
CITY OF HURST	1,055,724,083	687,831,807	367,892,277	35
CITY OF HUXLEY	32,563,833	24,247,567	8,316,267	26
CITY OF INGLESIDE	172,159,892	130,631,451	41,528,440	24
CITY OF INGLESIDE ON THE BAY	18,410,792	11,479,416	6,931,375	38
CITY OF IOWA PARK	143,545,808	111,181,921	32,363,887	23
CITY OF IRAAN	55,353,917	33,022,136	22,331,781	40
CITY OF IRVING	4,037,566,750	2,817,436,717	1,220,130,033	30
CITY OF JACKSONVILLE	337,882,869	264,481,129	73,401,739	22
CITY OF JOAQUIN	24,907,817	18,562,758	6,345,059	25
CITY OF JOHNSON CITY	31,498,159	22,997,352	8,500,807	27
CITY OF JOSEPHINE	93,608,095	57,082,154	36,525,941	39
CITY OF KATY	687,412,167	400,360,827	287,051,339	42
CITY OF KERMIT	327,297,042	208,341,542	118,955,500	36
CITY OF KINGSVILLE	12,785,076	6,655,099	6,129,977	48

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
CITY OF KIRBYVILLE	40,319,318	33,388,204	6,931,113	17
CITY OF KOUNTZE	40,759,968	34,722,898	6,037,070	15
CITY OF LA PORTE	696,693,820	569,477,351	127,216,469	18
CITY OF LADONIA	12,741,775	6,833,917	5,907,858	46
CITY OF LAGO VISTA	295,879,382	210,650,925	85,228,457	29
CITY OF LAKE WORTH	131,127,154	92,012,105	39,115,049	30
CITY OF LAMPASAS	228,023,642	148,813,584	79,210,057	35
CITY OF LAREDO	7,011,291,667	5,476,937,086	1,534,354,581	22
CITY OF LEANDER	1,754,857,722	1,051,668,424	703,189,299	40
CITY OF LITTLEFIELD	167,926,942	115,019,286	52,907,656	32
CITY OF LIVERPOOL	11,992,880	6,201,536	5,791,344	48
CITY OF LOCKHART	292,460,333	238,724,362	53,735,971	18
CITY OF LONGVIEW	2,039,317,925	1,367,122,762	672,195,163	33
CITY OF LORENA	77,831,043	61,021,989	16,809,054	22
CITY OF LORENZO	31,994,128	19,686,270	12,307,859	38
CITY OF MADISONVILLE	115,028,797	91,559,558	23,469,239	20
CITY OF MALONE	4,977,996	3,184,691	1,793,305	36
CITY OF MANOR	212,048,667	163,669,388	48,379,279	23
CITY OF MARION	34,889,822	26,471,224	8,418,598	24
CITY OF MASON	111,213,223	65,064,715	46,148,508	41
CITY OF MEADOWS PLACE	128,203,917	90,285,775	37,918,142	30
CITY OF MELISSA-CITY WATER DEPARTMENT	320,226,013	191,153,210	129,072,803	40
CITY OF MELVIN	8,154,075	5,484,716	2,669,359	33
CITY OF MENARD	47,876,858	34,406,044	13,470,814	28
CITY OF MERIDIAN	85,219,486	70,007,095	15,212,391	18
CITY OF MESQUITE	2,643,770,108	1,930,508,930	713,261,179	27
CITY OF MEXIA	111,053,833	90,409,611	20,644,223	19
CITY OF MIDWAY	5,565,276	3,254,593	2,310,683	42
CITY OF MINERAL WELLS	318,056,227	260,156,493	57,899,734	18
CITY OF MOBEETIE	5,618,958	3,091,020	2,527,938	45
CITY OF MONAHANS	342,276,417	221,456,176	120,820,240	35
CITY OF MOODY	31,487,630	23,637,410	7,850,220	25
CITY OF MORTON	60,327,500	42,047,490	18,280,010	30
CITY OF MOUNT PLEASANT	450,397,993	355,133,330	95,264,664	21
CITY OF MOUNT VERNON	52,929,167	38,828,149	14,101,018	27
CITY OF MURPHY	861,058,758	507,558,936	353,499,822	41
CITY OF NAVASOTA	183,066,625	144,891,052	38,175,573	21
CITY OF NEEDVILLE	72,871,021	59,761,847	13,109,174	18
CITY OF NEW LONDON	72,350,025	55,110,766	17,239,259	24

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
CITY OF NEW WAVERLY	19,753,438	15,638,711	4,114,727	21
CITY OF NIXON	66,225,725	54,417,362	11,808,363	18
CITY OF NOCONA	85,563,671	61,394,795	24,168,875	28
CITY OF NORTH RICHLAND HILLS	2,011,985,346	1,265,541,840	746,443,507	37
CITY OF ODEM	104,277,457	80,585,689	23,691,768	23
CITY OF ODESSA	2,939,838,663	2,120,322,139	819,516,524	28
CITY OF OLNEY	80,581,443	60,711,495	19,869,948	25
CITY OF ORANGE	319,653,500	257,234,110	62,419,390	20
CITY OF ORANGE GROVE	62,117,829	39,384,652	22,733,176	37
CITY OF ORCHARD	13,635,481	8,807,845	4,827,636	35
CITY OF PARIS	439,947,823	326,828,935	113,118,888	26
CITY OF PASADENA	2,285,233,398	1,972,195,668	313,037,731	14
CITY OF PEARSALL	296,792,417	197,702,445	99,089,972	33
CITY OF PFLUGERVILLE	1,078,034,863	673,033,413	405,001,450	38
CITY OF PINELAND	19,284,651	15,142,921	4,141,730	21
CITY OF PLAINS	69,291,125	40,304,692	28,986,433	42
CITY OF POTEET	82,745,782	51,336,818	31,408,964	38
CITY OF QUANAH	48,313,938	36,484,151	11,829,786	24
CITY OF QUINLAN	30,766,841	22,672,555	8,094,286	26
CITY OF RICHMOND	333,860,592	227,986,692	105,873,900	32
CITY OF RIVER OAKS	164,236,408	117,588,107	46,648,301	28
CITY OF ROBINSON	461,453,155	312,513,229	148,939,926	32
CITY OF ROCKWALL	1,474,514,577	845,318,268	629,196,309	43
CITY OF ROSENBERG	601,038,424	457,533,483	143,504,941	24
CITY OF ROUND ROCK	3,208,462,688	2,104,202,846	1,104,259,842	34
CITY OF RULE	10,966,684	7,792,461	3,174,223	29
CITY OF SADLER	8,227,353	6,108,426	2,118,927	26
CITY OF SAINT JO	36,775,888	27,709,650	9,066,238	25
CITY OF SAN AUGUSTINE	43,855,083	36,320,640	7,534,443	17
CITY OF SAN MARCOS	781,981,636	672,234,821	109,746,815	14
CITY OF SCHERTZ	1,250,849,450	864,330,639	386,518,811	31
CITY OF SEALY	140,359,917	96,317,606	44,042,311	31
CITY OF SEMINOLE	348,536,809	188,294,738	160,242,071	46
CITY OF SHALLOWATER	91,465,542	58,219,990	33,245,551	36
CITY OF SHENANDOAH	107,713,500	71,540,007	36,173,493	34
CITY OF SHINER	79,401,675	57,417,249	21,984,426	28
CITY OF SMITHVILLE	119,069,375	84,863,896	34,205,479	29
CITY OF SOMERVILLE	42,791,580	32,588,979	10,202,601	24
CITY OF SONORA	110,350,218	85,340,810	25,009,407	23
CITY OF SPEARMAN	146,303,440	75,892,333	70,411,107	48

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
CITY OF STINNETT	66,029,833	42,873,228	23,156,605	35
CITY OF STOCKDALE	57,447,829	41,125,389	16,322,440	28
CITY OF SUGAR LAND	2,862,730,224	1,882,060,698	980,669,526	34
CITY OF SUNDOWN	56,456,333	31,948,108	24,508,226	43
CITY OF SUNRAY	67,677,500	35,853,361	31,824,139	47
CITY OF SWEETWATER	232,589,583	184,974,937	47,614,647	20
CITY OF TEAGUE	87,864,752	68,344,267	19,520,485	22
CITY OF TEMPLE	2,874,635,186	1,950,599,421	924,035,765	32
CITY OF TERRELL	304,984,111	236,553,239	68,430,872	22
CITY OF THORNDALE	30,273,250	19,606,193	10,667,057	35
CITY OF TIMPSON	27,368,208	22,537,053	4,831,156	18
CITY OF TIOGA	28,313,299	20,428,212	7,885,087	28
CITY OF TOLAR	22,899,667	16,633,993	6,265,673	27
CITY OF TOMBALL	299,926,055	197,693,545	102,232,510	34
CITY OF TROUP	38,832,393	31,650,650	7,181,744	18
CITY OF TYLER	3,360,744,250	2,238,855,404	1,121,888,846	33
CITY OF UNIVERSAL CITY	458,012,667	342,259,084	115,753,583	25
CITY OF UVALDE	501,137,383	368,104,893	133,032,491	27
CITY OF VICTORIA	1,708,318,500	1,332,412,064	375,906,436	22
CITY OF WACO	3,476,216,205	2,502,046,193	974,170,012	28
CITY OF WALLIS	28,173,468	22,052,818	6,120,650	22
CITY OF WASKOM	49,094,004	41,242,608	7,851,395	16
CITY OF WAXAHACHIE	840,926,969	619,779,808	221,147,161	26
CITY OF WEATHERFORD	747,242,612	470,780,012	276,462,600	37
CITY OF WEBSTER	44,930,327	36,098,344	8,831,983	20
CITY OF WELLINGTON	90,261,812	68,404,809	21,857,003	24
CITY OF WEST UNIVERSITY PLACE	689,658,653	482,483,939	207,174,715	30
CITY OF WHARTON	190,294,392	159,929,764	30,364,628	16
CITY OF WHITESBORO	81,329,092	60,642,940	20,686,152	25
CITY OF WICHITA FALLS	1,978,837,183	1,452,403,913	526,433,270	27
CITY OF WILSON	12,281,216	8,348,701	3,932,515	32
CITY OF WOODVILLE	55,508,377	47,918,979	7,589,398	14
CITY OF WOODWAY	570,277,796	330,248,907	240,028,889	42
CITY OF WYLIE	1,046,994,750	675,752,138	371,242,612	35
DALHART MUNICIPAL WATER SYSTEM	371,572,139	193,394,019	178,178,120	48
EL PASO WATER UTILITIES PUBLIC SERVICE B	17,894,279,156	12,253,340,487	5,640,938,669	32
LINDALE RURAL WSC	269,213,795	187,211,766	82,002,029	30
LUBBOCK PUBLIC WATER SYSTEM	6,294,506,783	4,675,650,785	1,618,855,998	26
NEW BRAUNFELS UTILITIES	2,269,045,540	1,612,684,836	656,360,704	29

WUS Survey Name	Total Use (Gallons)	Indoor Use (Gallons)	Outdoor Use (Gallons)	Outdoor Use Percent
PLAINVIEW MUNICIPAL WATER SYSTEM	571,363,408	394,591,767	176,771,642	31
RICHLAND SUD	115,941,878	82,930,284	33,011,593	28
SAN ANTONIO WATER SYSTEM	36,398,244,546	28,753,709,060	7,644,535,487	21
TOWN OF FLOWER MOUND	3,612,647,796	1,766,413,954	1,846,233,842	51
TOWN OF HIGHLAND PARK	856,858,167	467,561,278	389,296,889	45
VILLAGE OF SAN LEANNA	14,572,035	9,860,454	4,711,580	32

The weighted statewide average SF residential outdoor water use is 27%. This value is computed by weighting each system-year's outdoor use percentage by its corresponding SF connections count, consistent with the population-weighting approach applied in the Technical Note 12-01 study. 31% was reported by Technical Note 12-01 for the 2004-2008 period. The unweighted system average for this study is 30%, with a median of 28% and a standard deviation of 9%. SF residential outdoor water use percentages range from 12% in Galena Park to 54% in Highland Village. Average annual SF residential outdoor use volumes range from 1.8 million gallons in Malone to 7.6 billion gallons in San Antonio. The unweighted average per-household daily outdoor use across all study CWSs is 69 gallons per day with indoor use averaging 150 gallons per day; while weighing each system by its connection count results in 65 gallons per day outdoor and 163 gallons per day indoor. The extreme range of per-household daily use rates may reflect data quality issues in some systems and may not reflect genuine demand patterns.

A. System-Level Patterns

SF residential outdoor water use percentages vary considerably across CWSs, with regional differences (**Figure 12**) broadly consistent with the Technical Note 12-01 study. Systems in Southeast Texas consistently show the lowest outdoor use percentages across all study years: Galena Park (12%), Huntington (15%), Alvin (15%), Wharton (16%), Houston (17%) and Bridge City (18%), all fall well below the statewide average and are consistently low across the full study period. In contrast, systems in drier inland regions show persistently high outdoor use across all study years: Highland Village (54%), Flower Mound (51%), and Corinth (48%), all in the Dallas-Fort Worth metropolitan area, maintain average outdoor use percentages with annual estimates consistently in the 38-64% range across the full study period.

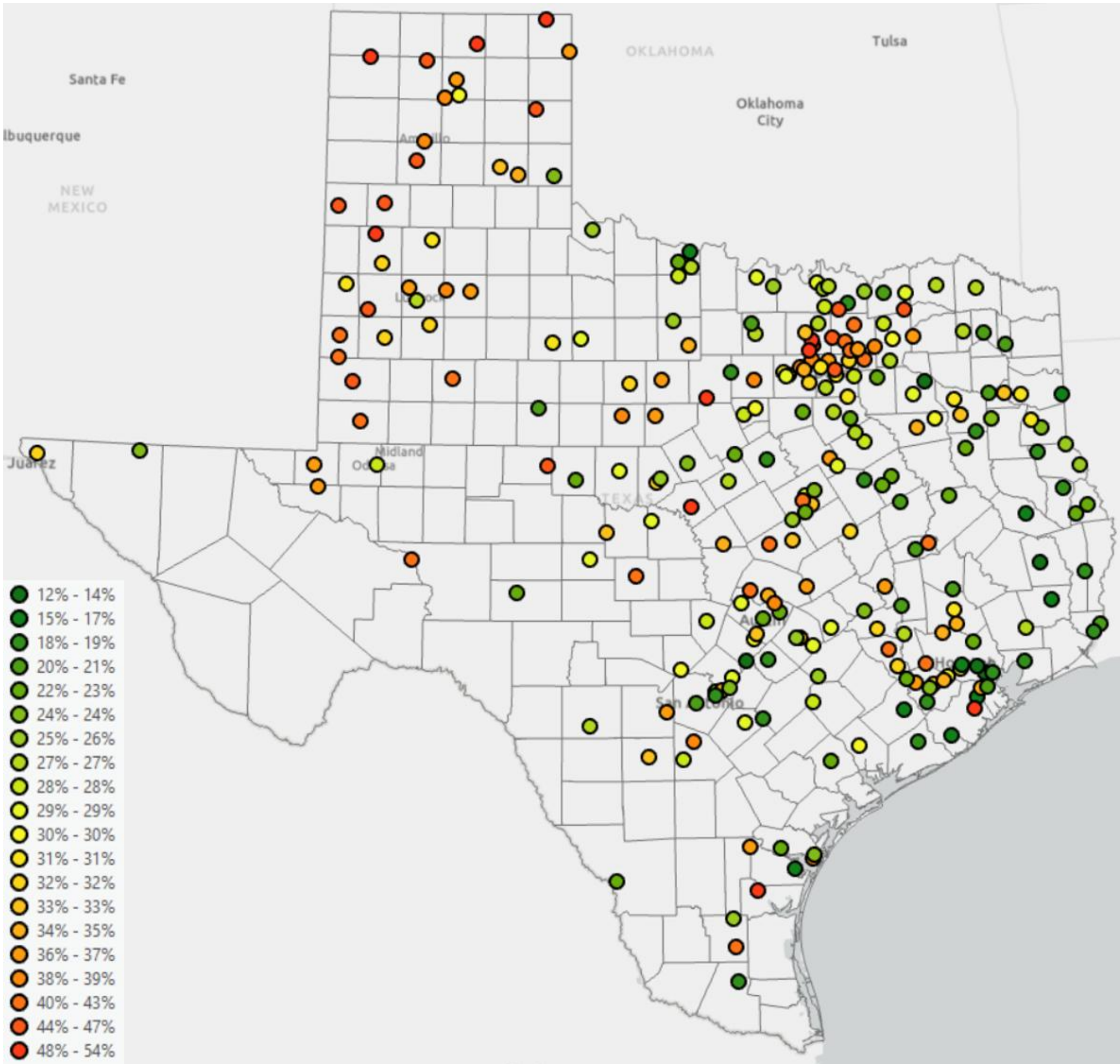

Figure 12. Weighted average SF residential outdoor water use by CWS for the 2012-2023 study period.

Systems such as Galena Park, Huntington, Alvin, and Waskom show low SF residential outdoor water use consistent with the Technical Note 12-01 study, suggesting their low estimates reflect persistent characteristics of those communities (**Figure 13**). Houston (17%) and Corpus Christi (15%), despite their system size, are among the lowest outdoor use systems in the dataset. Both CWSs use retail SF as the monthly seasonal curve yet show consistently low and declining outdoor use relative to the Technical Note 12-01 study. Houston shows a modest and stable decline (17% vs 20%) and Corpus Christi declines more substantially (15% vs 26%). Corpus Christi also shows greater year-to-year variability, ranging from 8% in 2020 to 24% in 2015, suggesting that the magnitude of the decline may be partly influenced by variability in the retail data used to derive the monthly SF seasonal curve.

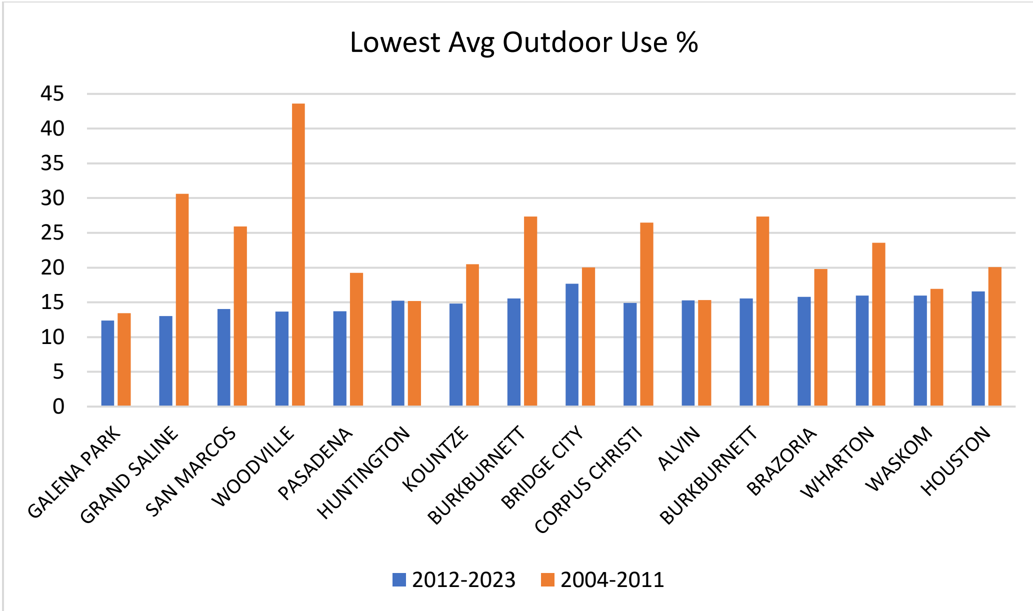

Figure 13. 16 CWS with the lowest outdoor use in the current study period compared to Technical Note 12-01 (Phase 1).

Interestingly, several systems show significantly lower outdoor use compared to the Technical Note 12-01 study (**Figure 14**) across the full study period: Lorena (21% vs 41%), San Marcos (13% vs 26%), Woodway (42% vs 62%), Irving (30% vs 45%), and Austin (22% vs 33%) all show consistent declines across all available study years.

Approximately 55 CWSs present high SF residential outdoor water use with low year-to-year variability that closely tracks the Technical Note 12-01 study estimates. Highland Village (54% vs 51%), Flower Mound (51% vs 50%), Corinth (48% vs 47%), and Highland Park (45% vs 45%) are notable examples, suggesting these communities have maintained persistently high outdoor use across both study periods. Gunter (41% vs 33%) and Baird (39% vs 28%) present notably higher outdoor use than the Technical Note 12-01 study. The increase may be an artifact of the difference in estimation methods, or it may be linked to urban/suburban expansion of residential lots into previously undeveloped land.

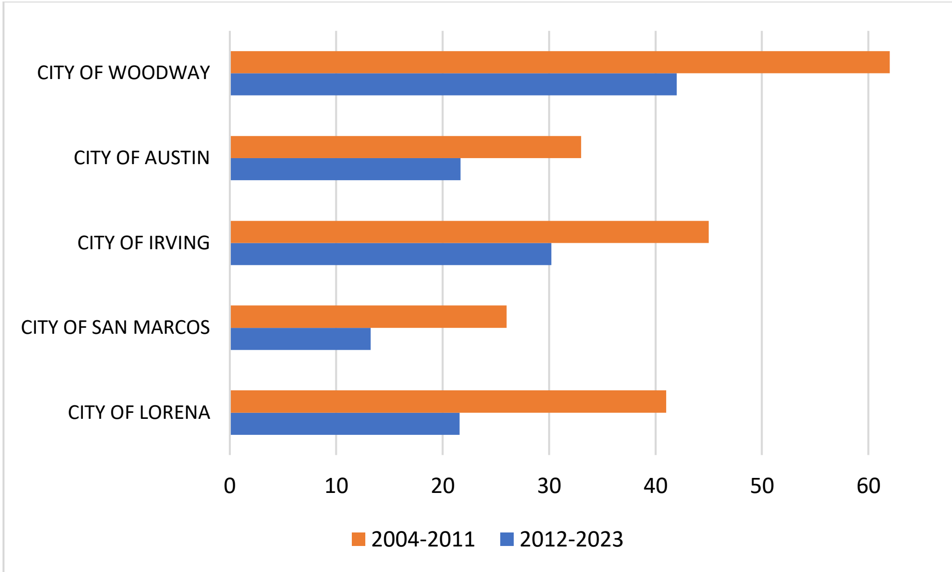

Figure 14. Select declines in outdoor use from Technical Note 12-01 study years to current study years.

The observed declines in systems such as San Marcos (14% vs. 26%) are consistent with a broad statewide shift toward more rigorous municipal water management and standardized conservation reporting that has been documented since the Technical Note 12-01 study period. In these cases, the significant reduction in SF residential outdoor water use may reflect the impact of sustained, high-level drought response measures and implementation of Best Management Practices that have increased by 36% statewide between 2015 and 2019 (*SWP22-Water-For-Texas*, n.d.). Conversely, persistently high SF residential outdoor water use in several north Texas systems may suggest that in high-growth, high-wealth areas, structural drivers such as large irrigated parcel sizes and established two-day-per-week watering schedules may create a "demand floor" that remains resilient to conservation efforts (Region C Water Planning Group, 2021).

B. Interannual Variability in Outdoor Use

The weighted statewide average outdoor use percentage shows pronounced year-to-year variation over the study period (**Figure 15**) and reflects the influence of drought and post-drought cycles on SF residential outdoor water demand. The 2012 average of 32% is the highest of the study period, consistent with the exceptional drought conditions that persisted across much of Texas from 2011 into 2015. This is consistent with the Technical Note 12-01 study (Phase 2) findings, which noted elevated outdoor use during the 2011 drought for the 17-city subset. The statewide average declined somewhat as drought conditions persisted through 2013-2014 before rising again to 30% in 2015.

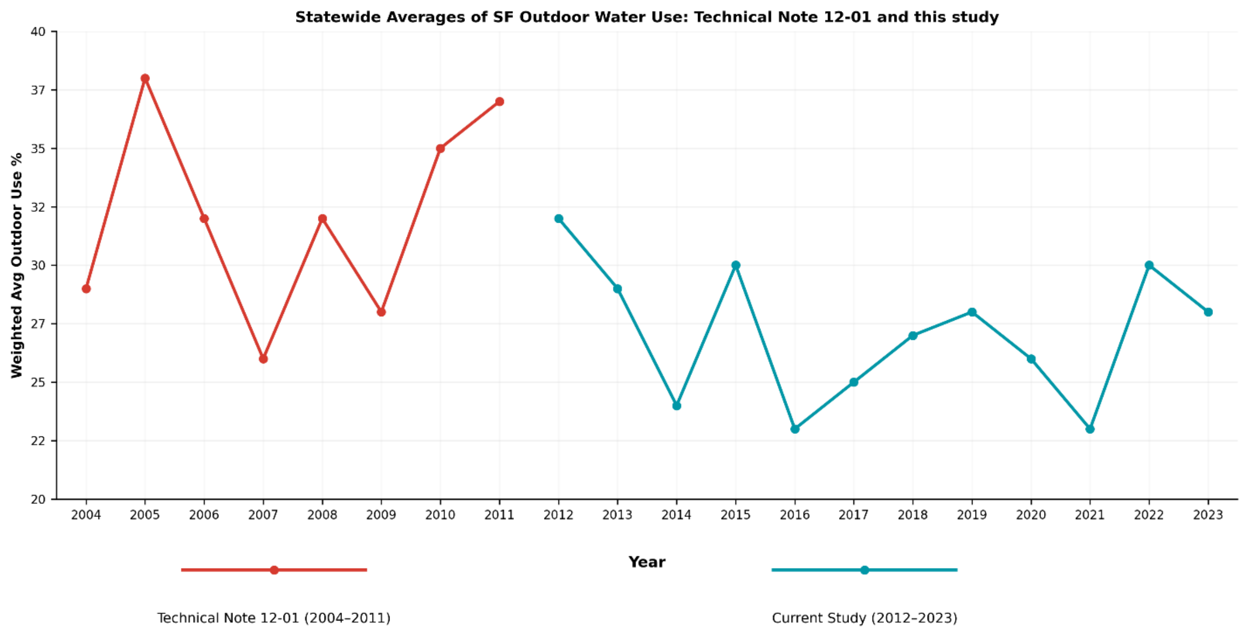

Figure 15. Weighted statewide average SF residential outdoor water use characterized by the Technical Note 12-01 study and this study over time.

2015 is one of the wettest years on record for Texas. The elevated SF residential outdoor water use seen here in 2015 (the second highest year of the study period) likely reflects the fact that while rainfall improved across much of the state by year's end, much of 2015 remained dry as Texas transitioned out of the multi-year drought. Additionally, SF residential irrigation habits established in drought years may not have adjusted immediately when rainfall returned. Similarly, billing records from late 2014 drought conditions may have also been carried forward into early 2015 reporting cycles. The sharp drop to 23% in 2016 (the study-period low alongside 2021) reflects the full effect of above-normal rainfall after a complete year of improved moisture conditions. By this point both the physical landscape deficit and established SF residential irrigation patterns had time to respond. The pattern from 2012 through 2016 therefore captures not just the drought itself but also the lag between improving climate conditions and the adjustment of SF residential outdoor water demand.

Following the 2016 low, the statewide average stabilizes in the 25-28% range through 2017-2020, suggesting that SF residential outdoor water use may have settled at a structurally lower level than the Technical Note 12-01 study period, even in non-drought years. A return to 30% in 2022 corresponds to renewed drought conditions that year, followed by 28% in 2023 as conditions moderated. This post-2016 stabilization, punctuated by drought-driven spikes in 2015 and 2022 is consistent with the broader statewide trend of declining outdoor use documented in the system-level patterns discussion.

Also notable is the 2021 outdoor use of 23%, which reflects the possible influence of Winter Storm Uri rather than a genuine reduction in outdoor demand. The storm caused water infrastructure failures and water loss across Texas, likely inflating February 2021 SF volumes which were on average 22% higher than typical for that month. This inflated total annual SF volumes, while concurrently January became the minimum month for 41% of systems compared to 5-11% in other years, setting a lower indoor baseline than typical. The combined effect of an inflated annual total and a depressed indoor baseline compressed the outdoor use percentage as a share of total annual SF, producing an artificially low statewide estimate for that year.

C. Outdoor Use Results vs Technical Note 12-01

A direct comparison of system-level average outdoor use percentages between the current and Technical Note 12-01 study is presented in **Figure 16** with each point representing one CWS appearing in both studies. A full system-by-system comparison of outdoor use volumes and percentages between the two studies is provided in **Table A2** (Appendix).

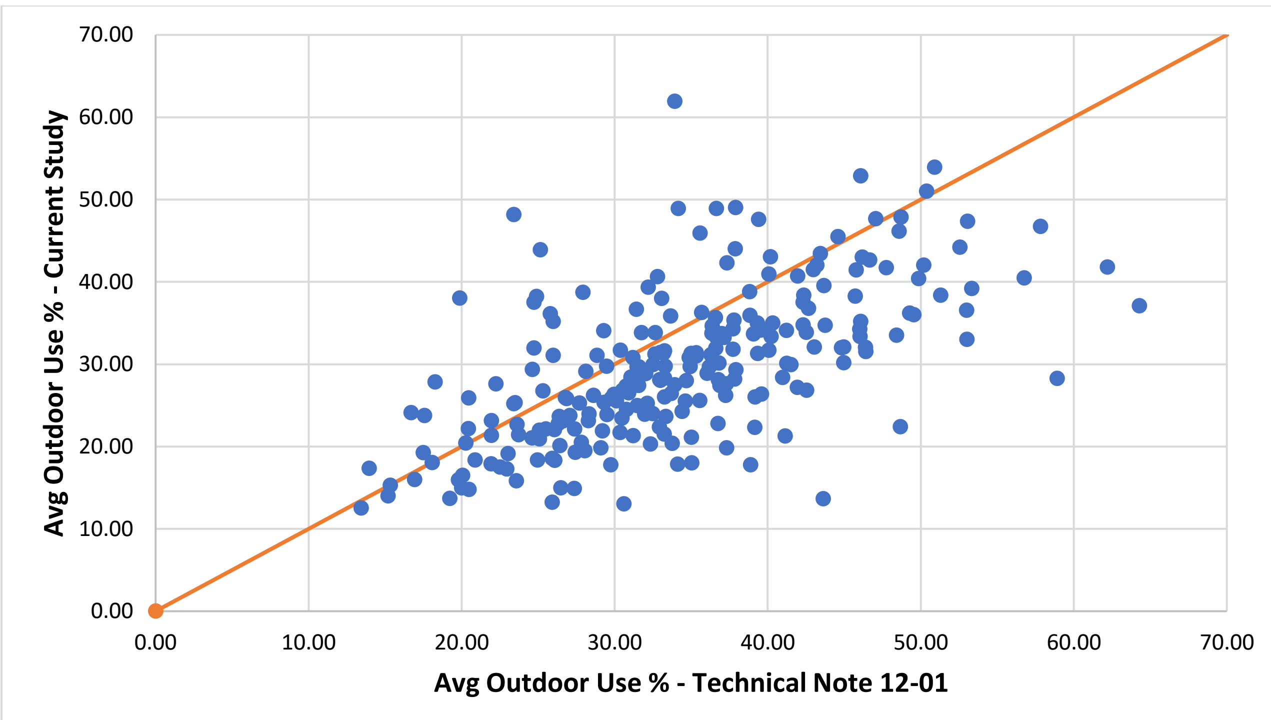

Figure 16. Scatter plot showing the relative deviation of average SF residential outdoor water use percentages from this study to the Technical Note 12-01 study. The diagonal line indicates exact agreement between the two studies: points falling on the line indicate no change in outdoor use between the two studies and points further from the diagonal in either direction reflect larger differences between the two studies. Points above the line indicate higher outdoor use in the current study, and points below the line indicate lower outdoor use.

The majority of systems fall below the diagonal: 188 of 241 systems show lower outdoor use estimates in the current study than in the Technical Note 12-01 study, with a mean difference of -5% and 59 systems showing differences exceeding 10% in either direction. The differences between the two studies do not necessarily indicate that one overestimated or the other underestimated outdoor water use. The two studies cover different time periods; the Technical Note 12-01 study reflects 2004-2008 conditions while the current study covers 2012-2023.

Moreover, methodological differences between the two studies are expected to play a role, as the current study derives monthly SF distributions through proxy methods rather than directly reported monthly volumes, introducing estimation uncertainty that varies by system. That said, the overall downward shift observed across the majority of systems is consistent with the broader patterns discussed above; including statewide expansion of conservation programs, improvements in irrigation technology, and behavioral shifts documented in both academic literature and state water planning. This suggests that at least part of the observed decline reflects genuine changes in SF residential outdoor water use behavior occurring since the Technical Note 12-01 study. Systems showing the largest increases relative to the Technical Note 12-01 study tend to cluster in high-growth areas where demographic and land use shifts may have driven structural increases in outdoor demand.

Systems where intake estimation errors remained high despite corrections, such as Nocona (-31%), Teague (-26%) and Mineral Wells (-21%) reflect some of the largest differences from the Technical Note 12-01 study. Where these estimation errors could not be fully resolved, the monthly SF distributions derived from intake remain less reliable and the resulting outdoor use differences relative to the Technical Note 12-01 study are likely a result of residual uncertainty in the underlying monthly SF breakdown rather than a genuine difference in outdoor use. Similarly, Woodville, Howe and Mount Pleasant which show large apparent declines from the Technical Note 12-01 study, present low confidence in the indoor/outdoor split for this study. This is driven by inconsistent minimum month identification across available validation years, meaning the indoor/outdoor split itself is uncertain for those systems independent of the monthly SF breakdown quality.

Beyond the systems discussed above, eleven systems exceed two standard deviations above the statewide system average. Most, including Highland Village (54%), Flower Mound (51%), Corinth (48%), and Dalhart (47%), carry high confidence in both the methodology and outdoor use split, indicating their high estimates are supported. A few – Darrouzett (53%), Goldthwaite (49%) and Kingsville (48%) – present low method confidence, meaning their monthly SF distributions carry higher uncertainty. Of these, Darrouzett retains high outdoor use confidence, indicating that the trough timing is consistent across available validation years and the indoor baseline is reliably identified. This lends some confidence to the outdoor use percentage, even though the monthly SF distribution carries higher uncertainty. Among retail-assigned systems, Grand Saline, Kingsville, Goldthwaite, and Meridian are based on five or fewer years of data, providing an insufficient basis for stable system-level estimates regardless of the method applied. Despite the system-level averages reported, 115 of 253 systems show at least one year where SF residential outdoor use deviates substantially from their own typical range. In 113 of those cases this is limited to a single year, suggesting these are isolated anomalies rather than persistent patterns and they do not overly impact system-level averages.

D. Climate and Outdoor Use Relationships

Monthly SF residential water use across the study CWSs shows a predominantly positive and statistically significant relationship with temperature. 232 systems (92%) exhibit significant positive Pearson correlations between monthly SF volumes and the monthly aggregate of daily mean temperature. The mean system-level temperature correlation is 0.54, ranging from −0.09 to 0.92 (**Figure 17**), reflecting substantial variation in climate sensitivity across the dataset. By contrast, the precipitation correlation signal (**Figure 18**) is substantially weaker. Only 89 systems (35%) show statistically significant precipitation correlations with a mean near zero (-0.06). (*See* **Table A3** in Appendix for system-specific correlation results.)

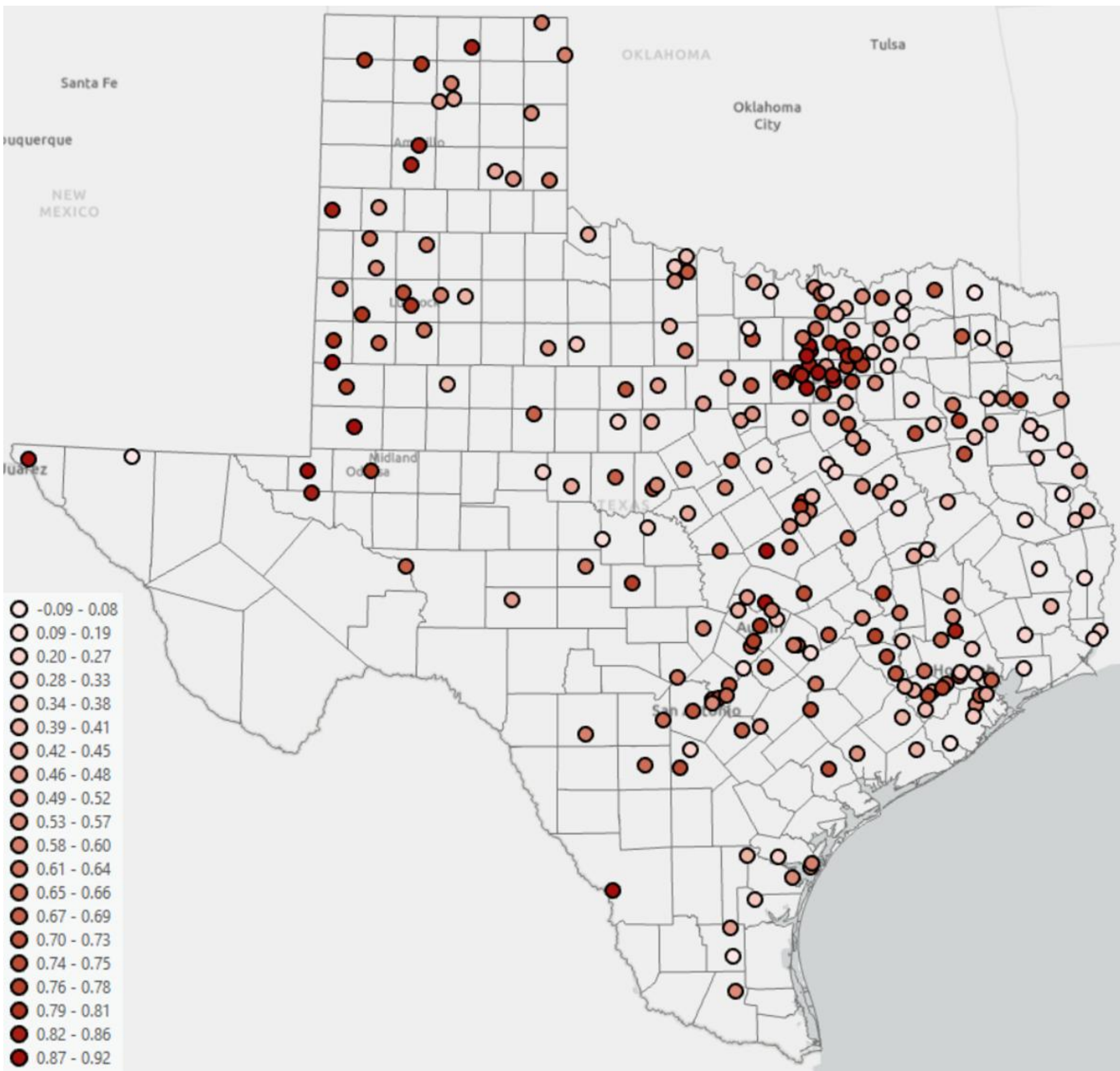

Figure 17. Pearson correlation coefficients for monthly SF residential water use and temperature by CWS for the 2012-2023 study period. Deeper colors indicate a stronger correlation.

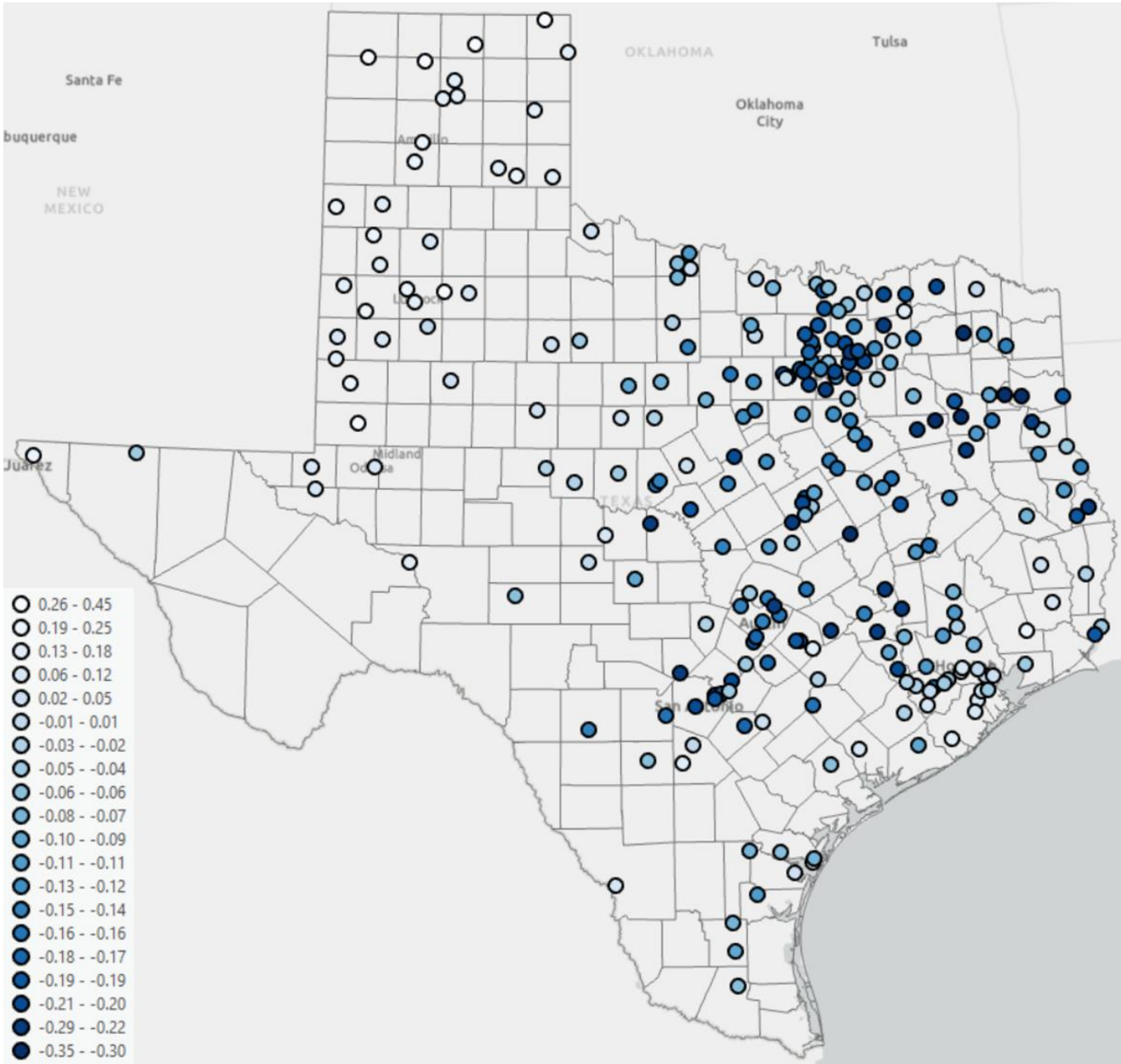

Figure 18. Pearson correlation coefficients for monthly SF residential water use and precipitation by CWS for the 2012-2023 study period. Deeper colors indicate a stronger correlation.

The disparity between the temperature and precipitation signal correlations is a notable finding. If outdoor use responded primarily to landscape water demand, temperature and precipitation might be expected to exert opposing influences of comparable strength, with higher temperatures increasing demand and rainfall suppressing it. Instead, the weak mean precipitation correlation (≈ -0.06) alongside a much stronger mean temperature correlation (≈ 0.54) indicates that, at the monthly scale, outdoor water use tracks seasonal temperature patterns more consistently than it does variability in rainfall. This suggests that SF residential irrigation practices are more closely aligned with seasonal temperature patterns than with precipitation variability.

CWSs with the strongest temperature correlations are predominantly systems with high outdoor use percentages located in arid to semi-arid climates: El Paso (r = 0.92), Andrews (r = 0.91), Highland Village (r = 0.90), Corinth (r = 0.89), Flower Mound (r = 0.89), and Arlington (r = 0.87). In contrast, weak or non-significant temperature correlations are concentrated in south and east Texas, including CWS such as San Augustine (r = -0.04), Brazoria (r = 0.06), Huntington (r = 0.15) and Bridge City (r = 0.16). These systems receive substantially higher annual precipitation; Bridge City for example averages over 63 inches per year with peak precipitation occurring in August (also coinciding with peak temperatures) and exhibits relatively low outdoor water use throughout the year. In these cases, the seasonal outdoor signal is less obvious in the aggregate monthly water demand series. This does not imply the absence of outdoor water use, but rather reflects its smaller contribution relative to the more stable indoor component, which dampens the overall temperature relationship at the system level. This distinction highlights that correlation strength reflects not only climate responsiveness, but also the relative magnitude of outdoor demand.

Significant negative precipitation correlations (i.e., where months with higher rainfall are associated with lower observed SF use) are present across a broad geographic footprint. Some of the CWSs with the strongest precipitation correlation include: east Texas CWSs such as Hallsville (r = -0.32), Mount Vernon (r = -0.32), Brownsboro (r = -0.31), and Jacksonville (r = -0.27); central Texas systems such as College Station (r = -0.22), Brenham (r = -0.23), Navasota (r = -0.25), and Boerne (r = -0.23); and Dallas-Fort Worth area systems such as Arlington (r = −0.21), Duncanville (r = −0.24), and Allen (r = -0.20). These systems span a wide range of annual precipitation from roughly 32 inches per year in central Texas to over 48 inches per year in east Texas. This shows that a measurable negative precipitation relationship can emerge where outdoor use is sufficient to register in the monthly aggregate and where year-to-year rainfall variability is meaningful enough to produce a detectable signal.

Furthermore, the fact that this pattern extends into some north Texas systems while remaining absent in the highest outdoor use Dallas-Fort Worth suburbs, such as Highland Village and Flower Mound, suggests that the degree of rainfall suppression may partly reflect the magnitude and structure of outdoor demand. Where outdoor use is highest and most structured around fixed seasonal schedules, the rainfall suppression signal appears weakest, while systems with more moderate outdoor use fractions show a more detectable response.

In sharp contrast, twenty systems concentrated in the High Plains and Panhandle, including Spearman (r = 0.44), Sunray (r = 0.33), Dalhart (r = 0.31), Andrews (r = 0.31) and Amarillo (r = 0.25), all show significant but weak positive precipitation correlations (i.e., increased rainfall correlates to increased water demand) as well as strong temperature correlations. These are among the most arid systems in the dataset, with annual precipitation averaging 13–20 inches in wet summer months driven by convective thunderstorm activity and very dry winters averaging less than an inch per month. Here, the wettest months are also the hottest months, and even above-average summer rainfall may not provide sufficient moisture relief against the extreme evapotranspiration deficit. This could mean that wetter months remain high-use months because the underlying landscape moisture deficit is not meaningfully resolved by typical rainfall amounts.

Because the hottest months are also the wettest months in these systems, it is difficult to separate the effects of temperature and rainfall using simple correlations. Thus, a more detailed approach that considers both variables together should be considered for future research.

CONCLUSION AND RECOMMENDATIONS

This study extends the statewide SF residential outdoor water use estimates originally published in Technical Note 12-01 for 254 Texas CWSs over a 2012-2023 study period. In the absence of directly reported monthly SF water use volumes, two methods are developed, validated, and applied to derive monthly SF distributions from available WUS data. The weighted statewide SF residential outdoor water use average of 27% represents a decline from the 31% reported in the Technical Note 12-01 study. This shift reflects a combination of factors: differences in climate conditions from one period to the other, methodological differences in how monthly SF water use is determined, and a seemingly genuine reduction in SF residential outdoor water use in some systems.

SF residential outdoor water use remains highly variable across the state, with persistent regional differences and pronounced year-to-year variation driven by drought and post-drought cycles. The climate driver correlation analysis confirms temperature as the dominant monthly driver of SF water use variation across Texas CWSs, while the weak and asymmetric pattern seen in the precipitation signal is consistent with irrigation behavior that tracks seasonal temperature patterns but is largely insensitive to rainfall. With notable exceptions, regional differences broadly follow the 100th meridian; drier conditions to the west satisfy a smaller fraction of landscape water needs, higher rainfall to the east moderates the outdoor signal and residential SF demand tracks seasonal temperature (**Figure 19**).

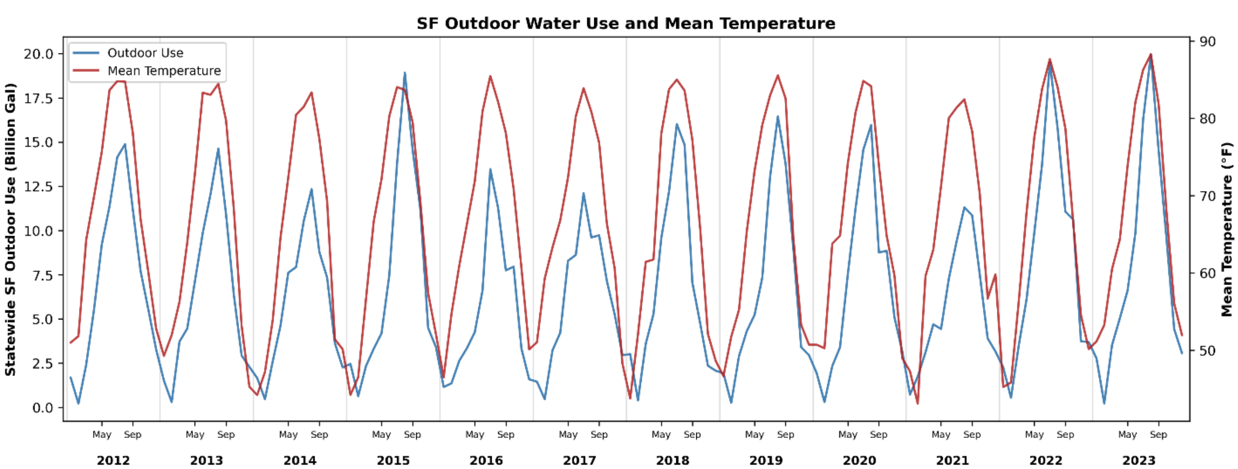

Figure 19. Statewide monthly total single-family outdoor water use and mean temperature

Systems showing the strongest temperature response and weakest rainfall response tend to also show the highest and most stable SF residential outdoor water use demand, suggesting that structural and behavioral drivers sustain outdoor demand in those areas independently of climate variability. Where genuine declines in outdoor use appear to have occurred, they are broadly consistent with documented expansions in conservation program implementation and policy stringency since the Technical Note 12-01 study period. However, the relative impact of behavioral change versus climate and methodological differences remains an open question that future research with more direct data could address.

The most significant recommendation from this study is the reinstatement of monthly SF volume reporting via the TWDB WUS. Restoring this requirement would allow future research to apply the minimum-month method directly rather than through estimation approximation, eliminating the uncertainty that we characterize but cannot eliminate here. Similarly, collecting monthly retail water sales disaggregated by customer category, rather than as aggregate totals, would substantially improve retail-based seasonal estimates by enabling direct isolation of SF billing patterns. Finally, improving the accuracy of reporting across all WUS data elements would reduce or eliminate the need for QA/QC procedures to correct and gap-fill the data, thereby reducing error and uncertainty in SF residential outdoor water use values. Together, these improvements would enhance the integrity of SF residential outdoor water use estimates that directly inform regional and state water planning processes.

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Update to Technical Note 12-01

Contract # 2500012883

Outdoor Residential Water Use in Texas – 2026

Appendix

by

Mary G. Eminue, M.S. and Justin C. Thompson, Ph.D.

BUREAU OF ECONOMIC GEOLOGY

August 2026

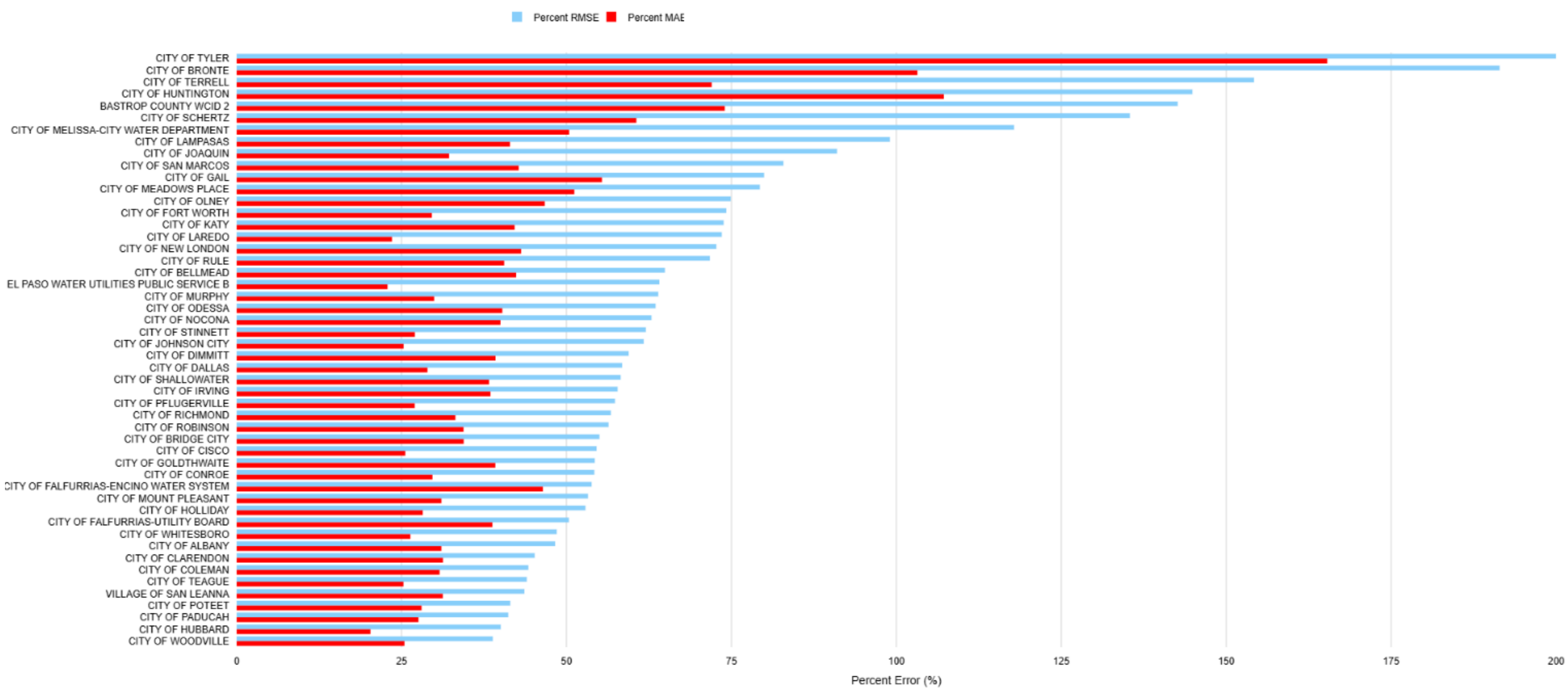

Figure A1. 50 CWSs with the highest MAE and RMSE before data improvements for Phase 1 years.

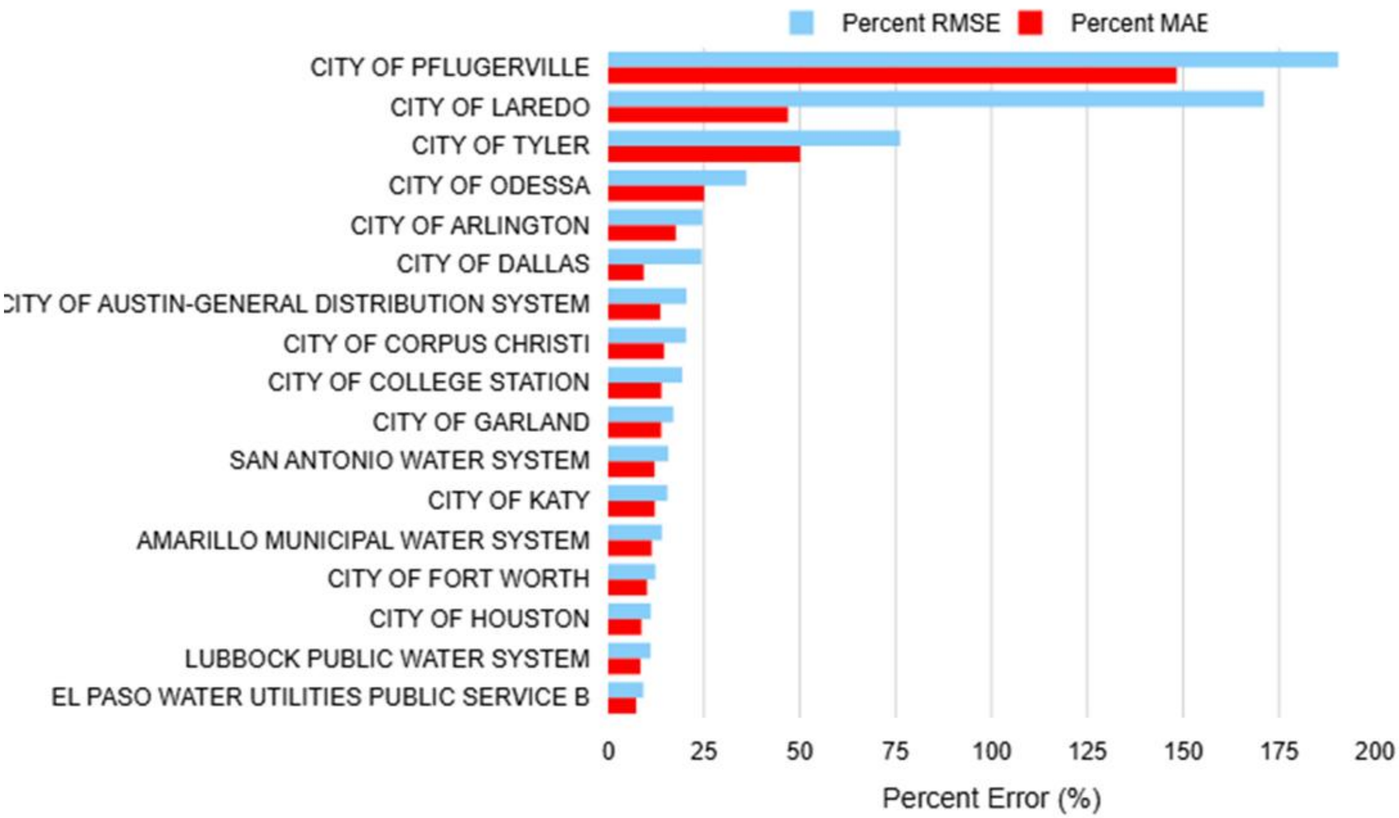

Figure A2. RMSE/MAE results for Phase 2 systems before data improvements

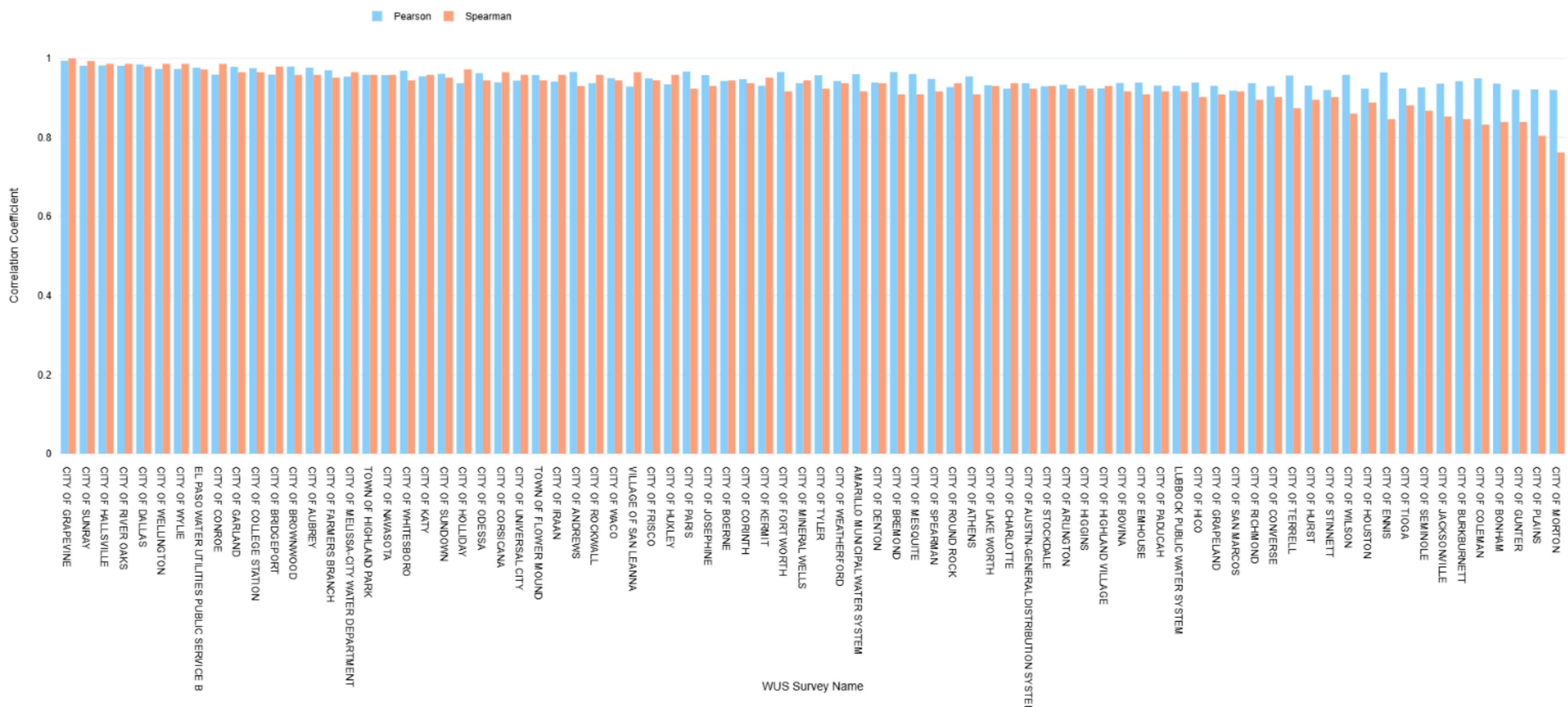

Figure A3. Top 80 systems with >0.7 correlation coefficient before data corrections for the 2012 and 2023 period.

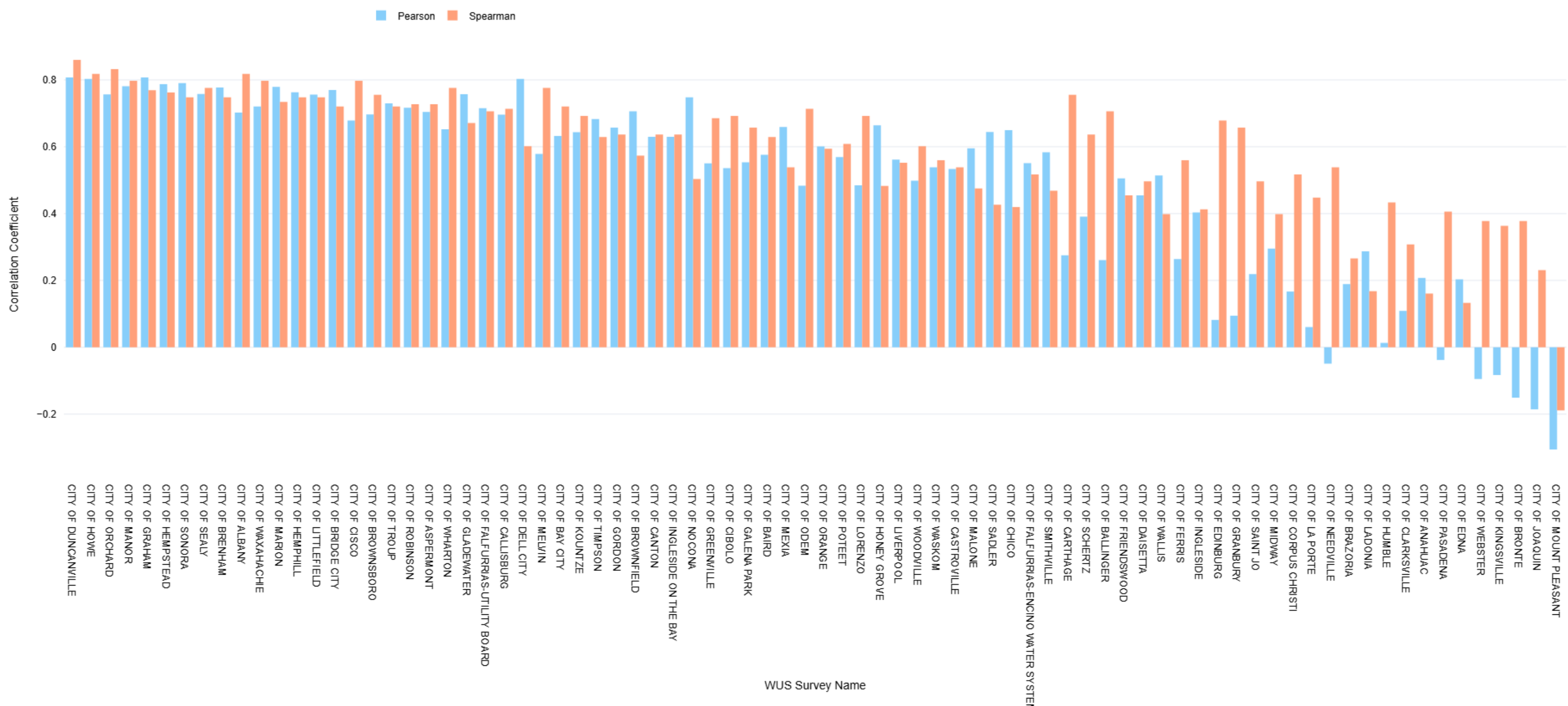

Figure A4. 70 systems with the lowest correlation before data corrections.

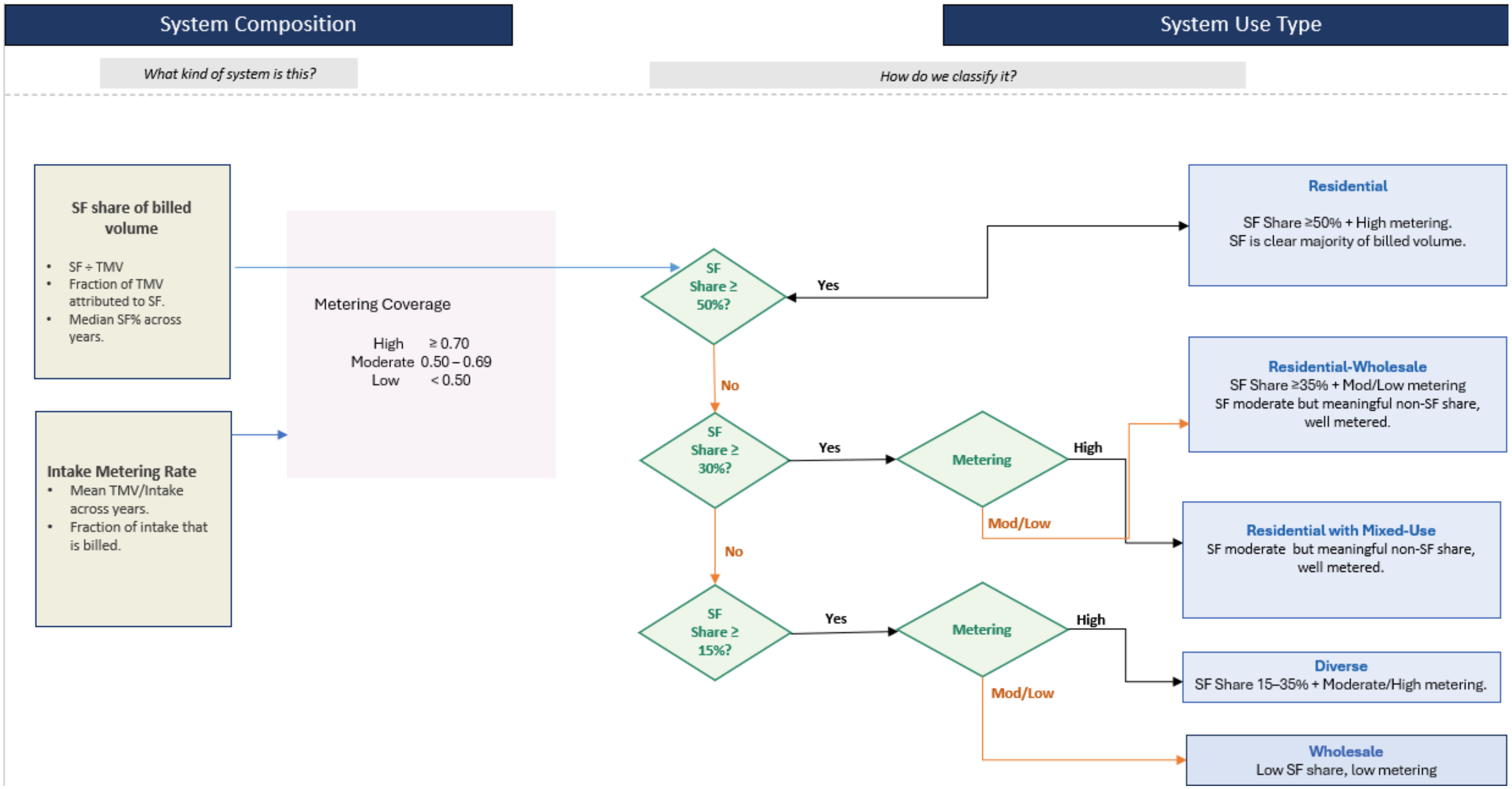

Figure A5. Framework used to understand system use type based on intake and billing composition

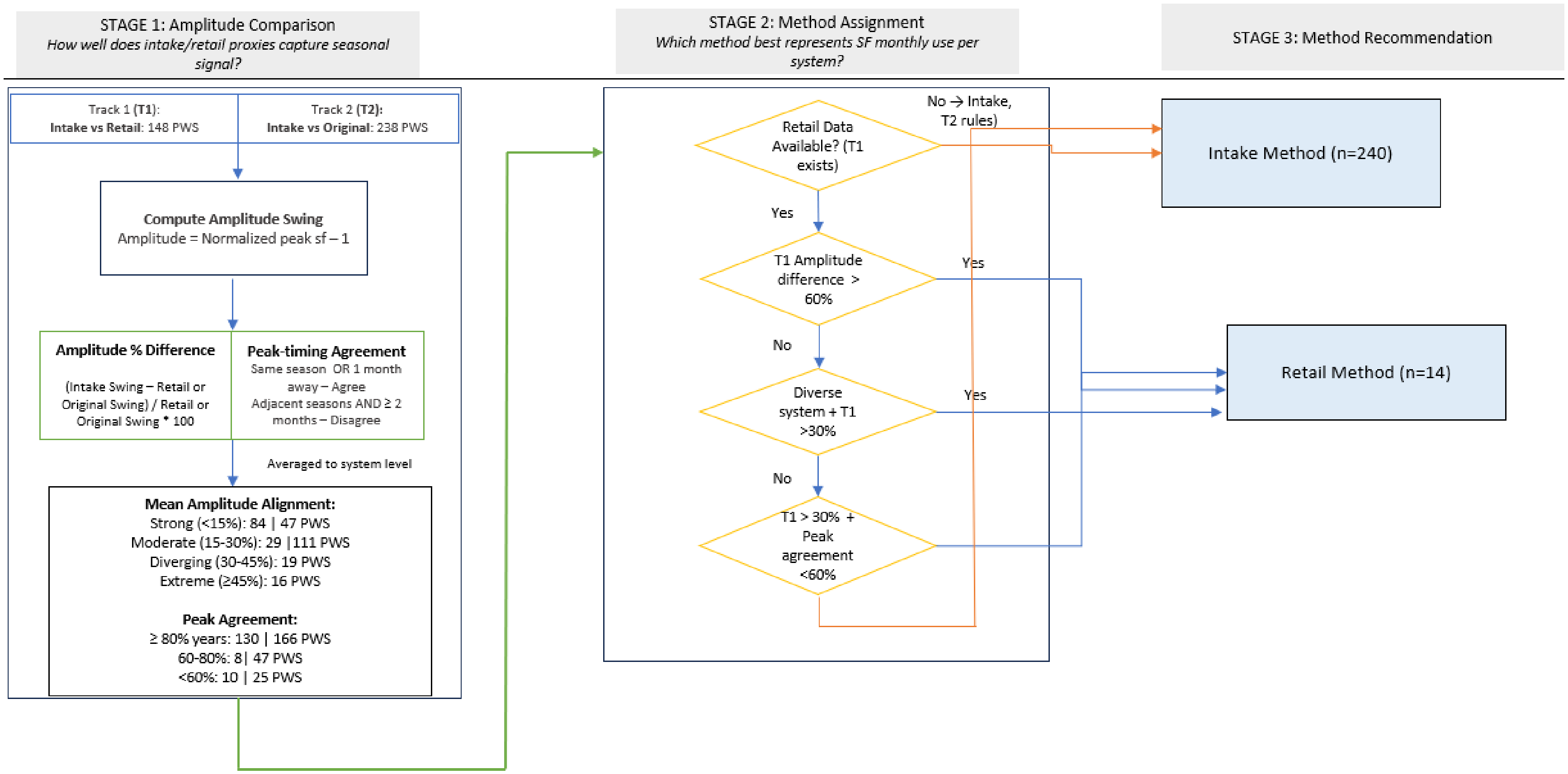

Figure A6. Threshold framework used to assign/recommend methods for all CWSs.

Table A1. Percentage changes in RMSE and MAE between this study's intake-derived monthly SF volumes and Technical Note 12-01's, after data quality was improved through magnitude corrections, lump sums redistribution and gap-filling.

WUS Survey Name	%RMSE Change	%MAE Change
AMARILLO MUNICIPAL WATER SYSTEM	2	2
BASTROP COUNTY WCID 2	52	10
BORGER MUNICIPAL WATER SYSTEM	11	11
CITY OF ALBANY	2	-1
CITY OF ALLEN	0	0
CITY OF ALVARADO	0	0
CITY OF ALVIN	0	0
CITY OF ANAHUAC	0	0
CITY OF ANDREWS	0	0
CITY OF ARLINGTON	0	0
CITY OF ASPERMONT	0	0
CITY OF ATHENS	0	0
CITY OF AUBREY	0	0
CITY OF AUSTIN-GENERAL DISTRIBUTION SYSTEM	8	5
CITY OF BAIRD	0	0
CITY OF BALLINGER	0	0
CITY OF BAY CITY	0	0
CITY OF BECKVILLE	0	0
CITY OF BELLMEAD	36	22
CITY OF BELLS	0	0
CITY OF BELLVILLE	16	10
CITY OF BOERNE	0	0
CITY OF BONHAM	0	0
CITY OF BOVINA	0	0
CITY OF BRAZORIA	0	0
CITY OF BRECKENRIDGE	0	0
CITY OF BREMOND	0	0
CITY OF BRENHAM	0	0
CITY OF BRIDGE CITY	33	18
CITY OF BRIDGEPORT	0	0
CITY OF BRONTE	98	49
CITY OF BROWNFIELD	0	0
CITY OF BROWNSBORO	0	0
CITY OF BROWNWOOD	0	0
CITY OF BUDA	0	0
CITY OF BUFFALO	0	0
CITY OF BURKBURNETT	0	0

WUS Survey Name	%RMSE Change	%MAE Change
CITY OF CALLISBURG	0	0
CITY OF CANTON	0	0
CITY OF CANYON	2	1
CITY OF CARTHAGE	0	0
CITY OF CASTROVILLE	0	0
CITY OF CELESTE	0	0
CITY OF CHARLOTTE	0	0
CITY OF CHICO	0	0
CITY OF CIBOLO	0	0
CITY OF CISCO	21	4
CITY OF CLARENDON	0	1
CITY OF CLARKSVILLE	17	11
CITY OF COLEMAN	16	11
CITY OF COLLEGE STATION	0	0
CITY OF COMANCHE	0	0
CITY OF CONROE	57	28
CITY OF CONVERSE	0	0
CITY OF CORINTH	0	0
CITY OF CORPUS CHRISTI	2	2
CITY OF CORSICANA	0	0
CITY OF CROSBYTON	2	1
CITY OF CUMBY	0	0
CITY OF DAINGERFIELD	0	0
CITY OF DAISETTA	0	1
CITY OF DALLAS	20	7
CITY OF DARROUZETT	0	0
CITY OF DENTON	0	0
CITY OF DENVER CITY	0	0
CITY OF DIMMITT	24	13
CITY OF DUNCANVILLE	0	0
CITY OF EARLY	0	0
CITY OF EARTH	0	0
CITY OF EDINBURG	0	0
CITY OF EDNA	0	0
CITY OF EMHOUSE	0	0
CITY OF ENNIS	0	0
CITY OF FAIRFIELD	0	0
CITY OF FALFURRIAS-ENCINO WATER SYSTEM	71	63
CITY OF FALFURRIAS-UTILITY BOARD	14	12
CITY OF FARMERS BRANCH	0	0

WUS Survey Name	%RMSE Change	%MAE Change
CITY OF FERRIS	0	0
CITY OF FLATONIA	0	0
CITY OF FORT WORTH	58	18
CITY OF FRIENDSWOOD	0	0
CITY OF FRISCO	0	0
CITY OF FRITCH	0	0
CITY OF GALENA PARK	0	0
CITY OF GARLAND	5	4
CITY OF GIDDINGS	0	0
CITY OF GLADEWATER	0	1
CITY OF GOLDTHWAITE	1	1
CITY OF GORDON	0	0
CITY OF GRAHAM	0	0
CITY OF GRANBURY	0	0
CITY OF GRAND SALINE	0	0
CITY OF GRAPELAND	0	1
CITY OF GRAPEVINE	0	0
CITY OF GREENVILLE	0	0
CITY OF GUNTER	0	0
CITY OF HALLSVILLE	0	0
CITY OF HAMILTON	0	0
CITY OF HARKER HEIGHTS	0	0
CITY OF HEDLEY	0	0
CITY OF HEMPHILL	0	0
CITY OF HEMPSTEAD	0	0
CITY OF HICO	0	0
CITY OF HIGGINS	0	0
CITY OF HIGHLAND VILLAGE	0	0
CITY OF HOLLIDAY	34	16
CITY OF HONEY GROVE	0	0
CITY OF HOUSTON	1	1
CITY OF HOWE	0	0
CITY OF HUBBARD	0	0
CITY OF HUMBLE	0	0
CITY OF HUNTINGTON	63	46
CITY OF HURST	0	0
CITY OF HUXLEY	0	0
CITY OF INGLESIDE	2	1
CITY OF INGLESIDE ON THE BAY	0	0
CITY OF IOWA PARK	0	0

WUS Survey Name	%RMSE Change	%MAE Change
CITY OF IRAAN	0	0
CITY OF IRVING	24	15
CITY OF JACKSONVILLE	0	0
CITY OF JOAQUIN	53	6
CITY OF JOHNSON CITY	45	13
CITY OF JOSEPHINE	0	0
CITY OF KATY	39	19
CITY OF KERMIT	0	0
CITY OF KINGSVILLE	0	0
CITY OF KOUNTZE	0	0
CITY OF LA PORTE	0	0
CITY OF LADONIA	1	0
CITY OF LAGO VISTA	0	0
CITY OF LAKE WORTH	0	0
CITY OF LAMPASAS	72	20
CITY OF LAREDO	63	14
CITY OF LITTLEFIELD	0	0
CITY OF LIVERPOOL	7	2
CITY OF LORENA	0	0
CITY OF LORENZO	0	0
CITY OF MADISONVILLE	0	0
CITY OF MALONE	0	0
CITY OF MANOR	0	0
CITY OF MARION	0	0
CITY OF MASON	0	0
CITY OF MEADOWS PLACE	39	25
CITY OF MELISSA-CITY WATER DEPARTMENT	102	35
CITY OF MELVIN	1	1
CITY OF MENARD	0	0
CITY OF MERIDIAN	15	5
CITY OF MESQUITE	0	0
CITY OF MEXIA	0	0
CITY OF MIDWAY	34	24
CITY OF MINERAL WELLS	0	0
CITY OF MOBEETIE	0	0
CITY OF MONAHANS	0	0
CITY OF MOODY	0	0
CITY OF MORTON	0	0
CITY OF MOUNT PLEASANT	12	3
CITY OF MURPHY	40	12

WUS Survey Name	%RMSE Change	%MAE Change
CITY OF NAVASOTA	0	0
CITY OF NEEDVILLE	0	0
CITY OF NEW LONDON	38	19
CITY OF NEW WAVERLY	0	0
CITY OF NIXON	0	0
CITY OF NOCONA	0	0
CITY OF ODEM	0	0
CITY OF ODESSA	30	17
CITY OF OLNEY	39	22
CITY OF ORANGE	0	0
CITY OF ORANGE GROVE	0	0
CITY OF ORCHARD	0	0
CITY OF PADUCAH	13	9
CITY OF PARIS	0	0
CITY OF PASADENA	0	0
CITY OF PEARSALL	0	0
CITY OF PFLUGERVILLE	44	16
CITY OF PINELAND	0	0
CITY OF PLAINS	0	0
CITY OF POTEET	4	4
CITY OF QUANAH	0	0
CITY OF RICHMOND	31	16
CITY OF RIVER OAKS	0	0
CITY OF ROBINSON	9	8
CITY OF ROCKWALL	0	0
CITY OF ROSENBERG	0	0
CITY OF ROUND ROCK	0	0
CITY OF RULE	44	24
CITY OF SADLER	0	0
CITY OF SAN MARCOS	116	56
CITY OF SAN SABA	0	0
CITY OF SCHERTZ	123	51
CITY OF SEALY	0	0
CITY OF SEMINOLE	0	0
CITY OF SHALLOWATER	27	16
CITY OF SHENANDOAH	0	0
CITY OF SHINER	0	0
CITY OF SMITHVILLE	0	0
CITY OF SOMERVILLE	0	0
CITY OF SONORA	0	0

WUS Survey Name	%RMSE Change	%MAE Change
CITY OF SPEARMAN	0	0
CITY OF STINNETT	38	10
CITY OF STOCKDALE	0	0
CITY OF SUGAR LAND	0	0
CITY OF SUNDOWN	0	0
CITY OF SUNRAY	0	0
CITY OF SWEETWATER	0	0
CITY OF TEAGUE	0	0
CITY OF TEMPLE	0	0
CITY OF TERRELL	399	181
CITY OF THORNDALE	0	0
CITY OF TIMPSON	0	0
CITY OF TIOGA	0	0
CITY OF TOLAR	0	0
CITY OF TOMBALL	0	0
CITY OF TROUP	0	0
CITY OF TYLER	63	51
CITY OF UNIVERSAL CITY	0	0
CITY OF UVALDE	0	0
CITY OF VICTORIA	0	0
CITY OF WACO	3	2
CITY OF WALLIS	0	0
CITY OF WASKOM	0	0
CITY OF WAXAHACHIE	0	0
CITY OF WEATHERFORD	0	0
CITY OF WEBSTER	0	0
CITY OF WELLINGTON	14	6
CITY OF WHARTON	0	0
CITY OF WHITESBORO	51	25
CITY OF WICHITA FALLS	0	0
CITY OF WILSON	0	0
CITY OF WOODVILLE	3	4
CITY OF WYLIE	0	0
DALHART MUNICIPAL WATER SYSTEM	15	12
EL PASO WATER UTILITIES PUBLIC SERVICE B	51	14
LUBBOCK PUBLIC WATER SYSTEM	5	4
NEW BRAUNFELS UTILITIES	13	11
PLAINVIEW MUNICIPAL WATER SYSTEM	5	3
SAN ANTONIO WATER SYSTEM	4	3
TOWN OF FLOWER MOUND	7	4

WUS Survey Name	%RMSE Change	%MAE Change
TOWN OF HIGHLAND PARK	0	0
VILLAGE OF SAN LEANNA	24	17

Table A2. Method Confidence and Outdoor Use Confidence ratings (trough month agreement) for CWSs in this study compared with difference in outdoor use percentages between this study and Technical Note 12-01.

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
AMARILLO MUNICIPAL WATER SYSTEM	Intake	High	High	-4
BORDEN COUNTY WATER SYSTEM	Intake	High	High	-23
BORGER MUNICIPAL WATER SYSTEM	Intake	Moderate	High	-3
CITY OF ALBANY	Intake	Moderate	High	-15
CITY OF ALLEN	Intake	High	High	-1
CITY OF ALVARADO	Intake	Moderate	Moderate	-4
CITY OF ALVIN	Intake	High	High	0
CITY OF ANAHUAC	Intake	Low	High	4
CITY OF ANDREWS	Intake	High	Moderate	-6
CITY OF ARLINGTON	Intake	Moderate	High	-5
CITY OF ASPERMONT	Intake	High	Moderate	-1
CITY OF ATHENS	Intake	Low	High	-9
CITY OF AUBREY	Intake	High	High	-6
CITY OF AUSTIN-GENERAL DISTRIBUTION SYSTEM	Intake	High	High	-11
CITY OF BAIRD	Intake	High	High	10
CITY OF BALLINGER	Intake	Low	Moderate	-5
CITY OF BAY CITY	Intake	Moderate	High	-3
CITY OF BECKVILLE	Intake	High	Moderate	6
CITY OF BELLMEAD	Intake	High	High	1
CITY OF BELLS	Intake	High	High	2
CITY OF BELLVILLE	Intake	High	High	5
CITY OF BOERNE	Intake	High	High	0
CITY OF BONHAM	Intake	Moderate	High	-9
CITY OF BOVINA	Intake	Moderate	High	7
CITY OF BRAZORIA	Intake	Low	Moderate	-4
CITY OF BRECKENRIDGE	Intake	Moderate	High	-4
CITY OF BREMOND	Intake	Moderate	High	-4
CITY OF BRENHAM	Intake	High	High	-1
CITY OF BRIDGE CITY	Intake	High	High	-2
CITY OF BRIDGEPORT	Intake	High	Moderate	-1
CITY OF BRONTE	Intake	Low	Low	11
CITY OF BROWNFIELD	Intake	Moderate	Moderate	-2

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
CITY OF BROWNSBORO	Intake	Moderate	High	-4
CITY OF BROWNWOOD	Intake	High	High	2
CITY OF BUDA	Intake	High	High	-7
CITY OF BUFFALO	Intake	High	High	-4
CITY OF BURKBURNETT	Intake	Low	Moderate	-12
CITY OF CALLISBURG	Intake	Moderate	High	-8
CITY OF CANTON	Intake	Low	High	-9
CITY OF CANYON	Intake	Moderate	High	4
CITY OF CARTHAGE	Intake	Moderate	High	-11
CITY OF CASTROVILLE	Intake	High	High	-3
CITY OF CELESTE	Intake	Moderate	Low	-4
CITY OF CHARLOTTE	Intake	High	High	-10
CITY OF CHICO	Intake	Moderate	Moderate	-8
CITY OF CIBOLO	Intake	Moderate	High	-2
CITY OF CISCO	Intake	Moderate	High	-14
CITY OF CLARENDON	Intake	Low	Low	-14
CITY OF CLARKSVILLE	Intake	Moderate	Low	5
CITY OF COLEMAN	Intake	Low	Moderate	-3
CITY OF COLLEGE STATION	Intake	High	High	-2
CITY OF COMANCHE	Intake	Moderate	Moderate	-3
CITY OF CONROE	Intake	High	High	-11
CITY OF CONVERSE	Intake	High	High	-7
CITY OF CORINTH	Intake	High	High	1
CITY OF CORPUS CHRISTI	Retail	Moderate	Moderate	-12
CITY OF CORSICANA	Intake	Moderate	High	-15
CITY OF CROSBYTON	Intake	High	High	4
CITY OF CUMBY	Intake	Moderate	Low	11
CITY OF DAINGERFIELD	Intake	High	High	-6
CITY OF DAISETTA	Intake	High	High	-3
CITY OF DALLAS	Intake	Moderate	High	-11
CITY OF DARROUZETT	Intake	Low	High	7
CITY OF DELL	Intake	Low	High	-4
CITY OF DENTON	Retail	High	High	-8
CITY OF DENVER CITY	Intake	High	High	-4
CITY OF DIMMITT	Intake	Moderate	Moderate	-2
CITY OF DUNCANVILLE	Intake	High	High	-7

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
CITY OF EARLY	Intake	High	High	-9
CITY OF EARTH	Intake	High	Moderate	8
CITY OF EDINBURG	Retail	Moderate	Moderate	-6
CITY OF EDNA	Intake	Low	Low	5
CITY OF EMHOUSE	Intake	Moderate	Moderate	-4
CITY OF ENNIS	Intake	High	Moderate	-10
CITY OF FAIRFIELD	Intake	Moderate	Moderate	-14
CITY OF FALFURRIAS-ENCINO WATER SYSTEM	Intake	Low	Moderate	8
CITY OF FALFURRIAS-UTILITY BOARD	Intake	Moderate	High	-7
CITY OF FARMERS BRANCH	Intake	Moderate	High	-4
CITY OF FERRIS	Intake	High	Moderate	1
CITY OF FLATONIA	Intake	High	High	-5
CITY OF FORT WORTH	Intake	Moderate	High	-4
CITY OF FRIENDSWOOD	Intake	Moderate	High	-14
CITY OF FRISCO	Intake	High	High	-3
CITY OF FRITCH	Intake	Moderate	High	-1
CITY OF GALENA PARK	Intake	High	High	-1
CITY OF GARLAND	Intake	Low	High	-2
CITY OF GIDDINGS	Intake	Moderate	Moderate	-5
CITY OF GLADEWATER	Intake	High	High	-2
CITY OF GOLDTHWAITE	Retail	Low	Moderate	12
CITY OF GORDON	Retail	Moderate	Low	14
CITY OF GRAHAM	Intake	High	High	-8
CITY OF GRANBURY	Retail	Low	High	-5
CITY OF GRAND SALINE	Retail	Low	High	-18
CITY OF GRAPELAND	Intake	High	Moderate	-5
CITY OF GRAPEVINE	Intake	Moderate	High	-6
CITY OF GREENVILLE	Intake	Moderate	High	1
CITY OF GUNTER	Intake	High	High	11
CITY OF HALLSVILLE	Intake	Moderate	Moderate	-4
CITY OF HAMILTON	Intake	Moderate	High	-8
CITY OF HARKER HEIGHTS	Intake	High	High	-8
CITY OF HEDLEY	Intake	Moderate	Moderate	-5
CITY OF HEMPHILL	Intake	Moderate	Low	2
CITY OF HEMPSTEAD	Intake	Moderate	Low	-4

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
CITY OF HICO	Intake	Low	Moderate	-7
CITY OF HIGGINS	Intake	Moderate	Moderate	-16
CITY OF HIGHLAND VILLAGE	Intake	High	High	3
CITY OF HOLLIDAY	Intake	High	High	2
CITY OF HONEY GROVE	Intake	Moderate	Moderate	-7
CITY OF HOUSTON	Retail	Moderate	Low	-4
CITY OF HOWE	Intake	Moderate	Low	-17
CITY OF HUBBARD	Intake	Low	High	-4
CITY OF HUMBLE	Retail	Moderate	High	-3
CITY OF HUNTINGTON	Intake	High	High	0
CITY OF HURST	Intake	High	High	-9
CITY OF HUXLEY	Intake	Moderate	Moderate	-9
CITY OF INGLESIDE	Intake	High	Low	7
CITY OF INGLESIDE ON THE BAY	Intake	High	Moderate	13
CITY OF IOWA PARK	Intake	High	Moderate	-6
CITY OF IRAAN	Intake	Moderate	Moderate	-10
CITY OF IRVING	Intake	High	High	-15
CITY OF JACKSONVILLE	Intake	Moderate	High	-9
CITY OF JOAQUIN	Intake	Moderate	High	-17
CITY OF JOHNSON CITY	Intake	High	High	-4
CITY OF JOSEPHINE	Intake	High	High	5
CITY OF KATY	Intake	High	High	2
CITY OF KERMIT	Intake	Moderate	High	-13
CITY OF KINGSVILLE	Retail	Low	Moderate	25
CITY OF KOUNTZE	Intake	Moderate	Moderate	-6
CITY OF LA PORTE	Intake	High	High	0
CITY OF LADONIA	Intake	Moderate	High	21
CITY OF LAGO VISTA	Intake	High	High	-12
CITY OF LAKE WORTH	Intake	Moderate	High	-2
CITY OF LAMPASAS	Intake	Low	High	-2
CITY OF LAREDO	Intake	High	High	-3
CITY OF LEANDER	Intake	Low	High	-6
CITY OF LITTLEFIELD	Intake	Moderate	High	-4
CITY OF LIVERPOOL	Intake	Moderate	Low	10
CITY OF LONGVIEW	Intake	Low	Low	-12
CITY OF LORENA	Intake	High	High	-20

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
CITY OF LORENZO	Intake	Moderate	Low	-13
CITY OF MADISONVILLE	Intake	Moderate	Moderate	-13
CITY OF MALONE	Intake	Moderate	High	10
CITY OF MANOR	Intake	Moderate	Moderate	-8
CITY OF MARION	Intake	Moderate	Low	-4
CITY OF MASON	Intake	High	High	-2
CITY OF MEADOWS PLACE	Intake	Moderate	Low	2
CITY OF MELISSA-CITY WATER DEPARTMENT	Intake	Moderate	High	-13
CITY OF MELVIN	Intake	High	High	-13
CITY OF MENARD	Intake	High	High	-10
CITY OF MERIDIAN	Retail	Low	Moderate	-16
CITY OF MESQUITE	Intake	Low	High	-4
CITY OF MEXIA	Intake	High	High	-6
CITY OF MIDWAY	Intake	High	High	22
CITY OF MINERAL WELLS	Intake	Low	Moderate	-21
CITY OF MOBEETIE	Intake	High	High	-8
CITY OF MONAHANS	Intake	High	High	-11
CITY OF MOODY	Intake	Moderate	Moderate	-7
CITY OF MORTON	Intake	Moderate	Moderate	-7
CITY OF MOUNT PLEASANT	Retail	High	Low	-16
CITY OF MURPHY	Intake	Low	Moderate	-16
CITY OF NAVASOTA	Intake	Moderate	High	-7
CITY OF NEEDVILLE	Intake	Moderate	High	-4
CITY OF NEW LONDON	Intake	Moderate	Low	-8
CITY OF NEW WAVERLY	Intake	Moderate	High	1
CITY OF NIXON	Intake	Moderate	High	-12
CITY OF NOCONA	Intake	Low	Low	-31
CITY OF ODEM	Intake	Moderate	Moderate	-1
CITY OF ODESSA	Intake	Low	Low	-9
CITY OF OLNEY	Intake	Low	High	-10
CITY OF ORANGE	Intake	Low	High	2
CITY OF ORANGE GROVE	Intake	Moderate	High	-6
CITY OF ORCHARD	Intake	Moderate	High	4
CITY OF PARIS	Intake	High	Moderate	-1
CITY OF PASADENA	Intake	Low	Moderate	-6

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
CITY OF PEARSALL	Intake	Moderate	High	-3
CITY OF PFLUGERVILLE	Intake	High	High	-1
CITY OF PINELAND	Intake	Moderate	Low	-2
CITY OF PLAINS	Intake	Moderate	High	-4
CITY OF POTEET	Intake	Low	Low	5
CITY OF QUANAH	Intake	Moderate	Low	-6
CITY OF RICHMOND	Intake	Moderate	High	6
CITY OF RIVER OAKS	Intake	Moderate	High	-5
CITY OF ROBINSON	Retail	Moderate	Low	-8
CITY OF ROCKWALL	Intake	High	High	-1
CITY OF ROSENBERG	Intake	High	High	6
CITY OF ROUND ROCK	Intake	High	High	-3
CITY OF RULE	Intake	High	High	11
CITY OF SADLER	Intake	Moderate	Low	-3
CITY OF SAINT JO	Intake	Moderate	Low	-7
CITY OF SAN MARCOS	Intake	Moderate	Moderate	-12
CITY OF SCHERTZ	Intake	High	High	0
CITY OF SEALY	Intake	High	High	-8
CITY OF SEMINOLE	Intake	High	High	-3
CITY OF SHALLOWATER	Intake	High	High	0
CITY OF SHENANDOAH	Intake	Moderate	High	-4
CITY OF SHINER	Intake	Moderate	High	-6
CITY OF SMITHVILLE	Intake	Moderate	High	-8
CITY OF SOMERVILLE	Intake	Moderate	Moderate	-3
CITY OF SONORA	Intake	Low	High	-17
CITY OF SPEARMAN	Intake	High	Moderate	-1
CITY OF STINNETT	Intake	Moderate	Moderate	-6
CITY OF STOCKDALE	Intake	High	High	-5
CITY OF SUGAR LAND	Intake	High	High	2
CITY OF SUNDOWN	Intake	Moderate	High	0
CITY OF SUNRAY	Intake	Moderate	High	-11
CITY OF SWEETWATER	Intake	Low	Moderate	-12
CITY OF TEAGUE	Intake	Low	Low	-27
CITY OF TEMPLE	Intake	Moderate	High	-6
CITY OF TERRELL	Intake	High	Moderate	-11
CITY OF THORNDALE	Intake	Low	Moderate	9

Water Use Survey Name	Method Recommended	Method Confidence	Outdoor Use Confidence	Study Difference %
CITY OF TIMPSON	Intake	Moderate	Moderate	-5
CITY OF TIOGA	Intake	High	High	-3
CITY OF TOLAR	Intake	Moderate	Moderate	5
CITY OF TOMBALL	Intake	Moderate	High	-12
CITY OF TROUP	Intake	Low	Low	-8
CITY OF TYLER	Intake	Low	Moderate	-20
CITY OF UNIVERSAL CITY	Intake	High	High	-2
CITY OF UVALDE	Intake	Moderate	High	-11
CITY OF VICTORIA	Intake	Moderate	High	-3
CITY OF WACO	Intake	Low	High	-7
CITY OF WALLIS	Intake	Low	High	-4
CITY OF WASKOM	Intake	Moderate	Low	-1
CITY OF WAXAHACHIE	Intake	Moderate	High	-13
CITY OF WEATHERFORD	Intake	Moderate	High	1
CITY OF WEBSTER	Intake	High	High	-3
CITY OF WELLINGTON	Intake	High	High	-5
CITY OF WHARTON	Intake	Moderate	High	-8
CITY OF WHITESBORO	Intake	High	High	2
CITY OF WICHITA FALLS	Retail	High	Moderate	-13
CITY OF WILSON	Intake	High	High	-11
CITY OF WOODVILLE	Intake	Moderate	Low	-30
CITY OF WOODWAY	Intake	Moderate	High	-20
CITY OF WYLIE	Intake	High	High	-5
DALHART MUNICIPAL WATER SYSTEM	Intake	High	High	-5
EL PASO WATER UTILITIES PUBLIC SERVICE B	Intake	High	High	-2
LUBBOCK PUBLIC WATER SYSTEM	Intake	Moderate	High	-10
NEW BRAUNFELS UTILITIES	Intake	High	High	-3
PLAINVIEW MUNICIPAL WATER SYSTEM	Intake	Moderate	High	-4
SAN ANTONIO WATER SYSTEM	Intake	Moderate	High	-4
TOWN OF FLOWER MOUND	Intake	High	High	1
TOWN OF HIGHLAND PARK	Intake	High	High	1
VILLAGE OF SAN LEANNA	Intake	Moderate	High	-13

Table A3. Pearson correlation results of outdoor use and temperature and precipitation between 2012 and 2023.

WUS Survey Name	r_Temp	r_Precip
AMARILLO MUNICIPAL WATER SYSTEM	0.8285	0.2529
AQUA WSC	0.6244	-0.1894
BASTROP COUNTY WCID 2	0.7282	-0.1945
BORDEN COUNTY WATER SYSTEM	0.3935	0.0166
BORGER MUNICIPAL WATER SYSTEM	0.4309	0.1679
CITY OF ALBANY	0.7162	-0.0994
CITY OF ALLEN	0.8328	-0.2013
CITY OF ALVARADO	0.3659	-0.1312
CITY OF ALVIN	0.5617	0.0976
CITY OF ANAHUAC	0.1083	-0.0509
CITY OF ANDREWS	0.9072	0.3093
CITY OF ARLINGTON	0.8733	-0.2106
CITY OF ASPERMONT	0.5093	0.0148
CITY OF ATHENS	0.7409	-0.2578
CITY OF AUBREY	0.6525	-0.1895
CITY OF AUSTIN-GENERAL DISTRIBUTION SYSTEM	0.8057	-0.1542
CITY OF BAIRD	0.1946	0.0533
CITY OF BALLINGER	0.4345	-0.0159
CITY OF BAY CITY	0.3931	-0.0898
CITY OF BECKVILLE	0.2516	-0.2238
CITY OF BELLMEAD	0.3972	-0.0986
CITY OF BELLS	0.5471	-0.0316
CITY OF BELLVILLE	0.7511	-0.0998
CITY OF BOERNE	0.6335	-0.2312
CITY OF BONHAM	0.6788	-0.2122
CITY OF BOVINA	0.839	0.2475
CITY OF BRAZORIA	0.0588	0.1471
CITY OF BRECKENRIDGE	0.4727	-0.0832
CITY OF BREMOND	0.6557	-0.3011
CITY OF BRENHAM	0.784	-0.2334
CITY OF BRIDGE CITY	0.1594	-0.1867
CITY OF BRIDGEPORT	0.7449	-0.004
CITY OF BRONTE	0.2654	-0.0179
CITY OF BROWNFIELD	0.6838	0.0953
CITY OF BROWNSBORO	0.3686	-0.3129
CITY OF BROWNWOOD	0.725	-0.16
CITY OF BUDA	0.714	-0.2066
CITY OF BUFFALO	0.2365	-0.187
CITY OF BURKBURNETT	0.3783	-0.1088
CITY OF CALLISBURG	0.5641	-0.0693

WUS Survey Name	r_Temp	r_Precip
CITY OF CANTON	0.2824	-0.0781
CITY OF CANYON	0.8234	0.2361
CITY OF CARTHAGE	0.1169	-0.0538
CITY OF CASTROVILLE	0.6603	-0.1683
CITY OF CELESTE	0.4312	-0.2246
CITY OF CHARLOTTE	0.7521	0.1247
CITY OF CHICO	0.0647	-0.0969
CITY OF CIBOLO	0.7729	-0.1772
CITY OF CISCO	0.4279	-0.0347
CITY OF CLARENDON	0.4463	0.1634
CITY OF CLARKSVILLE	-0.0931	-0.0096
CITY OF COLEMAN	0.6787	-0.0502
CITY OF COLLEGE STATION	0.7921	-0.2229
CITY OF COMANCHE	0.651	0.0382
CITY OF CONROE	0.5588	-0.107
CITY OF CONVERSE	0.5523	-0.1856
CITY OF CORINTH	0.8941	-0.1822
CITY OF CORPUS CHRISTI	0.5636	0.0141
CITY OF CORSICANA	0.6133	-0.174
CITY OF CROSBYTON	0.3953	0.0932
CITY OF CUMBY	0.1908	-0.1642
CITY OF DAINGERFIELD	0.3171	-0.1502
CITY OF DAISETTA	0.2374	0.1951
CITY OF DALLAS	0.8613	-0.1315
CITY OF DARROUZETT	0.6128	0.2921
CITY OF DELL	0.0817	-0.0515
CITY OF DENTON	0.6362	-0.1919
CITY OF DENVER CITY	0.8733	0.1204
CITY OF DIMMITT	0.5056	0.1842
CITY OF DUNCANVILLE	0.7634	-0.2367
CITY OF EARLY	0.5498	-0.144
CITY OF EARTH	0.6459	0.2106
CITY OF EDINBURG	0.5473	-0.0572
CITY OF EDNA	0.4965	0.0916
CITY OF EMHOUSE	0.443	-0.1015
CITY OF ENNIS	0.7246	-0.1378
CITY OF FAIRFIELD	0.2352	-0.158
CITY OF FALFURRIAS-ENCINO WATER SYSTEM	0.0676	-0.1029
CITY OF FALFURRIAS-UTILITY BOARD	0.4559	-0.0857
CITY OF FARMERS BRANCH	0.4813	-0.0644

WUS Survey Name	r_Temp	r_Precip
CITY OF FERRIS	0.482	-0.0798
CITY OF FLATONIA	0.6321	-0.0211
CITY OF FORT WORTH	0.7952	-0.1573
CITY OF FRIENDSWOOD	0.7315	0.0613
CITY OF FRISCO	0.7904	-0.1658
CITY OF FRITCH	0.4552	0.1261
CITY OF GALENA PARK	0.295	-0.0044
CITY OF GARLAND	0.7669	-0.2096
CITY OF GIDDINGS	0.7093	-0.2412
CITY OF GLADEWATER	0.2428	-0.0981
CITY OF GOLDTHWAITE	0.4401	-0.1967
CITY OF GORDON	0.4752	-0.071
CITY OF GRAHAM	0.6349	-0.1468
CITY OF GRANBURY	0.5028	-0.1397
CITY OF GRAPELAND	0.383	-0.1286
CITY OF GRAPEVINE	0.8453	-0.1427
CITY OF GREENVILLE	0.4053	-0.0316
CITY OF GUNTER	0.351	-0.0703
CITY OF HALLSVILLE	0.7418	-0.3179
CITY OF HAMILTON	0.5754	-0.1435
CITY OF HARKER HEIGHTS	0.8914	-0.1077
CITY OF HEDLEY	0.5223	0.2391
CITY OF HEMPHILL	0.4301	-0.2314
CITY OF HEMPSTEAD	0.3004	-0.0794
CITY OF HICO	0.691	-0.2051
CITY OF HIGGINS	0.605	0.1486
CITY OF HIGHLAND VILLAGE	0.8969	-0.1486
CITY OF HOLLIDAY	0.5411	-0.0767
CITY OF HONEY GROVE	0.2722	-0.1721
CITY OF HOUSTON	0.3205	0.118
CITY OF HOWE	0.3999	-0.0577
CITY OF HUBBARD	0.2088	-0.16
CITY OF HUMBLE	0.3131	-0.0776
CITY OF HUNTINGTON	0.1544	-0.0769
CITY OF HURST	0.8559	-0.1998
CITY OF HUXLEY	0.461	-0.1425
CITY OF INGLESIDE	0.5799	-0.0742
CITY OF INGLESIDE ON THE BAY	0.4885	0.1328
CITY OF IOWA PARK	0.3108	-0.0622
CITY OF IRAAN	0.6884	0.1618

WUS Survey Name	r_Temp	r_Precip
CITY OF IRVING	0.8612	-0.1506
CITY OF JACKSONVILLE	0.7476	-0.2659
CITY OF JOAQUIN	0.2213	-0.0381
CITY OF JOHNSON CITY	0.5921	-0.0296
CITY OF JOSEPHINE	0.3158	-0.1226
CITY OF KATY	0.6532	-0.1061
CITY OF KERMIT	0.8916	0.1058
CITY OF KINGSVILLE	0.2918	-0.1087
CITY OF KIRBYVILLE	0.1079	-0.0169
CITY OF KOUNTZE	0.3912	0.0823
CITY OF LA PORTE	0.6668	0.0197
CITY OF LADONIA	0.044	0.1697
CITY OF LAGO VISTA	0.3948	-0.1534
CITY OF LAKE WORTH	0.8279	-0.1888
CITY OF LAMPASAS	0.6734	-0.1433
CITY OF LAREDO	0.8835	0.0717
CITY OF LEANDER	0.4618	-0.0452
CITY OF LITTLEFIELD	0.5342	0.1473
CITY OF LIVERPOOL	0.3082	0.1149
CITY OF LOCKHART	0.7018	-0.1824
CITY OF LONGVIEW	0.6048	-0.3491
CITY OF LORENA	0.431	-0.0769
CITY OF LORENZO	0.5816	0.3411
CITY OF MADISONVILLE	0.4446	-0.1128
CITY OF MALONE	0.1587	-0.1551
CITY OF MANOR	0.2981	-0.1612
CITY OF MARION	0.6512	-0.0538
CITY OF MASON	0.7763	-0.091
CITY OF MEADOWS PLACE	0.6553	-0.0528
CITY OF MELISSA-CITY WATER DEPARTMENT	0.4135	-0.1554
CITY OF MELVIN	0.1305	0.1112
CITY OF MENARD	0.6199	0.0042
CITY OF MERIDIAN	0.3285	-0.1253
CITY OF MESQUITE	0.7807	-0.1964
CITY OF MEXIA	0.5579	-0.0895
CITY OF MIDWAY	0.2425	-0.1687
CITY OF MINERAL WELLS	0.5037	-0.169
CITY OF MOBEETIE	0.5313	0.1599
CITY OF MONAHANS	0.8411	0.0826
CITY OF MOODY	0.5057	-0.2516

WUS Survey Name	r_Temp	r_Precip
CITY OF MORTON	0.6693	0.1612
CITY OF MOUNT PLEASANT	0.1587	-0.125
CITY OF MOUNT VERNON	0.7122	-0.317
CITY OF MURPHY	0.837	-0.2336
CITY OF NAVASOTA	0.638	-0.246
CITY OF NEEDVILLE	0.3601	0.0726
CITY OF NEW LONDON	0.4177	-0.1596
CITY OF NEW WAVERLY	0.5065	-0.0769
CITY OF NIXON	0.4691	0.0166
CITY OF NOCONA	0.507	-0.022
CITY OF NORTH RICHLAND HILLS	0.8689	-0.1906
CITY OF ODEM	0.2594	-0.0667
CITY OF ODESSA	0.7941	0.0842
CITY OF OLNEY	0.3934	-0.0228
CITY OF ORANGE	0.2665	-0.054
CITY OF ORANGE GROVE	0.4061	-0.0786
CITY OF ORCHARD	0.3999	-0.0208
CITY OF PARIS	0.7139	-0.2037
CITY OF PASADENA	0.1427	0.0202
CITY OF PEARSALL	0.6433	-0.0595
CITY OF PFLUGERVILLE	0.5967	-0.2232
CITY OF PINELAND	0.3336	-0.1899
CITY OF PLAINS	0.8136	0.094
CITY OF POTEET	0.2705	0.007
CITY OF QUANAH	0.4364	0.0506
CITY OF QUINLAN	0.2463	-0.0942
CITY OF RICHMOND	0.4435	-0.169
CITY OF RIVER OAKS	0.7452	0.0005
CITY OF ROBINSON	0.6038	-0.0465
CITY OF ROCKWALL	0.79	-0.2063
CITY OF ROSENBERG	0.7443	-0.0068
CITY OF ROUND ROCK	0.8727	-0.1531
CITY OF RULE	0.289	-0.0389
CITY OF SADLER	0.0941	-0.0626
CITY OF SAINT JO	0.183	-0.0732
CITY OF SAN AUGUSTINE	-0.0355	-0.1104
CITY OF SAN MARCOS	0.1413	-0.0514
CITY OF SCHERTZ	0.7739	-0.1791
CITY OF SEALY	0.708	-0.2122
CITY OF SEMINOLE	0.7747	0.1954

WUS Survey Name	r_Temp	r_Precip
CITY OF SHALLOWATER	0.7511	0.2098
CITY OF SHENANDOAH	0.8236	-0.024
CITY OF SHINER	0.7439	-0.1684
CITY OF SMITHVILLE	0.1353	0.1246
CITY OF SOMERVILLE	0.5683	-0.1394
CITY OF SONORA	0.454	-0.0615
CITY OF SPEARMAN	0.8174	0.445
CITY OF STINNETT	0.5809	0.1425
CITY OF STOCKDALE	0.6704	-0.1749
CITY OF SUGAR LAND	0.7751	-0.0394
CITY OF SUNDOWN	0.7865	0.2017
CITY OF SUNRAY	0.7932	0.3265
CITY OF SWEETWATER	0.6787	0.0136
CITY OF TEAGUE	0.5385	-0.1342
CITY OF TEMPLE	0.6625	-0.0631
CITY OF TERRELL	0.5693	-0.0368
CITY OF THORNDALE	0.7333	-0.1586
CITY OF TIMPSON	0.2116	-0.1211
CITY OF TIOGA	0.7199	-0.1952
CITY OF TOLAR	0.4771	-0.1282
CITY OF TOMBALL	0.6577	-0.1156
CITY OF TROUP	0.3622	-0.1138
CITY OF TYLER	0.7631	-0.3104
CITY OF UNIVERSAL CITY	0.7755	-0.2046
CITY OF UVALDE	0.6048	-0.1529
CITY OF VICTORIA	0.7546	-0.0619
CITY OF WACO	0.7943	-0.1854
CITY OF WALLIS	0.3912	-0.0227
CITY OF WASKOM	0.5013	-0.1882
CITY OF WAXAHACHIE	0.5364	-0.1222
CITY OF WEATHERFORD	0.7187	-0.1214
CITY OF WEBSTER	0.448	-0.0384
CITY OF WELLINGTON	0.6157	0.1231
CITY OF WEST UNIVERSITY PLACE	0.7946	0.0589
CITY OF WHARTON	0.393	-0.0221
CITY OF WHITESBORO	0.729	-0.1791
CITY OF WICHITA FALLS	0.7283	0.0149
CITY OF WILSON	0.6218	-0.0016
CITY OF WOODVILLE	0.171	0.0198
CITY OF WOODWAY	0.7905	-0.2104

WUS Survey Name	r_Temp	r_Precip
CITY OF WYLIE	0.7915	-0.1975
DALHART MUNICIPAL WATER SYSTEM	0.809	0.3107
EL PASO WATER UTILITIES PUBLIC SERVICE B	0.9241	0.2543
LINDALE RURAL WSC	0.6391	-0.1973
LUBBOCK PUBLIC WATER SYSTEM	0.7964	0.1755
NEW BRAUNFELS UTILITIES	0.7287	-0.204
PLAINVIEW MUNICIPAL WATER SYSTEM	0.6199	0.0961
RICHLAND SUD	0.3091	-0.2344
SAN ANTONIO WATER SYSTEM	0.7117	-0.2095
TOWN OF FLOWER MOUND	0.8904	-0.1833
TOWN OF HIGHLAND PARK	0.8476	-0.2079
VILLAGE OF SAN LEANNA	0.7758	-0.1745