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Guidance Document for Water Utilities

A Guide to Customer Water-Use Indicators for Conservation and Financial Planning

By

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Introduction

Customer water-use data and analyses are essential to understanding water use among different subgroups of customers, planning and implementing successful water conservation programs with appropriate water-saving goals, and setting rates that effectively meet utility objectives. By segmenting a customer base by water use and benchmarking consumption over time, utilities can better design and target conservation programs and rate structures. Water-use indicators can be used to categorize each customer's water use patterns over a period of time and identify subgroups of customers with similar patterns. These subgroups go beyond the sometimes ambiguous and generic classification of "residential" or "commercial, industrial and institutional (CII)" customers, to a more precise categorization of *individual* customers based on their own water-use patterns. This method segments a customer base further within the larger and more traditional classifications to help utilities better understand customer consumption patterns. Using the proposed indicators in this document will guide a utility to divide its customers into several subgroups based on unique water-use patterns.

Purpose

The purpose of this guidance document is to introduce nine indicators or metrics that a water utility can use to segment its customer base by water use and demonstrate how these indicators can be useful in conservation program planning and rate design. Ultimately, by integrating these data-driven metrics into conservation and financial planning, a utility can better anticipate customer water use for infrastructure planning and development purposes. Rather than assuming the traditional approach of designing and applying rate structures for large classifications of customers generalized as one average customer (e.g., "an average residential customer"), the application of customer water-use indicators enables planners to better focus program and budget allocations toward the smaller subset of inefficient customers likely to have the greatest need for conservation-oriented rate pricing signals and water-saving measures. This data-driven approach minimizes money and time spent on communicating with low-use "super savers" and thrifty customers for whom conservation education is not a significant need. It can also help a utility better anticipate and even influence customer demand to avoid costly infrastructure expansion.

This guidance document is intended to be accessible and easy-to-use. Recognizing the fact that there are dozens of water-use analytical techniques, indicators, and/or metrics that can be applied to utility metering and billing datasets, this document is purposely concise. The aim is to help water planners and engineers focus on common planning priorities while keeping them "out of the weeds" on what can quickly become a complicated topic. For this reason, simplified descriptions of definitions, calculations and examples of each indicator are provided to help jumpstart water planners and others in their preparation and use. References for additional documents that delve into more detail on water-use indicators and related topics are provided at the end of the document.

The Importance of Standardizing Water Use Indicators

Current utility practices for customer water-use data collection and analysis are often limited, resulting in water-use indicators that are overly general and of limited usefulness. Indicators can be prepared on many scales (e.g., utility-wide, system-wide, per account, per person, per service area), for different timelines (e.g., per day, per month, per year), and for many customer classes and water-use categories (e.g., all customers, only residential customers, single-family residential customers).

For example, one of the most commonly used water-use indicators is *average water use per capita*. Average water use is typically used

- to track and evaluate customer water demand in comparison to historical demands and available supply,
- to compare water use to a performance target set by conservation programs or by benchmarking to other utilities' average water use,
- as a demarcation point between low and high water users, and
- as the basis for making water-demand projections which are critical in setting rates and planning for system expansions.

Despite being a ubiquitous metric, calculating average water use using any one of these specific scales varies significantly among utilities, which complicates comparisons and benchmarking. For instance, while some utilities base the calculation of [average] gallons per capita per day (gpcd) on total water use, including demands from all residential, commercial, and industrial customers, other utilities compute gpcd based only on their residential water use and number of residential customers. Even in the latter case, some utilities include water use from multi-family residential customers in the calculation, while others only compute gpcd from individually-metered, single-family residential customers. Although all of the utilities in this example will determine a single gpcd estimate for average water use, the estimates are not comparable to each other when the types of data used to compute gpcd differ. While average single-family water-use metrics reflect a relatively small number of types of indoor and outdoor end uses of water that are common to most single-family homes, an average water use gpcd metric for an entire city reflects thousands of different types of water-using activities, including home, commercial, and industrial uses. Thus, one city's average water use is not necessarily comparable to another's. Furthermore, a system-wide average neglects the nuances of individual customer behavior and is not specific enough to detect some significant changes in water-use behavior.

The lack of commonly defined metrics or customer water-use indicators can limit a water provider's ability to accurately profile its customer base and the nuances of each customer class and subgroup. In addition, many billing systems lack customer characteristics, such as building square footage, number of occupants, etc., that can help generate meaningful metrics. These limitations may be costly for a utility and result in a failure to reach conservation planning and rate design goals. For example:

- Water conservation programs that spend money on educational and rebate program campaigns that broadly appeal to all customers, such as customer billing inserts, are likely to cost more money than focused outreach approaches. In contrast, rebates and other types of water-saving programs that target the highest water-using customers by stratifying customer water demands and using indicators to identify subgroups of customers for whom a particular water-saving measure can often be more cost-effective, as discussed in Dallas (Texas) Water Utilities (2010), Waukesha Water Utility (2012), and Vickers (2012 and 2001).
- Rate structure design and levels set to target certain categories of water users without determining the number of customers impacted can bias financial decisions. For example, utilities often describe rate increases in terms of the amount a monthly bill would increase for “an average level of consumption” or for “an average customer.” Rate increases “at the average level of consumption,” therefore, are only meaningful to those customers whose water use is consistently near the average level. Through customer segmentation, a utility can better understand and communicate the impact of rate adjustments on its entire customer base.
- Revenue forecasts made using billing-level data, rather than customer-level data, can overlook customer-level behavior change. For example, a utility using a utility-wide average to track water use may overlook a sub-trend of high-water users using less and low-water users using more. This change in customer behavior could result in maintaining the utility-wide average water-use level but decrease the revenues collected from high volume sales, particularly for utilities with increasing block rate structures.

This guidance document defines nine water use indicators and their application to conservation and financial planning. The indicators focus mostly on single-family customer water use, unless otherwise noted. Utilities may wish to develop additional water-use indicators that guide their conservation and financial planning and decision-making process. As long as data are collected consistently and comprehensively, they can be revisited and new indicators can be calculated in the future as needed.

Data Preparation

Preparation of customer meter or billing data is an important step in the generation of accurate water-use indicators, but it can also take time because most water utility billing systems are not built and designed to easily produce customer analytics. While this guidance document does not describe that process, guidance on how to collect and prepare customer water-use data from basic billing records to calculate many of the indicators described in this document are outlined in the *Journal AWWA* article, “Mining Water Billing Data to Inform Policy and Communication Strategies” (Boyle et al. 2011).

Benefits

Benefits of mining customer water use data from billing or meter records and using quantitative indicators to develop utility plans include:

- Better informed conservation program goal-setting and targeting of high water use customers,
- Development of a deeper understanding of the multiple types of customer subgroups that exist within a service area and within the same customer category or class,
- Definitions of thresholds for water-use efficiency that are comparable to benchmarks,
- Communication of the impact of rates and conservation programs to targeted customers establishing rate blocks that are most appropriate considering the diversity of customers,
- Monitoring of changing water use trends among key customer groups for financial and water resources planning,
- More accurate forecasting of customer water demands,
- Determination of conservation program costs, such as on a million gallons per day (mgd) capacity, that are comparable to infrastructure expansion and other water supply development options,
- Efficient targeting of customers for participation (or not) in conservation programs
- Better understanding of the trends and drivers of customer water use to use in setting rates and budgeting revenues, and
- Tailoring rate structures at the individual customer level that can help overcome the challenges of setting rates to achieve revenue and conservation goals.

Nine Customer Water Use Indicators to Segment a Customer Base for Conservation Planning and Rate Design

Descriptions, examples, and simplified calculations are provided for the following single-family customer water use indicators[3]:

1. Customer Average Use
2. Rank of Customer Average Use
3. Percentile of Customer Average Use
4. Zero- and Low-Use Accounts
5. Customer Baseline Demand
6. Customer Maximum Demand
7. Customer Peaking Ratio
8. Customer Use Profile
9. “Hidden” Irrigation Accounts

Examples of what each indicator can be used to identify are shown in Table 1.

[3] The indicators are hyperlinked to the relevant document location. Click on any indicator title to read about it.

Table 1. Examples of what each single-family customer water use indicator can be used to identify

Single-family customer water use indicator	Customers that use relatively low volumes of water	Customers that use relatively high volumes of water	Customers with potential meter accuracy problems or water theft	Customers that are part-time or seasonal residents	Customers that are affected by tiered water rates	Each customer's non-discretionary demand	Customers with significant discretionary water use	Customers with outdoor demand not measured through separate meters
Customer Average Use	X	X			X		X	
Rank of Customer Average Use	X	X						
Percentile of Customer Average Use	X	X						
Zero- and Low-Use Accounts	X		X	X				
Customer Baseline Demand		X			X	X		
Customer Maximum Demand	X	X			X		X	
Customer Peaking Ratio				X			X	
Customer Use Profile	X	X		X	X	X	X	
"Hidden" Irrigation Accounts		X					X	X

1. CUSTOMER AVERAGE USE

Average customer water use is a common indicator that can be computed in many ways, each with its own interpretation of the data, as explained previously.

For conservation planning, the gallons per capita per day (gpcd) water use indicator for single-family residential customers across a utility service area is a useful one that can be computed, monitored, and reliably compared with a water efficiency target or average single-family gpcd factors reported by other water utilities. Conservation planners may also set a water efficiency goal or target, such as 50 gpcd for homes with little or no outdoor water demand, that they aim to achieve among their residential customer base system-wide.

For financial planning, the average monthly water use indicator for single-family customers is useful to evaluate the distribution (frequency) of water demand across all households in a service area. Similar to the single-family gpcd indicator, monthly household water demands can be compared with efficiency standards and goals and are also useful in utility rate design and setting related customer fee allocations.

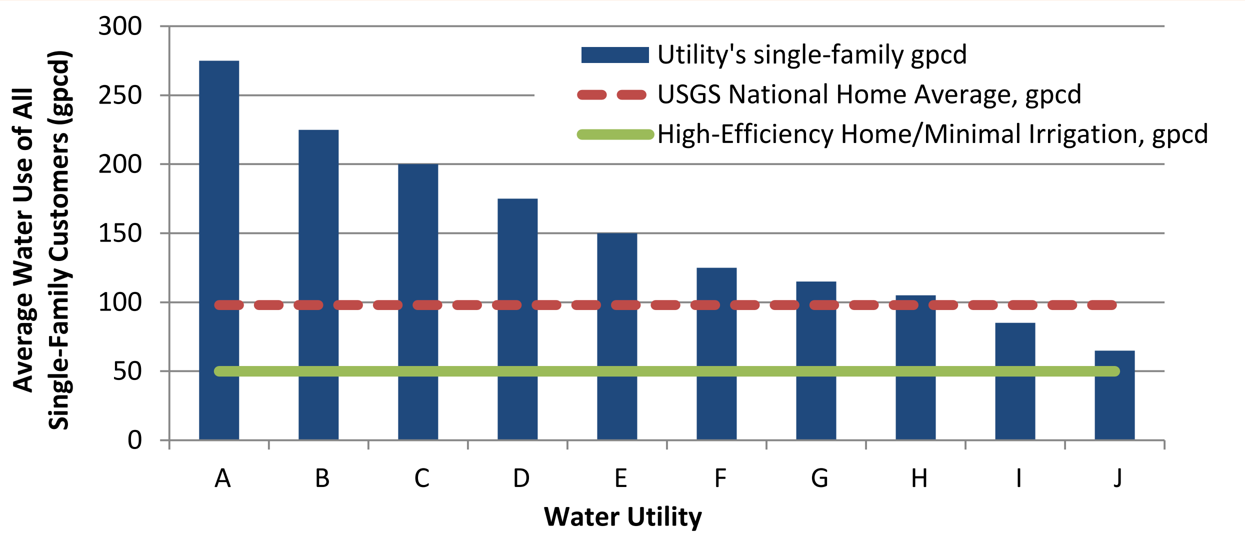
Few customers' average water use is actually exactly the average reported for all customers in a service area. For example, if a utility determines that the average single-family residential water use is 125 gpcd, the vast majority of single-family residential customers average consumption levels will be either lower than or greater than 125 gpcd. Single-family residential customers can, therefore, be further segmented into separate subgroups based on their own individual-level water use, which can improve financial and conservation planning. Calculating every single-family residential customer's average use over a period of time allows the utility to better understand the level of water resource use of its residential customer base and also determine the effect of changing rates or rate structures on different subgroups of residential customers.

Examples

a) *System-wide* single-family gpcd for conservation planning:

Representative examples of average single-family water use, calculated in terms of gpcd, among 10 U.S. cities is provided in Figure 1. These examples illustrate both variations in water use among households and how close to the national average (and how far apart from) some cities' water-use efficiency is compared to the suggested benchmark for a high-efficiency home with minimal irrigation. For example, residential water demand is reported to average about 98 gpcd, according to the most recent U.S. Geological Survey (USGS) report of estimated water use in the United States (Kenny, et al. 2009). However, the widespread availability of high-efficiency plumbing fixtures, appliances, and water-thrifty outdoor water practices, such as native and adaptive turf and other plants that can thrive with rainfall only once they are established, can reduce combined home indoor and outdoor water use to 50 gpcd or lower (Vickers 2001) for many, if not most households. While most U.S. single-family homes do not have that level of water efficiency due to older inefficient fixtures and wasteful outdoor water use practices, 50 gpcd can often be a realistic goal and water efficiency benchmark for many given current plumbing, appliance, and landscape water conservation standards and practices.

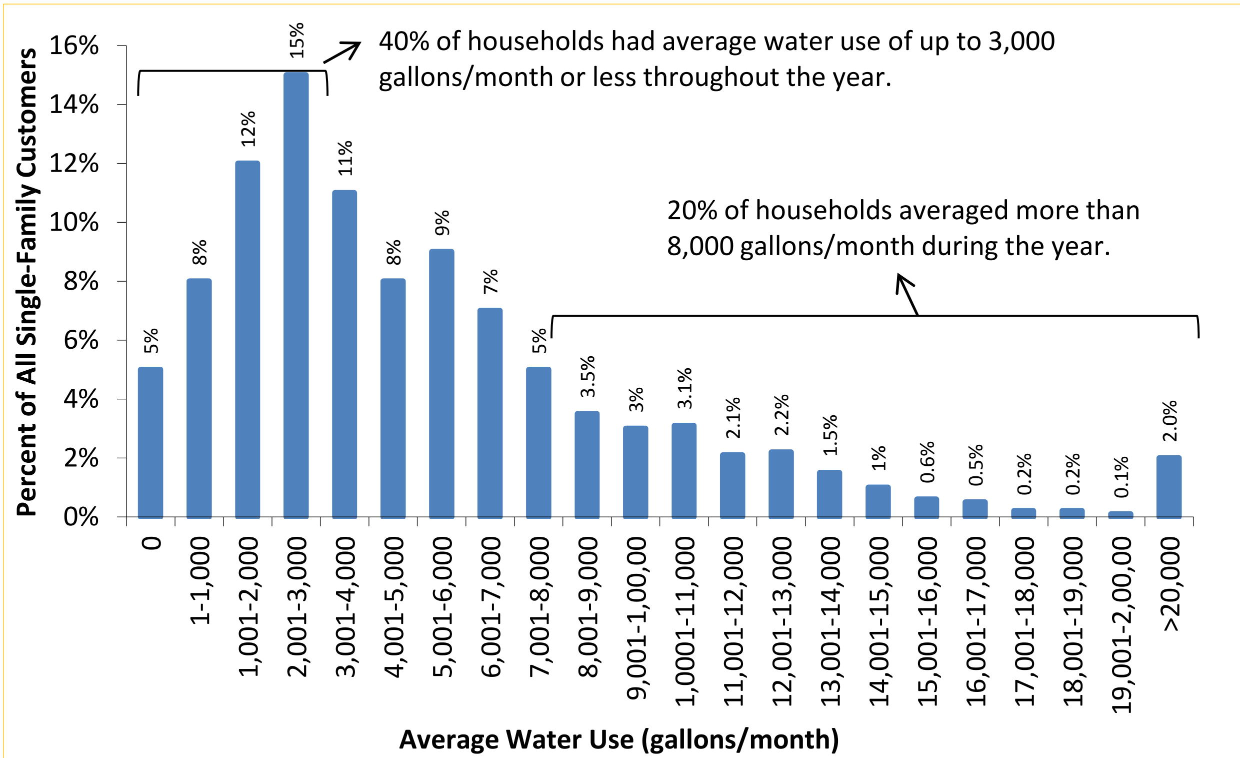
Figure 1. Representative examples of system-wide average water use of all single-family customers among 10 U.S. water utilities compared with national average and high-efficiency benchmarks



There are two methods to determine the average water use for single-family customers in gallons per capita per day (gpcd): sum all single-family water demand and divide it by the total single-family population, or calculate the average single-family account water demand and divide it by the average household size for single-family dwelllings in the service area. The water use efficiency of a utility's single-family gpcd can be compared with regional or national single-family averages as well as efficiency benchmarks or goals.

b) *Individual* single-family customers' average use for financial planning: A distribution of single-family residential customers' average monthly water use for one utility is shown in Figure 2. In this utility, 40 percent of the single-family customers averaged up to 3,000 gallons/month (or 100 gal/account/day), indicating that these customers have lower water needs on average throughout the year compared with the other 60 percent of single-family customers. On the other hand, 20 percent of the single-family customers had an average water use of more than 8,000 gallons/month (gal/mo). These customers vary between those that use large volumes of water throughout the year and those that have significant seasonal (discretionary) water-use demands.

Figure 2. Percentage of single-family residential customers' average monthly water use over a 12-month period



Each single-family residential customer's average demand is calculated for the year. The average demand is calculated as the individual single-family's total demand divided by the number of bills that single-family customer had during the year.

Simplified Calculations

a) System-wide single-family gpcd:

1. Identify all single-family residential bills over 12 months (note: billing periods may vary by utility. Exclude zero- and low-use water-use accounts from calculations.).
    a. *Single-family gpcd:* Sum total water use in gallons for the year among all households and divide by 365 days in the year, and divide by the reported or estimated average total number of individuals living in single-family residences in the customer base. The result is average single-family gpcd.
    b. *Single-family average use per account:* Sum total water use in gallons for the year among all households and divide by 365 days in the year, and divide by the total number of single-family accounts (households). The result is average single-family gallons per account per day.
2. Calculations for other customer average use metrics are numerous and vary for each metric. See Dziegielewski and Kiefer (2010b) for specific guidance.

b) Individual single-family customers' average water use:

1. Identify all single-family residential bills over 12 months (note: billing periods may vary by utility). Track each household's bills over time using a premise or account identification number.
2. For each household, calculate the total water use over the 12 months at that specific household, and divide by the household's number of bills during the year. This computes the customer average use for each individual household.
3. Compute the cumulative distribution by increasing or decreasing volume of all customers' average water use from 1,000 gal/mo to the highest average water use for any customer, as expressed in the example shown in Figure 2.
4. See Boyle et al. (2011) for more detailed guidance.

2. RANK OF CUSTOMER AVERAGE USE

The individual customer's average water use can be ranked to express its relative position to other customers in a service area. Customer ranking is typically assigned using ordinal numbers in ascending order, e.g., the highest rank (number 1) for the individual customer who is the highest volume user, and on a percentile rank basis for a group of customers, e.g., the 100th percentile. A rank analysis of individual customers' average water use is very similar to a percentile use analysis (water use distribution or frequency), described in Section 3, and the two are often described and evaluated together.

Ranking individual customers by their average water use relative to other customers is useful to identify and prioritize those customers with the highest potential for water savings from conservation. For example, targeting a utility's highest water-using groups of customers, such as the top 500 water users, for participation in conservation programs may often yield the largest water savings on a per customer basis, as well as per program dollar spent. Furthermore, identifying high water users is important when setting rates and budgets because these customers pay a disproportionately large percentage of total customer charges that generate utility revenues. Thus, utilities typically want to be prepared for any significant declines in water use by customers with high water demands.

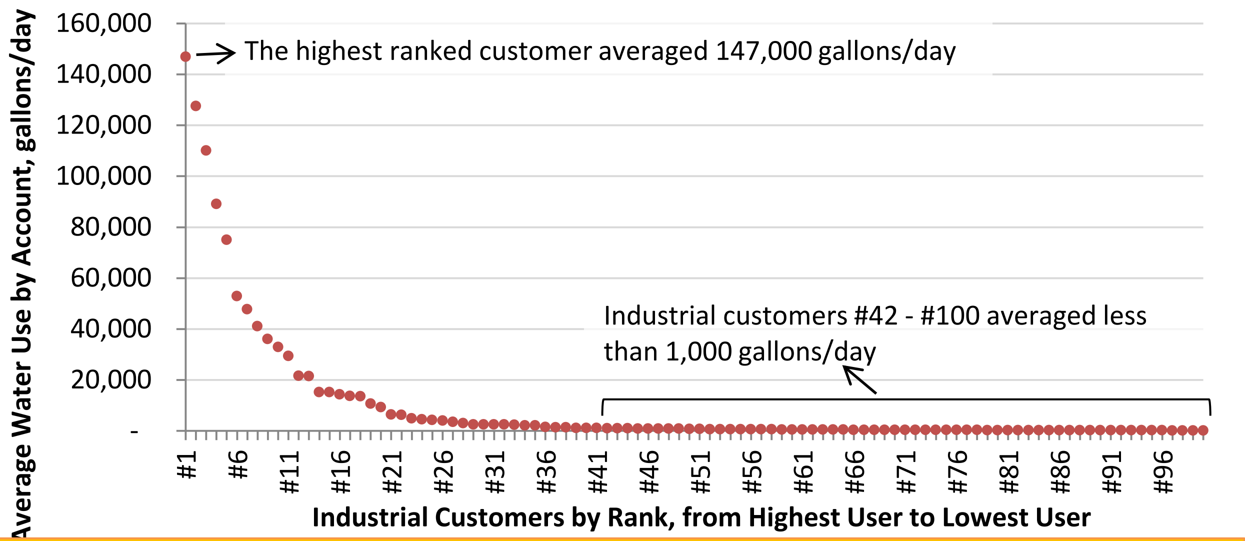
Example

An example of individual customers' average water use on an ordinal rank basis for 100 industrial customers served by a mid-size water utility is shown in Figure 3. Findings from this ranking indicator include:

- The highest ranked (number 1) industrial water customer averages 147,000 gal/day or 16 percent of all industrial water demand. That customer, along with the next 14 (numbers 2 to 15) top-ranked customers, use 84 percent of all industrial demand in the service area. The water-use efficiency of these top 15 customers is unknown, but their disproportionate water demands indicate they may have significant potential for reduced demands compared with lower-ranked customers with much lower water demands. Infrequently, very high water use can be indicative of an over-registering meter. Time and money spent conducting industrial water use audits and funding water efficiency measures for the highest ranked customers by average water use will likely produce better results than those realized at smaller industrial sites.
- Water use by the lowest ranked industrial customers, such as those ranked from 42 to 100 whose average use is less than 1,000 gal/day, indicate the need for follow-up by the utility to clarify why use is so low for an industrial account. For example, very low water-using accounts should be checked for meter size

accuracy, calibration, and sometimes water theft. Undersized and uncalibrated meters represent potential revenue losses that could be recouped. Very low-ranked industrial accounts with legitimate low usage may be more appropriately classified as commercial accounts in some cases. Low use can also reflect weak economic conditions for some customers that may be a short- or long-term trend and may affect utility revenues and financial planning.

Figure 3. Rank of industrial customers by average water use



The customer rank indicator is useful in singling out the highest volume customers. In ranking customers by average water use, ordinal numbers are assigned in ascending order from the highest using customer on to the lowest. Customer ranking is relative to other customers so that utilities can prioritize their conservation programming efforts. From a financial planning perspective, the revenue provided by these customers should be evaluated from a revenue stability standpoint.

Simplified Calculation

1. Determine each customer account's average water use over at least a 12-month period, preferably on an average daily basis. Exclude zero- and low-use water-use accounts from calculations.
2. Total the average daily water usage for all accounts.
3. Sort the list of customer average daily water use in descending order. For example, sorting a list of 100 customers, the customer with the highest average water use will be the first account in the list and ranked number 1, and the customer with the lowest water use will be the last account on the list and ranked number 100.
4. Compute the cumulative distribution of all customers' daily water use averages by volume and ranking across a range from the highest gal/day to the lowest.

3. PERCENTILE OF CUSTOMER AVERAGE USE

A percentile or frequency distribution of individual customers' average water use provides information about the relative significance of water demand by each water user or subset of users in relation to all water customers. After computing the rank of customer average use, customers are grouped into percentiles based on their rank. For example, the 1st percentile represents the group of 1 percent of customers with the highest water demands, while the 100th percentile represents the customers with the lowest water demands.

In conservation program planning, percentile distribution charts and tables are useful to identify customers with water use that is above or below a relative normal or reasonable value, such as the system-wide average water use or median individual customers' water use. For example, customers in the first 50th percentile (representing the median of customer average water use levels) can be characterized as high water users and are often good candidates to target for water conservation program participation. Similarly, customers whose average water use falls below the median (i.e., those between the 51st and 100th percentiles) may be described as low water users that are likely to be more efficient water users with a lower potential for water savings from conservation programs.

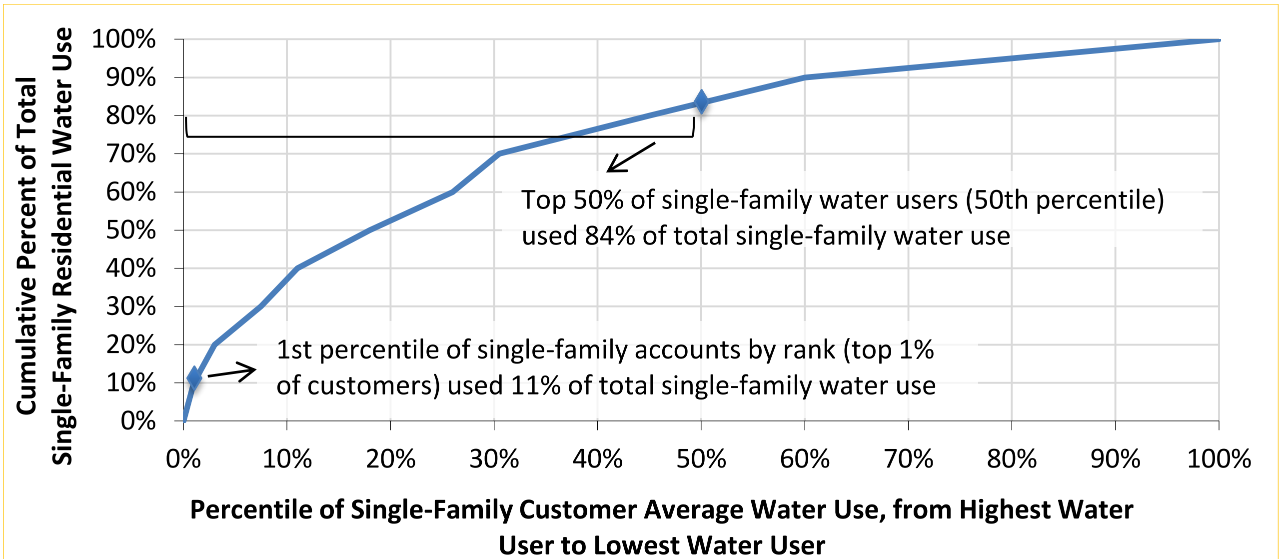
Example

An example of percentile distribution of single-family residential water use in one utility is illustrated in Figure 4 and summarized in Table 2. Findings from these data and illustrations include:

- The system-wide average water use for single-family residential customers is 286 gallons per account per day. By comparison, individual customer average water use by the customers in the 50th percentile of all single-family residential accounts significantly exceeds that system-wide average and consumes much higher volumes (average 481 gal/account/day). In contrast, the bottom 50th percentile of accounts average only 90 gal/account/day.
- Customers with the highest demands, particularly the top 1 percent and 10 percent of single-family residential customers (i.e., the 1st and 10th percentile, respectively), also are likely to have high to extremely high outdoor water demands, estimated at 2,011 gal/account/day to 559 gal/account/day, respectively. No matter their household sizes, these very high water demands likely reflect some water waste. The high outdoor water demands for customers in these accounts, which likely do not reflect household size because such high demands are typically associated with discretionary water use, are likely indications of excessive lawn and landscape irrigation and other outdoor uses that could be reduced with conservation measures. In some cases, very high water demands can be a misclassification of non-residential customers.

- The bottom 50 percent or lowest water-using single-family residential accounts, defined as being below the median (close to the average of 286 gal/account/day), as a group average only 90 gal/account/day. These relatively water thrifty or "super saver" customers, particularly in the highest percentile groups, likely have a small potential for water savings compared with customers in the 1st to 50th percentiles. The reasons for such low use among these customers could be many, but are likely due to small household sizes, part-time or infrequent occupancy, and less likely but possibly meter accuracy problems, data collection error, and water theft.

Figure 4. Cumulative distribution of residential water use by percentile of single-family residential customers based on rank of average water use over twelve months



This indicator describes the relative significance of water demand by each customer or subset of customers in relation to all customers. Customers are ranked on a scale of 1 to 100, with 1 representing customers with the highest water demands and higher percentiles representing customers with lower demands. This indicator is useful in identifying customers with use above or below a relatively normal/reasonable amount.

Table 2. Residential single-family customer water use by percentile

Single-family customers (percentile in parentheses)	Number of active accounts	Average account demand (gal/day)	Average account indoor demand[a] (gal/day)	Average account outdoor demand[b] (gal/day)	Outdoor water use percentage[c]
All accounts	270,804	286	188	98	34.2%
Top 1% accounts (1st)	2,708	3,288	1,277	2,011	61.2%
Top 10% accounts (10th)	27,080	1,093	534	559	51.2%
Top 25% accounts (25th)	67,701	701	383	319	45.4%
Top 50% accounts (50th)	135,402	481	291	190	39.5%
Bottom 50% accounts	135,402	90	76	14	15.3%

[a] Average demand for the minimum use month for the aggregated accounts.
[b] Calculated by subtracting average account indoor demand from the average account demand.
[c] One year's data (or multiples thereof) must be used to estimate an annualized outdoor water use percentage. The outdoor water use percentage for the chosen period represents recent residential water use and is reasonably consistent with the historical average.

Simplified Calculation

1. Compute the rank of customer average use as explained in Section 2. Sort the customers by rank from highest water user to lowest water user. Exclude zero- and low-use water-use accounts from calculations.
2. Divide the rank for each customer by the total number of customers. This number is the percentile of the customer based on the rank of their average water use.
3. Determine the percentage of average water use for each active account compared with the total demand of all active accounts. Adding the percentages for all accounts should total 100 percent.
4. Compute the cumulative distribution of customers' water use by summing the water use of all customers from the highest user (rank 1) to each subsequent user.

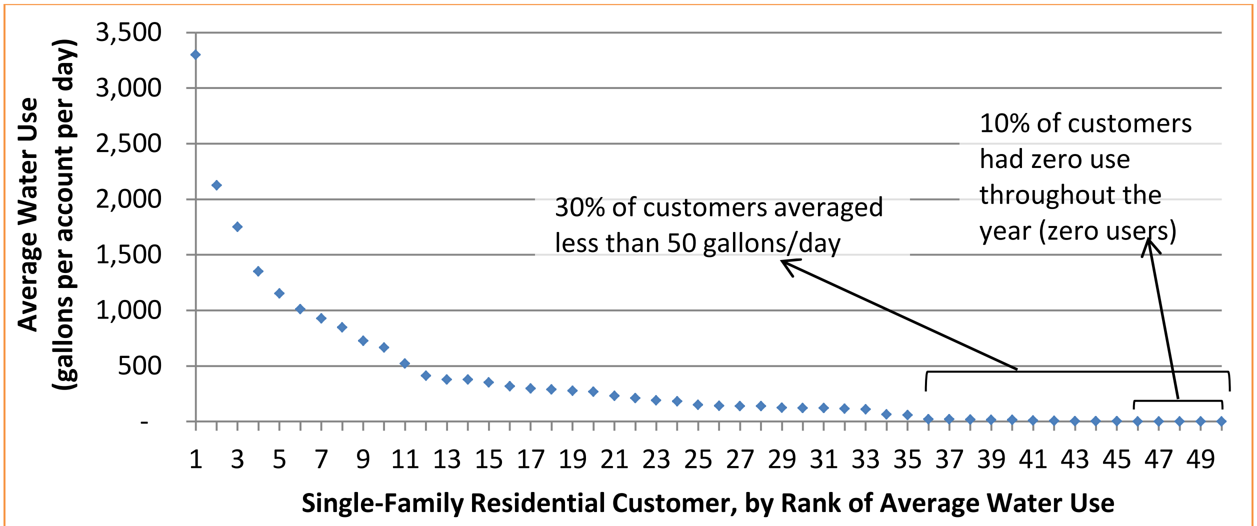
4. ZERO- AND LOW-USE ACCOUNTS

Customer accounts that are listed as active but have zero or very low water use consistently for several consecutive billing periods can be an indication of a potential problem that requires evaluation by the utility. Meters consistently registering zero or low water use can reflect legitimate conditions, such as customers who are away, seasonal residents and businesses, and submeters for industrial water-using equipment that is used irregularly, but they can also indicate problems. Common reasons for zero- and low-water-use meter readings include broken, under-registering, and poorly sized meters, water theft, and closed or unoccupied properties. Whatever the case, the reasons for the consistent zero or low readings merit investigation and correction, if necessary. Further, zero-water-use accounts for unoccupied or closed properties should be notated as such or purged from active billing records so calculations of average customer water use and related statistics do not include zero-using accounts or those with very low use (e.g., a few gallons or less per day).

Example

A distribution of 50 residential accounts, including low- and zero-use accounts, is shown in Figure 5. In this example, 30 percent of customers averaged less than 50 gal/day over 12 months, including 10 percent that averaged 0 gal/day. In other words, 10 percent of the customers registered zero water use over 12 months.

Figure 5. Distribution of single-family customer water use by rank, including zero-use and low-use accounts



In generating this indicator, active customers (from a billing perspective) are differentiated compared with those customers identified as inactive or low activity from a water use and revenue perspective. This list of customers is a good start for verifying building occupancy, checking meter operation and accuracy, and/or cleaning up active customer databases.

Simplified Calculation

1. Review customer account meter records monthly. Identify and flag all zero- and low-use accounts, particularly after several (e.g., three) consecutive billing periods of zero- or low-use.
2. Zero-consumption accounts are those for which no water use is recorded in a billing cycle. Utilities with real-time automatic metering reading information systems can detect potential problem accounts much earlier than would be noticed in a review of periodic customer billing reports, e.g., with a quarterly billing system.
3. Low-use customers are those with readings below a minimum threshold of water use, usually less than 1,000 gal/mo for single-family residential customers. Homes with one person that are very water-efficient may average less than 50 gpcd or approximately 1,500 gal/mo.
4. Customers with zero- or low-use, usually for two to three consecutive billing periods, should be contacted for a site visit to verify building occupancy, check for meter operation, accuracy and sizing, and investigate other possible reasons for low- or no water use.
5. Close or categorize legitimate (non-theft) zero-water-use accounts as inactive and remove them from the active customer water-use list. The customer account may be kept open or closed depending on customer circumstances and utility policy. Customers with legitimate low water use, such as those who are part-time or very water-thrifty occupants, should be noted as such on their account records to avoid further unnecessary evaluation.

5. CUSTOMER BASELINE DEMAND

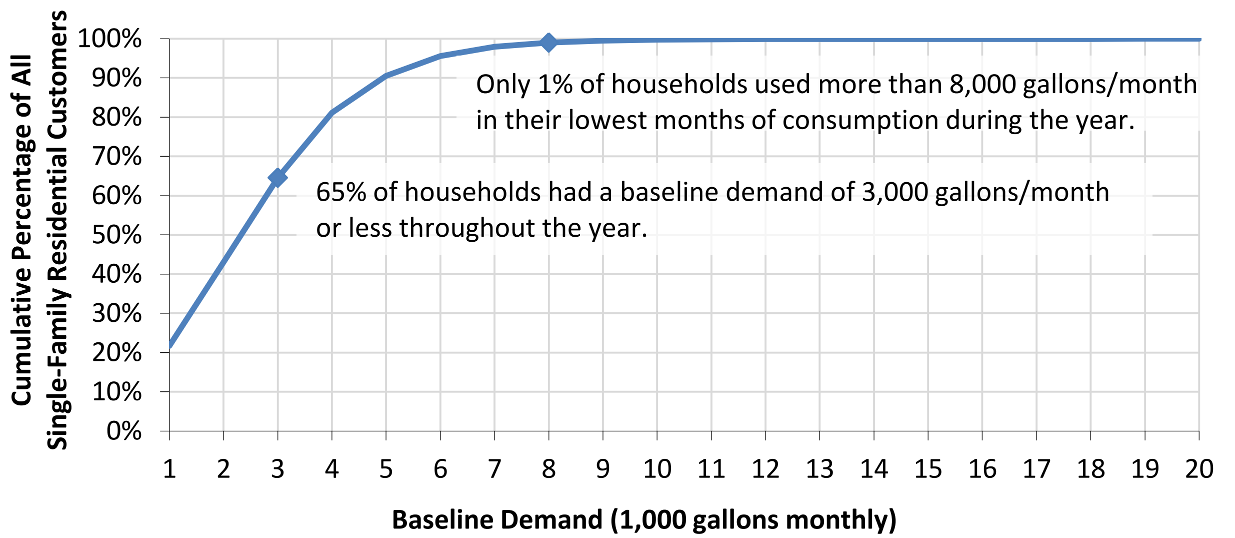
A customer's lowest months of consumption throughout a year indicate a baseline of demand that is a useful proxy for indoor demand. This baseline water demand can be used to estimate a household's nondiscretionary water use. For utilities with seasonal demand increases in warmer months only, many customer baselines are most likely to occur in the winter months. In contrast, baseline months do not necessarily occur during winter months in warmer regions where customers may irrigate year-round. In all cases, however, the baseline months do not necessarily occur in the same season for all customers of the utility. Customers that do not have seasonal demands for water can have baseline demands in any month of the year.

Water resource managers will find that tracking customers' baseline demands helps to assess the impact of indoor efficiency measures. Additionally, utilities can use baseline estimates to identify households and other water users that have high baseline water demand levels and to target those customers for appropriate conservation measures. These customers may have large household sizes or other reasons necessitating large baseline water demands, which would be difficult to reduce without the adoption of more efficient indoor water-using technologies. These households may also be financially penalized year-round under an increasing block rate structure where their baseline demands always exceed the lower rate blocks.

Example

A distribution of single-family residential customers' baseline demands is shown in Figure 6. In this example, 22 percent of the single-family residential customers had a baseline demand of up to 1,000 gal/mo, indicating that they have very low water needs for a large portion of the year, and may already be very efficient in their indoor water use. On the other hand, 1 percent of the single-family residential customers had a baseline demand of more than 8,000 gal/mo. These customers use large volumes of water throughout the year, whether because of inefficiencies or because of large family sizes, and may be penalized by increasing block rate structures that set higher tier rates before 8,000 gal/mo. Targeting indoor water-use efficiency programs to these customers may help lower their baseline (and year-round) water use.

Figure 6. Cumulative percentage of single-family customers' baseline demand



Each household's baseline demand is calculated for the year. The baseline demand is often calculated as the average of a household's three lowest months' of non-zero water use records (or two lowest non-zero periods of bimonthly records). This level of water use is usually the best way to estimate a household's non-discretionary water use, particularly for customers in climates that have cold winters (no landscape irrigation or outdoor water uses).

Simplified Calculation

1. Eliminate all bills with zero water use from the analysis.
2. For each customer, sort non-zero water-use records by volume over at least a 12-month period in ascending order. The lowest non-zero water use for the customer, regardless of what month it occurs in, will be sorted first. The second lowest is #2, etc. The bill periods do not have to be consecutive chronologically.
3. Average the lowest months:
   a. For utilities with monthly billing, average the lowest three non-zero water-use records (ranked 1, 2, and 3) for each customer to determine the customer's baseline demand.
   b. For utilities with bimonthly billing (or a combination of monthly and bimonthly billing), average the lowest two non-zero water-use records (ranked 1 and 2) for each customer to determine the customer's baseline demand.
   c. For utilities with quarterly billing, or for utilities with any billing frequency whose majority of customers irrigate year-round, the single lowest non-zero water-use record for each customer is the customer's baseline demand.
4. Compute the cumulative distribution of all customers' baseline demands by volume from 1,000 gal/mo to the highest baseline demand for any customer.

6. CUSTOMER MAXIMUM DEMAND

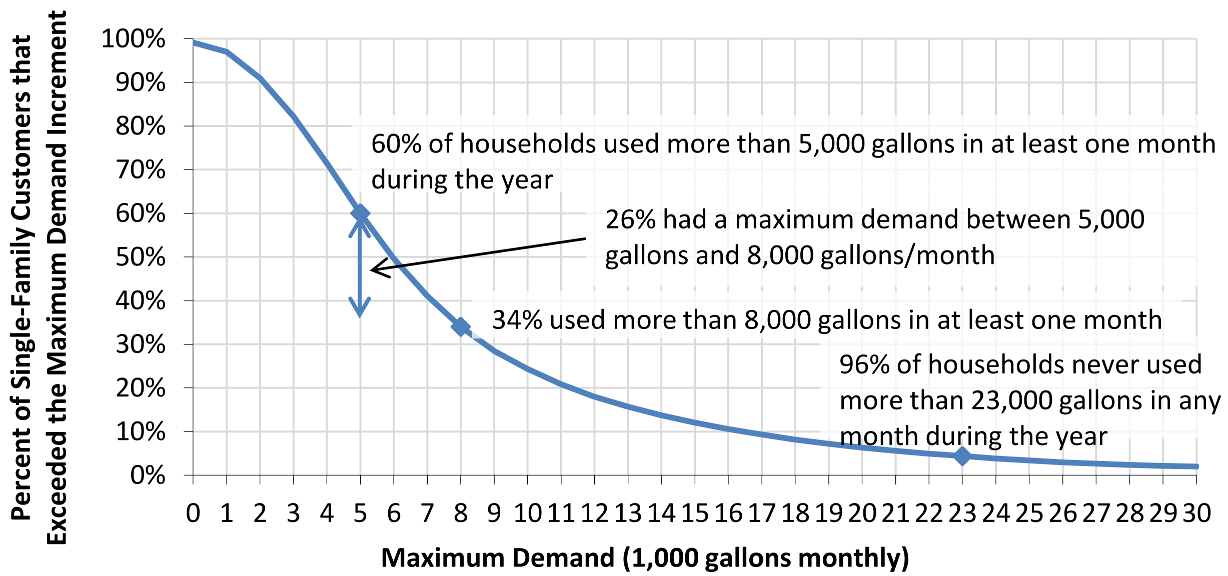
A customer's maximum demand is the point at which a customer's demand peaked in one year. Water utilities can use information about customer maximum demand levels for several planning purposes, including designing programs, pricing, or policies to drive down the highest levels of water consumption. Trends in maximum demand can show movement toward or away from a water efficiency goal or benchmark. In general, customers who have primarily only essential indoor demands (i.e., for washing, cooking, and drinking) will have lower levels of maximum demand than customers who also have non-consumptive discretionary uses of water (e.g., outdoor irrigation, car washing, filling swimming pools).

By assessing a customer's highest water use in a given year, a utility can determine the proportions of customers that have different types of water needs. This is particularly important for utilities with block rate structures, since this indicator allows the utility to determine how many customers are affected by the different block rates. For example, how many customers will always, sometimes, or never cross a certain threshold and be subjected to higher block rates?

Example

The inverse cumulative distribution of single-family residential customer maximum demands for one utility is shown in Figure 7. In this example, 60 percent of the single-family residential customers exceeded 5,000 gal/mo at least once during the year; i.e., 60 percent of the single-family residential customers had a maximum demand greater than 5,000 gal/mo. Thirty-four percent of the single-family residential customers had a maximum demand that exceeded 8,000 gal/mo. This means that 26 percent of single-family residential customers had a maximum demand between 5,000 gal/mo and 8,000 gal/mo. Only 4 percent of single-family residential customers exceeded 23,000 gallons in any one month during the year.

Figure 7. Percentage of single-family customers that exceeded maximum demand levels in at least one month of the year



Each household's maximum demand is calculated for the year. The maximum demand is the largest monthly water use of a household during the year, regardless of what month it occurs in. This level of water use is helpful to determine the number of households that are impacted by various block rates.

Simplified Calculation

1. For each customer, determine the highest water use over at least a 12-month period, regardless of what month it occurs in. This is the customer's maximum demand.
2. For customers with reported leaks, reduce their water volume by the portion that was determined to be due to a leak.
3. Calculate the number and percentage of customers whose maximum demands exceeded 1,000 gal/mo, 2,000 gal/mo, and so on through the highest maximum demand for any customer.

7. CUSTOMER PEAKING RATIO

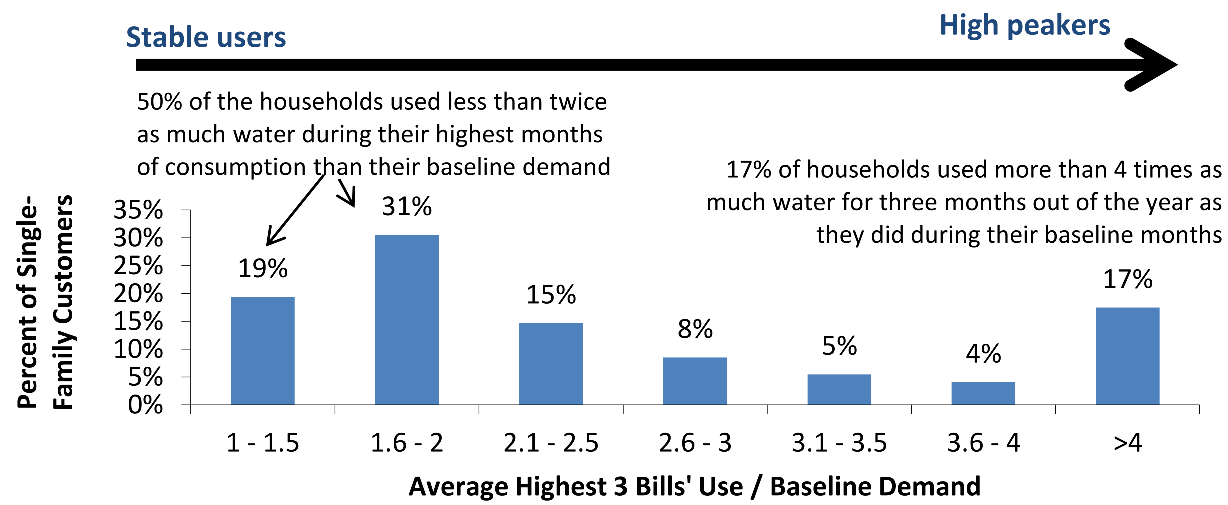
Peaking ratio compares a customer's highest demand to their baseline demand. The peaking ratio can be used to explain that for at least part of the year, a particular customer used [peaking ratio] times the amount of water than they did during their lowest months of use. For example, a customer with a peaking ratio of 2.0 used twice as much water during a specific period (i.e., the period with their highest demand) as they did during their period of lowest use (i.e., the customer's baseline). This indicator identifies the customers with discretionary water use and reveals how much water use "slack" a customer may have. This helps a utility target conservation messaging and programming to customers with the most slack or highest peaking ratio, which is also useful during periods of utility drought response.

Of course, there are other reasons why a customer may have a high peaking ratio. Customers who were absent from their homes for parts of some months are likely to have a high peaking ratio when they occupy their homes for whole months, as are those customers who have a significant change in their household condition (e.g., home remodel, installation of a new garden).

Example

The peaking ratios of all single-family residential customers for one utility are shown in Figure 8. In this example, 50 percent of the single-family residential customers used up to twice as much water in their highest months of use compared with their baseline demand, suggesting moderate levels of seasonal demand. Nineteen percent of customers used almost the same amount (peaking ratios up to 1.5) of water every month of the year, suggesting low seasonal fluctuation in water use. On the other hand, 17 percent of single-family residential customers used more than four times as much water in their three months of highest water use than they did during their baseline demand period. Customers with a high peaking ratio use only a small fraction of their highest demand during at least three months of the year, implying that their high demand may include significant discretionary use of water.

Figure 8. The peaking ratio of single-family customers' average water use during high-use months and their baseline demands



The average of each household's three highest bills is divided by its three lowest bills (baseline demand) to calculate the customers peaking ratio. If the difference between these two averages is small (i.e., low peaking ratio) that means that the customer used a consistent amount of water over the course of the year. However, if the difference is great, the peaking ratio will be high, which indicates that their usage fluctuated a great deal between the lowest months of consumption and the highest months of consumption.

Simplified Calculation

1. Eliminate all bills with zero water use from the analysis.
2. For each customer, sort their water-use records by volume over at least a 12-month period in descending order. The highest water use, regardless of what month it occurs in, will be first. The second highest will be second, etc. The bill periods do not have to be consecutive chronologically.
3. For utilities with monthly billing, average the highest three water-use records for each customer to determine the customer's average high demand. Averaging over three months reduces the effects of outliers that may have occurred due to leaks or abnormal water use behavior for one month.
4. For utilities with bimonthly billing, average the highest two water-use records for each customer to determine the customer's average high demand. Average over two periods reduces the effects of outliers that may have occurred in a single period.
5. For utilities with quarterly billing, or for utilities with any billing frequency whose majority of customers use the same amount of water year-round, the single highest non-zero water-use record for each customer is the customer's average high demand.
6. Divide each customer's average high demand by their baseline demand (as computed above). This is the customer's peaking ratio.

8. CUSTOMER USE PROFILE

Using two or more indicators simultaneously to categorize customer water use can further segment a customer base into smaller subgroups that can be targeted for conservation efforts and financial planning. This indicator uses both the customer baseline demand and customer peaking ratio to identify whether a single-family customer is a high or low water user year-round or only during a part of the year. For example, customers who have high peaking ratios are segmented into those that peak from a low baseline demand and those that start with a high baseline and still have significant discretionary use leading to a high peaking ratio. Segmenting the customer base by baseline use and peaking ratios simultaneously allows a utility to target different types of conservation messages to different customers and to avoid sending costly messages to customers that already exhibit efficient water use patterns. Tracking this indicator over time will also help a utility plan for future water demand.

Example

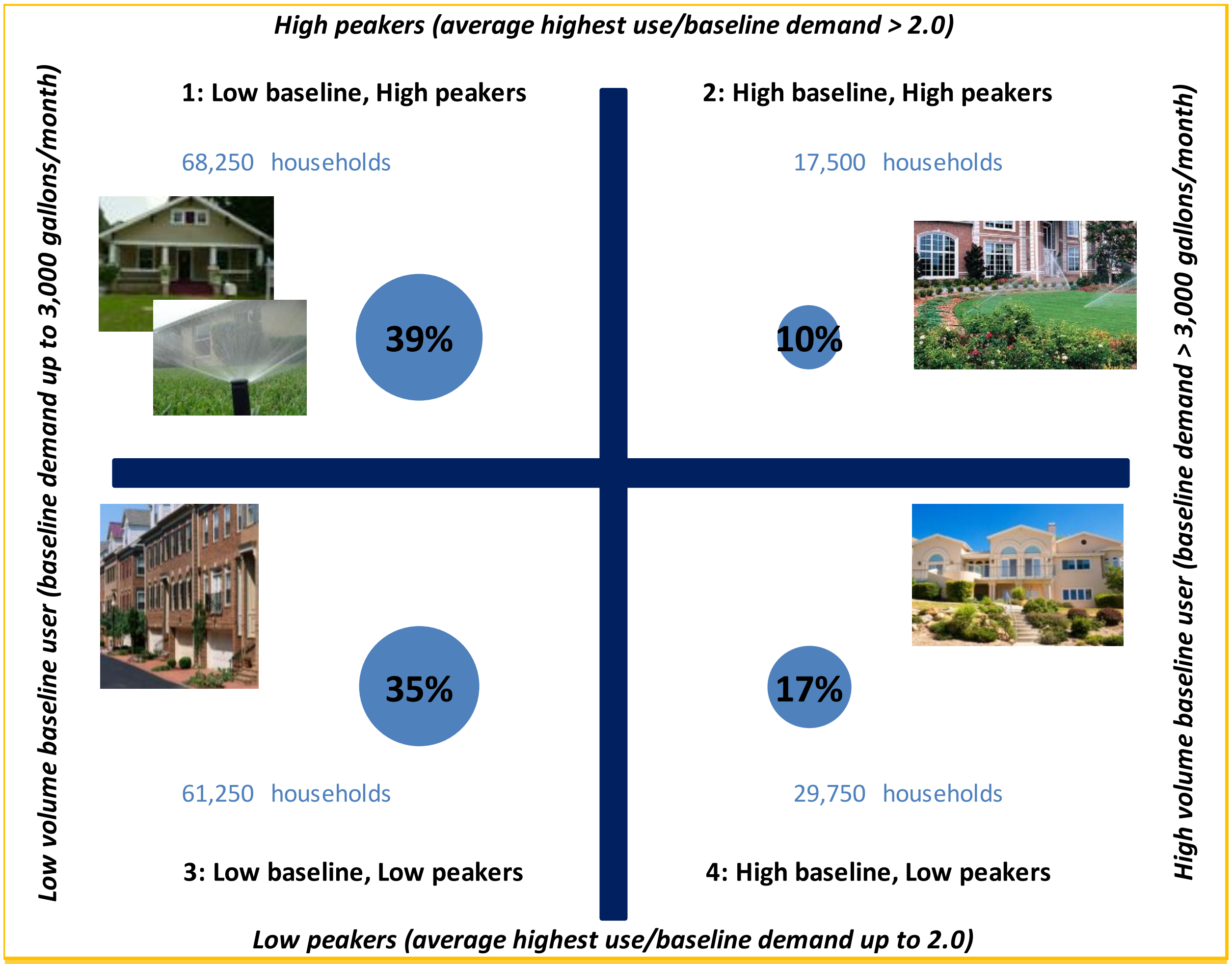
Figure 9 displays the breakdown of all single-family residential customers of a utility into four groups or profiles based on their baseline and peaking water-use patterns. In this example, the thresholds used to divide the four groups were baseline demand of 3,000 gal/mo and peaking ratio of 2.0. Single-family residential customers are then classified into one of the following four groups:

1. *Low baseline, high peakers*: The upper left quadrant shows the percentage of single-family residential customers who have a low baseline demand but use more than twice as much water for a few months out of the year. An example might be a small family that uses a moderate amount of water in the winter, but waters the lawn in the summer. This group of customers might be a target group for increasing block rate structures and conservation programs that target seasonal/discretionary water uses.
2. *High baseline, high peakers*: The upper right quadrant might also be a target for conservation. It shows the percentage of single-family residential customers who start with a high baseline need for water and also at least double their water use during some months of the year. These customers are typically targeted for increasing block rate structures, following the theory that their high use and peaking causes a utility to design larger facilities than they might otherwise need and that their peaking is indicative of discretionary use that can be influenced and reduced through pricing incentives. This group of single-family residential customers might also benefit from long-term conservation and efficiency strategies to bring down their baseline use.
3. *Low baseline, low peakers*: The customers in the lower left quadrant have a low baseline and do not vary their water use significantly over time, indicated by a peaking ratio of less than 2.0. These single-family residential customers are

already efficient water users year-round, with little or no seasonal/discretionary uses of water. An example might be a household living in a small townhouse with no yard. Conservation pricing and programs may not affect their water use significantly, and a utility might lower its communication costs by not targeting these customers with information about conservation.

4. *High baseline, low peakers*: Increasing block rate structures may penalize customers who have high baseline demands and low discretionary water uses, such as those in the bottom right quadrant. An example may be a household that has a large family, living in a large home, using a large volume of water year-round, but does not irrigate a lawn or have much discretionary water use (peaking ratio less than 2.0). These customers would still have to pay higher unit costs for their water. A utility with a large number of such customers that implements an increasing block rate structure is less likely to see a drop in water usage than a utility serving more high baseline, high-peaking customers. Conservation programs for these customers should focus on indoor water-use efficiency and, in warm climates where customers are irrigating year-round, providing information or incentives on more efficient irrigation technologies.

Figure 9. Customer baseline demands and peaking ratios over at least six months for single-family customers in one utility



Analysis is limited to households with at least six months of non-zero water use. Households are categorized based on whether their Customer Baseline Demand is high or low (above or below 3,000 gallons/mo, respectively) and whether their Customer Peaking Ratio is high or low (above or below 2.0, respectively). By segmenting the customer base based on customers' baseline use and peaking ratio simultaneously, utilities can better identify those customers who are good candidates for short-term conservation programs and/or long-term efficiency programming, while avoiding the unnecessary cost of communicating conservation goals to already-efficient customers. For example, customers with high baselines but low peaking ratios could benefit greatly from long-term efficiency efforts that would reduce the amount of water needed to do basic tasks in the house.

Simplified Calculation

1. For each customer, compute the customer peaking ratio and the customer baseline demand as described previously.
2. Calculate the number and percent of customers whose peaking ratio is below/above a specific threshold (e.g., 2.0) and whose baseline demand is below/above another threshold (e.g., 3,000 gal/mo). This divides customers into four groups with distinctive water use behaviors. The thresholds can be selected by the utility to determine customer groups with different sorts of water use patterns.

9. "HIDDEN" IRRIGATION ACCOUNTS[4]

"Hidden" irrigation accounts are those of customers who are irrigating using their standard meter and are not separately metered for irrigation water use. Separately metering and billing irrigation or outdoor water use generates many benefits for utilities (Tiger et al. 2011). Separately metered irrigation systems can be more easily identified, monitored, or turned off during times of water restrictions. When irrigation systems have separate meters, utilities can more easily enforce backflow prevention technology installation and maintenance requirements. Utilities can also better target pricing to separately metered irrigation water and design programming to manage the timing and extent of irrigation. However, most US water utilities have customers with irrigation systems connected behind their standard meters that are not metered separately.

Analysis of hidden irrigation accounts can help utilities identify what water (and revenue) is at stake if the utility experiences a particularly wet or dry year that will influence irrigation demand. Furthermore, the utility can target these hidden irrigators with conservation program messages that are focused on reducing outdoor water demand and can also market irrigation meters to these customers.

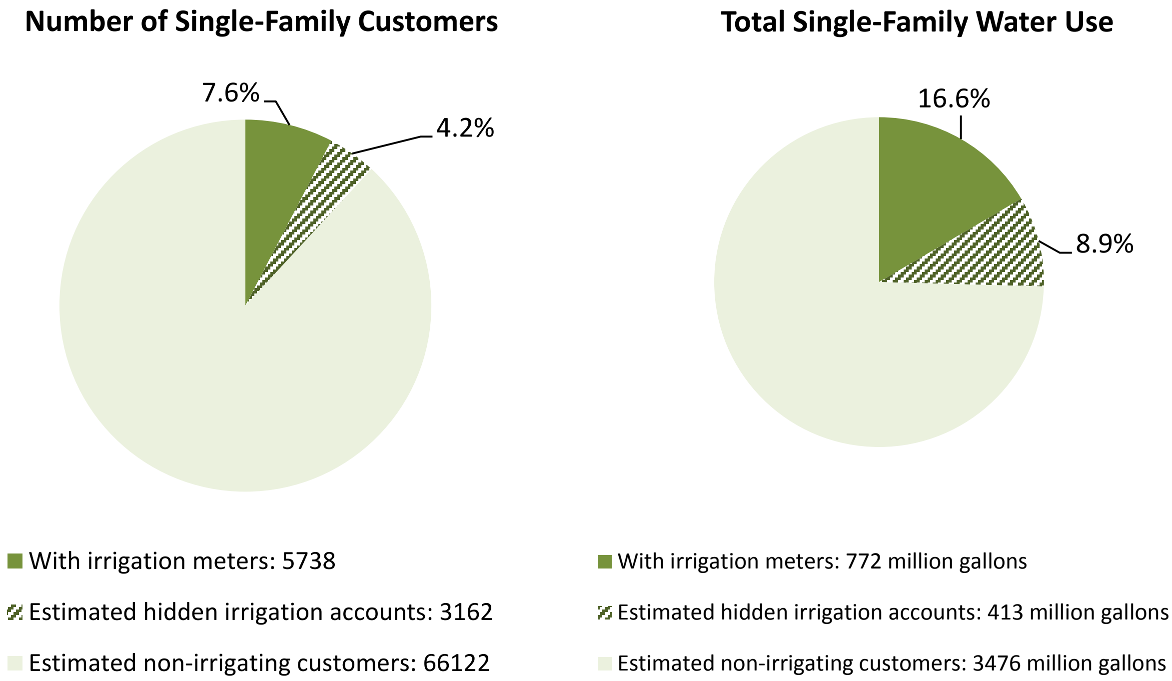
It is important to note that this analysis does not capture other prevalent (and in some areas, growing) sources of hidden irrigation: irrigation water drawn from a private well, home graywater, or a connection to a reclaimed water system that may or may not be metered. As such, this indicator cannot be used to fully assess the total amount of water being applied to landscapes across a utility's service area, but rather the amount of treated water being applied and the revenue associated with it.

Example

For one utility, 7.6 percent of single-family residential customers had separate irrigation meters, and used a total of 16.6 percent of single-family residential customer water use during the year, as shown in Figure 10. Yet, another 4.2 percent of single-family residential customers were estimated to have irrigation systems without a separate irrigation meter. These 3,162 hidden irrigators used another 8.9 percent of the single-family residential customer water use and may have in-ground irrigation systems that require the use of a backflow prevention device.

[4] This indicator is most appropriate for systems that have separate irrigation meters for customers who also have standard home or building meters.

Figure 10. Single-family residential customers irrigating using irrigation and standard meters



Simplified Calculation

A hidden irrigator customer is one who meets all three of these criteria:

1. The customer has a standard water meter but does not have a separate irrigation meter.
2. The single-family residential customer's average water use during typical or highest irrigation months[5] for the utility (e.g., between May and October) is greater than the year-round average water use for a vast majority of the customers (e.g., above 10,000 gal/mo, although this value can be specific to the utility's distribution of average demands and may be higher for other types of customers).
3. The customer's irrigation season peaking ratio is greater than or equal to the median irrigation season peaking ratio of customers of the same class (e.g., single-family residential customers) with irrigation meters. An irrigation season peaking ratio is calculated as the average water use during the irrigation months (e.g., May through October) divided by the average water use during the rest of the year (e.g., November through April).

[5] The irrigation months are contiguous and the same for all customers at the utility, unlike the months of high demands used to calculate each customer's peaking ratio, which are unique to each customer.

The following four steps are used to calculate the ratios and determine whether a customer meets criterion 3. First, the irrigation season peaking ratio is calculated for all irrigation-metered customers. Then, the utility-wide median of those ratios is determined. Third, the irrigation season peaking ratio is calculated for the customer who meets criteria 1 and 2 (i.e., a potential hidden irrigator). Finally, that ratio is compared with the median ratio of all irrigation-metered customers. If the irrigation season peaking ratio of the customer-in-question equals or exceeds the median ratio of irrigation-metered customers (i.e., have similar use patterns to known irrigators in the same year), the third criterion is satisfied and the customer is identified as a hidden irrigator.

This algorithm to identify possible hidden irrigators among customers is designed to be a conservative estimate. In other words, it is anticipated that there would be more customers irrigating, whether via a hose, an in-ground irrigation system or using a private well, than what this approach identifies as irrigators.

Conclusions

On the aggregate, any of the indicators described in this document can and should be generated on at least an annual basis to track changes in customer water use. This trend analysis can help utilities reevaluate demand projections, conservation program strategies, and pricing. However, each customer's water use can also be compared with itself across time to provide a more nuanced perspective on water-use behavior change. By identifying customers' average water use (or other indicator such as baseline or maximum water use or peaking ratio) in the previous year and calculating the change in demand in the current year, water utilities can scrutinize the impact of conservation messaging, pricing, restrictions, and other programmatic changes on customers with different water use patterns.

With a growing prevalence of advanced metering technology that, at the very least, increases the ability to read meters more frequently, utilities have an increased opportunity to segment and scrutinize water use by their customer base. With or without this technology, however, utilities can benefit from strategic indicators that align to the objectives of the utility and measure the impact of their programming.

References and Resources

Boyle, Christine, S. Eskaf, M.W. Tiger, and J.A. Hughes (2011). “Mining Water Billing Data to Inform Policy and Communications Strategies.” *Journal AWWA*, 103:11, 45–58. Link to article.

Boyle, Christine, M. Tiger, S. Eskaf, C. Wichman, and M. Ngo (2012). *Shifting Baselines in Water Utility Management.* Report by the Environmental Finance Center at the University of North Carolina, Chapel Hill. Project 11-09-UE Final Report to the North Carolina Urban Water Consortium, May 2012. Link to document.

Brehe, Todd A. and E. Coll (2012). “A Disruptive Innovation that will Transform Water Conservation Performance.” *Journal AWWA,* 104:10 60–63. Link to article.

Dallas (Texas) Water Utilities (2010). *City of Dallas Water Conservation Five-Year Strategic Plan Updated June 2010*. Prepared by Alan Plummer Associates, Inc in association with Amy Vickers & Associates, Inc., CP&Y, Inc., Miya Water, and BDS Technologies, Inc. Link to document.

Dziegielewski, Benedykt and J. C. Kiefer (2010a). “Appropriate Design and Evaluation of Water Use and Conservation Metrics and Benchmarks.” *Journal AWWA*, 102:6, 66–80. Link to article.

Dziegielewski, Ben and J. C. Kiefer (2010b). *Water Conservation Measurement Metrics: Guidance Report*. Report prepared for the American Water Works Association, Water Conservation Division, Denver, Colo. January 2010. Link to document.

Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin (2009). Estimated Use of Water in the United States in 2005. U.S. Geological Survey Circular #1344. Link to document.

Mayer, P.W., W.B. DeOreo, E. Opitz, J. Kiefer, B. Dziegielewski, W. Davis, J.O. Nelson (1999). *Residential End Uses of Water*. Report for the American Water Works Association Research Foundation, Denver, Colo. Link to summary of findings and links to updates in 2011-2013.

Tiger, Mary Wyatt, S. Eskaf and J. A. Hughes. (2011). “Implications of Residential Irrigation Metering for Customers’ Expenditures and Demand.” *Journal AWWA*, 103:12, 30–41. Link to article.

Vickers, Amy. (2001). *Handbook of Water Use and Conservation: Homes, Landscapes, Businesses, Industries, Farms.* WaterPlow Press, Amherst, Mass. Link to book.

Vickers, Amy L. (2012). “Slice ‘N Dice: Analytical Techniques For Customer Water Use Data To Evaluate Efficiencies And Identify Water Savings Potential.” *Proceedings of the Annual Conference of the American Water Works Association,* Dallas, June 10, 2012. Link to document.

Vickers, Amy L., M.W. Tiger, and S. Eskaf (2013). “Mining Customer Data to Better Inform Utility Decision-Making.” *Proceedings of the Annual Conference of the American Water Works Association*, Denver, Colo. June 13, 2013. Link to document.

Waukesha Water Utility, Waukesha, WI (2012). “Final Water Conservation Plan, May 2012.” Prepared by CH2MHILL in consultation with Amy Vickers & Associates, Inc. and Beth Foy & Associates, LLC. Link to document.

