

The commercial, industrial, and institutional (CII) sectors are significant contributors to public water demand. To estimate CII water use, utilities historically have relied on water use coefficients that use the number of employees as the measure of size. However, it is difficult to obtain this information at a resolution fine enough to differentiate among individual water users and adequately evaluate water conservation options. To overcome these challenges, a methodology was developed to estimate CII water use through spatial, physical, and economic property-based information publicly available from the Florida Department of Revenue (FDOR) for each of the 8.8 million parcels in the state. Water use data for 3,172 CII parcels were linked with FDOR data to develop average and peak water use coefficients normalized by heated building area. By estimating water use at the parcel level, the methodology provides baseline water use estimates essential to evaluating water conservation options.

Estimating commercial, industrial, and institutional water use on the basis of heated building area

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Commercial, industrial, and institutional (CII) users account for a significant portion of the the total water withdrawn and delivered by public or private suppliers to end water users. The US Geological Survey (USGS) estimated water use from public supplies across the United States in 1995 as 17% commercial, 12% industrial, and 15% public use and losses (Solley et al, 1998). CII water use comparisons across agencies and water utilities are complicated by dissimilar approaches to classifying customers. For example, the USGS generally groups institutional establishments within commercial water use and defines public water use as water from the public water supply used for such purposes as firefighting, street washing, and municipal parks; water losses are usually dealt with separately from public use. According to a survey of water agency reporting practices for water losses (Beecher, 2002), regulatory agencies in nearly all states have set upper limits on water losses ranging from 7.5 to 25%, with 15% being the most common value. Thus, the USGS estimate of CII water use in 1995 can be expressed as at least 29% of the total water delivered. The USGS did not include commercial water use in its 2005 update of the 1995 national water use assessment (Kenny et al, 2009), but other researchers (Dziegielewski et al, 2000) have estimated that CII water use accounts for approximately 15–25% of municipal water use. On the basis of metered data, the commercial/industrial sector of public water supply systems in the Southwest Florida Water Management District

used an average of 19% of total public water supply withdrawals in 2008 (Nourani & Bader, 2009). CII water use estimates can be expected to vary widely, depending on the demographics of the utility and the way CII sectors are defined.

CHALLENGES INVOLVED IN ESTIMATING CII WATER USE

Diversity within CII sectors. The US Environmental Protection Agency (USEPA) summarized many of the information and research needs for the commercial and institutional sectors in the white paper *Water Efficiency in the Commercial and Institutional Sector* (2009); those findings would also apply to the industrial use sector. The primary challenge in evaluating CII water use is that use patterns vary widely because of the diversity within the CII sectors, which range from small convenience stores to regional shopping malls. The USEPA white paper cites a lack of subsector-specific data (such as water use by facility and end use) and existing benchmarks by which to set targets. Although other studies (Colorado Water-Wise, 2007; Dziegielewski et al, 2000) have provided some subsector data, they have done so only for a limited number of subsectors. Other recent references on CII water use have documented end use breakdowns for certain CII subsectors (Gleick et al, 2003) and provided water-saving measures and technologies applicable to the CII sectors (NCDENR, 2009; EBMUD, 2008).

Limitations of using number of employees to estimate CII size. Water use for a specific sector can be expressed as the product of a rate of water use per unit of size times a measure of size summed over the number of parcels in that sector. To estimate CII water use, utilities historically have relied on similar customers within their service area or on water use coefficients developed from studies in other areas. Typically, these water use coefficients use the number of employees as the measure of size or means of coefficient normalization.

The water use model that has historically been predominant is the US Army Corps of Engineers' Institute for Water Resources Municipal and Industrial Needs (IWR-MAIN), the first model to estimate CII water use empirically and disaggregate the general sector into more distinct subsectors (Dziegielewski & Boland, 1989). In IWR-MAIN, the size of each CII sector was estimated by total employment, and CII water use was estimated based on Standard Industrial Classifications sectors as developed by the US Department of Commerce (Opitz et al, 1998). The latest release of the IWR-MAIN model was version 6.1 in 1995; this model is no longer available nor has the database been updated. Maddaus and Maddaus (2004) developed an end-use model, the Least Cost Planning Demand Management Decision Support System Model. This proprietary forecasting model uses employment data that have been disaggregated to the CII levels.

Employment data based on place of work are available from the US Census Bureau (USCB) or from private surveys. The Economic Census (USCB, 2010) is conducted every five years, and employment data are aggregated to geographic areas, the smallest being cities. Statistical data on employment are provided according to the North American Industry Classification System (NAICS) code, which was developed under the direction and guidance of the Office of Management and Budget and officially replaced Standard Industrial Classifications in 1997 as the standard for use by federal statistical agencies in classifying businesses. The size, density, and composition of parcels within these geographic areas vary widely, and the precision of total employment estimates for each sector by the Economic Census is limited because of this aggregation. County Business Patterns data (USCB, 2009a) provide annual USCB employment estimates at the zip code level and depend on the Economic Census and various other surveys. This method of collecting employment data is subject to nonsampling errors, such as an inability to identify all businesses, definition difficulties, and estimation of missing or misreported data. Classification of customers is provided through the NAICS, but employee estimates are largely presented in bins, or aggregate groups, to protect the identity of individual establishments. The Longitudinal Employer-Household Dynamics (LEHD) program is a new state/federal partnership between the USCB and 10 states (California, Florida, Illinois, Maryland, Minnesota, New Jersey, North Carolina, Oregon, Pennsylvania, and Texas). The LEHD program provides quarterly employment estimates at smaller geographic areas, including tract, block group, zip code, and traffic analysis zones. Because the quarterly estimates are still viewed as experimental, the program also provides annual employment figures (USCB, 2009b). Outside of the census, employment figures can be derived from commercial surveys, which are more thorough and precise because data are collected at the customer level. However, the accuracy of such surveys is dependent on the diligence of the respondent, and these data must be purchased.

Given that employment data can be inaccurate or unreliable, often must be purchased, and are generally difficult to obtain (especially for individual parcels because of confidentiality restrictions), the authors recommended using the heated building area of CII parcels as the measure of size to normalize water use. Heated building area—or building area under climate control—is preferred over number of employees because of the availability of these data from real estate records and the demonstrated correlation of heated building area to CII water use. The bottom-up methodology can be used to estimate CII average and peak water use on the basis of parcel-level land use and water billing databases. In the research described

here, customer-level water billing data for 3,172 CII customers were combined with a statewide inventory of the heated area for 326,000 CII parcels to provide a bottom-up, parcel-level assessment of CII water use patterns in Florida. This methodology can be applied outside of Florida using water use coefficients and land parcel information from property appraisers specific to a region.

BOTTOM-UP APPROACH USING HEATED AREA

The new approach was made possible by the availability of parcel-level information for every land parcel in the state of Florida. The Florida Department of Revenue (FDOR) database, in conjunction with Florida County Property Appraisers (FCPA), provides the heated building areas for every land parcel in the state along

TABLE 1 FDOR land use codes

FDOR Code	Description	FDOR Code	Description
00	Vacant residential	40	Vacant industrial
01	Single-family residential	41	Light manufacturing
02	Mobile homes	42	Heavy industrial
03	Multifamily (< 10 units)	43	Lumber yards, sawmills
04	Condominiums	44	Packing plants
05	Cooperatives	45	Canneries, distilleries, wineries
06	Retirement homes	46	Other food processing
07	Migrant camps, boarding homes	47	Mineral processing
08	Multifamily (> 10 units)	48	Warehouses, distribution centers
09	Undefined	49	Open industrial storage
10	Vacant commercial	50–69	Agricultural
11	Stores (one-story)	70	Vacant institutional
12	Mixed use	71	Churches
13	Department stores	72	Private schools and colleges
14	Supermarkets	73	Private hospitals
15	Regional shopping centers	74	Homes for the aged
16	Community shopping centers	75	Orphanages, nonprofits
17	Office buildings (one-story)	76	Mortuaries, cemeteries
18	Office buildings (multistory)	77	Clubs, lodges, union halls
19	Professional service buildings	78	Sanitariums, convalescent and rest homes
20	Airports, transportation terminals	79	Cultural organizations
21	Restaurants, cafeterias	80	Undefined
22	Drive-in restaurants	81	Military
23	Financial institutions	82	Forests, parks, recreation areas
24	Insurance company offices	83	Public schools
25	Repair service shops	84	Colleges
26	Service stations	85	Public hospitals
27	Automotive repair, sales	86	Counties
28	Mobile home parks	87	State, other
29	Wholesale outlets	88	Federal, other
30	Florists, greenhouses	89	Municipal other than parks
31	Drive-in theaters, open stadiums	90	Government property leased
32	Enclosed theaters, auditoriums	91	Utility, gas, electricity
33	Night clubs, bars	92	Mining, petroleum, gas lands
34	Bowling alleys, enclosed arenas	93	Subsurface rights
35	Tourist attractions	94	Rights-of-way, streets
36	Camps	95	Submerged lands
37	Race tracks	96	Sewage disposal, solid waste
38	Golf courses, driving ranges	97	Outdoor recreational or parkland
39	Hotels, motels	98	Centrally assessed
		99	Acreage not zoned for agricultural

FDOR—Florida Department of Revenue

with the land use classification, allowing for subsector-specific water use coefficients.

FDOR. FDOR maintains a database of legal, physical, and economic property-based information for each of the 8.8 million parcels of land in the state of Florida. Of this total number, 326,000 are CII parcels (215,000 commercial, 69,000 industrial, and 42,000 institutional). This database is audited and updated annually and is publicly available free of charge from the FDOR file transfer protocol website (<ftp://sdrftp03.dor.state.fl.us/>). FDOR partitions parcels on the basis of their land use into 100 subsectors using two-digit FDOR codes (Table 1). These codes are standardized across the state, providing consistent definitions of terms. The parcel information in this database is provided annually by the state's 67 FCPAs to FDOR for a statewide land use database.

The following attributes of interest are provided by the FDOR database: parcel identification (ID) number, land use code, effective year built, effective building area, and parcel area. The parcel ID number is a unique identifier for a plot of land and links the various databases presented in this methodology. The FDOR land use code is a two-digit classification system that identifies the primary use of the land by its economic activity. The FDOR land use classification system allows for various degrees of disaggregation following the hierarchical structure shown in Figure 1. Effective year built is defined as the

actual year built or the effective year major improvements were made to a building. The year built provides valuable time series information to estimate trends and is an essential tool in forecasting number of accounts, building and parcel characteristics, and water use rates.

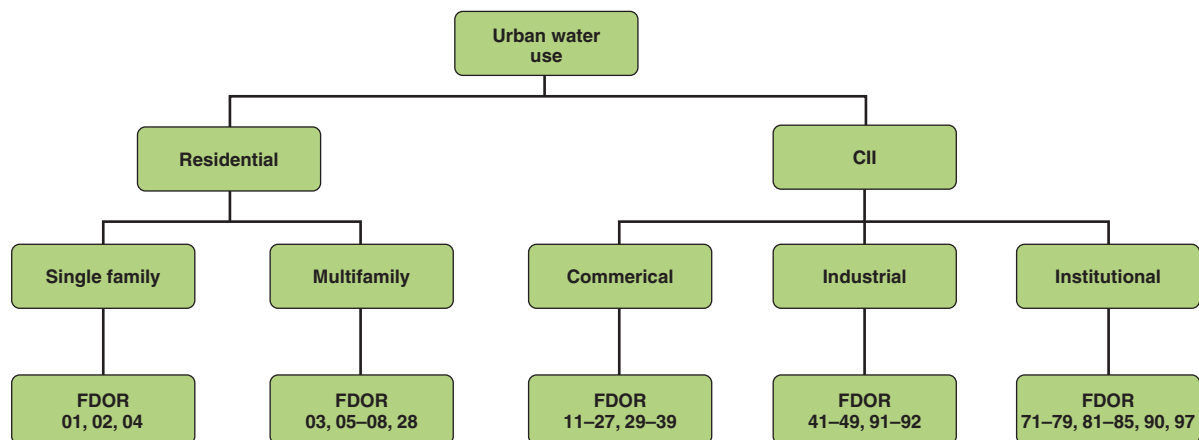
The effective, or adjusted, building area field, defined as the total effective area of all floors of all buildings on a given parcel, is not a true area but rather a calculated field. Effective area incorporates economic factors that can be used to weight differently the various building

area types found within a parcel. Parcel area is a derived field from the FDOR database. The FDOR database provides polygon shapefiles delineating every parcel in the state. Using standard geographic information system tools, the area of each parcel can be calculated and joined to the other parcel information provided in the FDOR attribute data. In addition to parcel dimensions, these polygon shapefiles offer the spatial location of every parcel in the state. This allows simple spatial queries to determine which parcels are within the service boundaries of a given utility.

FCPA. Each of Florida's 67 counties maintains an FCPA database that contains the same information as the FDOR database, along with additional attributes that vary from county to county. Attributes of interest in all FCPAs include parcel ID number and heated building area. Parcel ID number, a unique identifier, serves as the link between the

Commercial, industrial, and institutional water use comparisons across agencies and water utilities are complicated by dissimilar approaches to classifying customers.

FIGURE 1 Levels of FDOR land use disaggregation into nine residential and 55 CII sectors



CII—commercial, industrial, and institutional, FDOR—Florida Department of Revenue

FCPA and FDOR databases. FCPA provides the heated areas of buildings in a parcel, defined as all building areas under climate control. Unlike the effective building area provided by FDOR, heated area is a physical building area. Heated area is the commonly used measure of the size of the property for real estate descriptions. The two FCPA databases analyzed in this study were the Hillsborough County Property Appraiser and Alachua County Property Appraiser. These FCPA databases encompass the two utilities that provided monthly water billing data: Hillsborough County Water Resources Services (HCWRS) and Gainesville Regional Utilities (GRU) in Alachua County.

Relationship of effective area to heated area. Effective building area is not a physical area but rather a calculated value incorporating market values of the structures within a parcel. For this reason, heated building area is used as the measure of the size of the CII activity because it is a physical area not prone to misinterpretation and is available from FCPA. Figure 2 shows heated area and effective area for a sample of 3,172 CII parcels in Hillsborough and Alachua counties. Heated areas in the CII sector range from as low as a few hundred to more than a million square feet. Results in Figure 2 show that the ratio of heated area to effective area is linear over this wide range. Heated area and effective area have a strong positive correlation coefficient of $r = 0.996$, allowing for conversion between the two measures with minimal loss of accuracy. The ratio of heated area to effective area, K , for any aggregation of CII or other users is defined as the total heated area divided by the total effective area. The K ratio over all 3,172 CII parcels is 0.948.

$$K = \frac{\sum_{i=1}^n HA_i}{\sum_{i=1}^n EA_i} \quad (1)$$

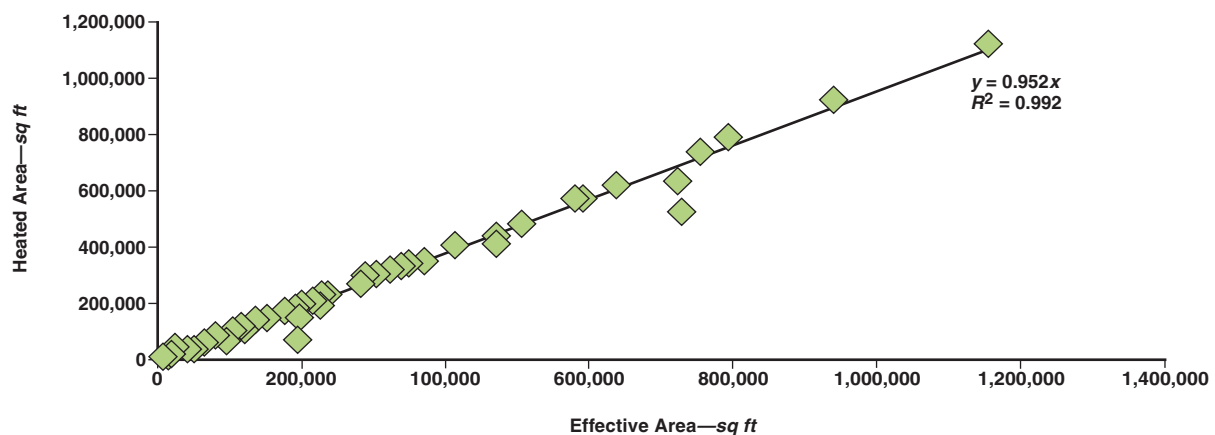
in which K is the effective-area-to-heated-area conversion coefficient for a group of n number of parcels, HA_i is the heated area of parcel i in sq ft, and EA_i is the effective area of parcel i in sq ft.

The range in CII parcel sizes shown in Figure 2 suggests one reason why the aggregate category is so heterogeneous. The coefficients of variation (COVs) in Table 2 for the sampled CII subsectors and the aggregate categories provide greater insight into the heterogeneity of heated area of establishments grouped in this methodology. COVs are defined as the standard deviation of a set of data divided by its mean. As Table 2 shows, the COVs for the two-digit FDOR CII subsectors varied widely. For example, one-story stores (FDOR 11) constituted a more heterogeneous subsector in terms of heated area than did restaurants (FDOR 21). Therefore, it is important to disaggregate into subsectors to develop more-accurate functional relationships based on more-homogeneous land use types. K coefficients have been developed at the two-digit FDOR level for each of the 55 CII subsectors. The K coefficients for the top CII water use subsectors in Florida, along with the aggregate CII sectors, are shown in Table 2 under the HA/EA sub-heading. These coefficients allow for the conversion of effective area to heated area for all of the 326,000 CII parcels in Florida. K coefficients allow for the application of water use coefficients, normalized by heated area, to the effective area measures available from FDOR.

HEATED AREA AND CII WATER USE

Parcel-level land use characteristics from the FDOR and FCPA databases were linked with historic water billing data for 3,172 CII parcels (1,770 in HCWRS and 1,402 in GRU) to develop water use coefficients normalized by heated building area. HCWRS provided four complete

FIGURE 2 Heated and effective area correlation for 3,172 CII parcels in HCWRS and GRU



CII—commercial, industrial, and institutional, HCWRS—Hillsborough County Water Resources Services, GRU—Gainesville Regional Utilities

years of monthly water billing from January 2003 through December 2006; GRU supplied two complete years of monthly water billing from January 2008 through December 2009. Water billing data were adjusted to prorate water use to the proper month and account for differing meter billing periods determined by the date on which each meter was read. The water billing records contained several key fields that made adjustment possible, including usage quantity, bill period length, and bill period end date. Usage quantity is the total water billed to a customer for a given billing period. Bill period length is the number of days in the billing period. This field allows water use per day to be calculated for each billing period, which is key to adjusting billing records. Bill period end date is the date on which a given billing period ends. This field allows for calculating how many billing period days are within the current “end period month.” Knowing how many days are in the month to be adjusted allows the analyst to use the information provided by these fields to adjust billing records following Eq 2. With the billing adjusted, data were then aggregated so that all meter records on a given parcel in a given month were summed.

$$Q_{\text{adjusted}} = Bx + (M - B)y \quad (2)$$

in which Q_{adjusted} is the adjusted month water use, B is the number of billing days in the current end-of-billing period month, M is the number of days in the adjusted month, x is the water use per day for the current end-of-billing period, and y is the water use per day following the billing period.

HCWRS and GRU provided the crucial link to FDOR via a parcel ID, the common identifier that allows parcel attributes from FDOR to be related to water use. Water billing data also provided valuable monthly time series information about the nature of water use in the CII sectors. By using FDOR land use codes, the researchers were able to place CII water customers into the appropriate CII sector or two-digit FDOR subsector (Figure 1).

The fact that heated area constitutes a good estimator of water use is essential to its use as a measure of size to normalize water use. Kim and McCuen (1979) studied retail stores and concluded that the two best predictors of water use were gross area and sales area (the only two measures of area analyzed), followed by average number

TABLE 2 Area conversion coefficients and associated heated area statistics for CII sectors

FDOR Code	Description	Sample Size	HA/EA	Mean HA sq ft	Coefficient of Variation	25th Percentile sq ft	50th Percentile sq ft	75th Percentile sq ft
11	Stores (one-story)	286	0.924	7,192	1.528	2,040	3,682	7,801
16	Community shopping centers	235	0.951	39,772	1.203	8,006	17,300	62,614
17	Offices (one-story)	380	0.963	5,991	1.342	1,962	3,147	6,318
18	Offices (multistory)	73	0.969	30,576	1.120	7,306	16,274	42,748
19	Medical offices	260	0.970	7,616	1.804	3,072	4,248	7,294
21	Restaurants	119	0.962	4,933	0.545	2,978	4,770	6,571
22	Fast food restaurants	103	0.965	2,892	0.434	2,165	2,932	3,876
23	Financial institutions	96	0.897	5,108	0.721	3,276	3,915	5,126
27	Auto sales, repair	172	0.865	8,047	3.543	2,196	3,823	6,429
39	Hotels, motels	49	0.945	32,650	0.861	12,642	23,865	48,147
	Other commercial	418	0.929	22,096	4.016	2,400	3,766	8,300
	Total commercial	2,191	0.941	14,371	3.153	2,520	4,422	9,547
41	Light manufacturing	32	0.902	39,329	1.974	6,334	10,650	40,429
48	Warehousing, distribution	221	0.946	30,114	1.154	7,200	14,479	43,990
49	Open storage	19	0.971	2,463	1.267	973	1,344	2,168
	Other industrial	27	0.946	50,931	2.339	9,818	16,814	41,340
	Total industrial	299	0.942	31,223	1.711	5,899	12,480	40,093
71	Churches	337	0.946	13,085	1.295	3,070	7,191	15,775
74	Homes for the aged	12	0.922	116,675	1.742	17,030	43,743	53,716
83	Public schools	52	0.980	126,588	0.657	76,088	94,850	123,840
	Other institutional	281	0.966	21,007	3.870	2,624	5,400	11,136
	Total institutional	682	0.963	26,826	2.650	3,100	6,690	18,118
	Total CII	3,172	0.948	18,638	2.846	2,719	5,150	13,030

CII—commercial, industrial, and institutional, EA—effective area, FDOR—Florida Department of Revenue, HA—heated area

of daily personnel hours and employees. In their investigation of five commercial and institutional water users, Dziegielewski and co-workers (2000) found only building area to be a significant indicator of water use across all customer categories.

Linking the water utility billing databases of HCWRS and GRU with the state agency land use databases of FDOR and FCPA allows the relationship between property attributes and CII water use to be evaluated. The strong correlation between heated area and water use for all 3,172 CII parcels in HCWRS and GRU (shown in Table 3) indicates that heated area, with a correlation coefficient of 0.635, is the best of the three predictors of water use within the CII sector.

Other property attributes such as parcel area and effective year built can be evaluated alongside heated area through stepwise multivariate regression (Neter et al, 1996). The stepwise regression was carried out using a statistical program¹ featuring a method that models the choice of entering predictive variables on the basis of their *p* value; if the *p* value is < 0.05, the variable is entered in the regression, and if the *p* value is > 0.1, the variable leaves the regression. The result for the stepwise regression showed that all three predictive variables are entered in the regression. The adjusted *R*² value of the stepwise regression equation (Eq 3) is equal to 0.42.

$$Q_i = (0.063) HA_i + (0.370) EYB_i - (0.638) TA_i \quad (3)$$

in which Q_i is the average gpd water use for parcel *i*, HA_i is the heated square footage of all buildings on parcel *i*, EYB_i is the effective year built of major improvements on parcel *i* (e.g., 1984), and TA_i is the area of parcel *i* in acres.

The order in which the predictive variables enter the regression model depends on their correlation to both water use and to one another and is essential to determining the best-fit regression model. The first predictive variable entered into the regression was heated building area because it is the most highly correlated variable to

water use. The adjusted *R*² value for the regression model of water use using solely heated square footage as the predictive variable is 0.40. Therefore, by adding effective year built and parcel acreage, little predictive power is gained because the overall stepwise multivariate regression equation produces an adjusted *R*² of 0.42.

Influence of seasonality and irrigation. Heated area may not be a good predictor of CII water use if seasonality is significant and the irrigable area of the parcel becomes an important predictor. The importance of seasonality was evaluated by plotting the monthly time series for each of the CII categories. As shown in Figure 3, results indicated that little seasonal variability was apparent at this level of aggregation. This finding was not surprising given that CII establishments tend to use much of the parcel area for parking facilities for their customers, thus significantly reducing their irrigable area.

Peak water use is another measure of seasonality. Peak water use in Florida generally occurs in May when lower precipitation and warmer weather increase outdoor water demand. The contribution of CII water use to this May peak can be evaluated using the time series data. The peak-to-average ratios for the commercial (1.06), industrial (1.05), and institutional (1.08) sectors indicated that seasonal influences were relatively minor. Therefore, the average water use coefficients associated with heated area should be good estimates of total water use.

Advantages of heated area as a metric. Because heated area is the best predictor of water use available from the property attributes evaluated and little is gained from the other variables, the methodology described here proposed water use relationships based solely on heated square footage of buildings on a parcel. Heated building area is also a good measure of size for CII parcels because it can be determined for every parcel in Florida by applying the *K* coefficients to the effective building area data available through the FDOR database. This database has a high level of accuracy because it is used for setting property taxes and is updated annually. Heated area is also a standardized area across most disciplines and outside

TABLE 3 Correlation matrix of FDOR and FCPA property attributes and average water use for 3,172 CII parcels in HCWRS and GRU

	Heated Area sq ft*	Parcel Area acres*	Effective Year Built*	Average Monthly Water Use—gal*
Heated area	1.000			
Parcel area	0.347	1.000		
Effective year built	0.028	0.003	1.000	
Average monthly water use	0.635	0.096	0.020	1.000

CII—commercial, industrial, and institutional, FCPA—Florida County Property Appraisers, FDOR—Florida Department of Revenue, HA—heated area, HCWRS—Hillsborough County Water Resources Services, GRU—Gainesville Regional Utilities

*Coefficients were derived from the data as measured in the units given.

Florida. Such a standardized metric as a measure of size allows water use coefficients normalized by heated area to be readily applied to property databases outside the state. Property databases such as FDOR and FCPA also offer an additional benefit in that they provide heated area at the parcel level, which is a finer spatial resolution than traffic analysis zone (TAZ). TAZ is the finest geographical area by which the USCB aggregates employment figures. In Florida, there are 12,747 TAZs compared with nearly 9 million parcels. Parcel-level CII data allow for much greater precision in estimating water use and identifying sectors and drivers of demand.

CII WATER USE COEFFICIENTS

CII public water use activity coefficients were developed by linking the parcel-level property attribute data with the water billing data from HCWRS and GRU. Two types of daily water use coefficients are presented in this article: average (Table 4) and May peak (Table 5). The weighted average water use coefficients were developed by summing the average monthly water use of all parcels within a given subsector and dividing by their total heated area and the average number of days in the months billed (Eq 4). This method of calculating the coefficients provided a weighted average that gives consistent results at any level of aggregation. Weighted peak (q_p) water use coefficients were developed by summing the average May water use of all parcels in a subsector and dividing by the total heated area of the subsector.

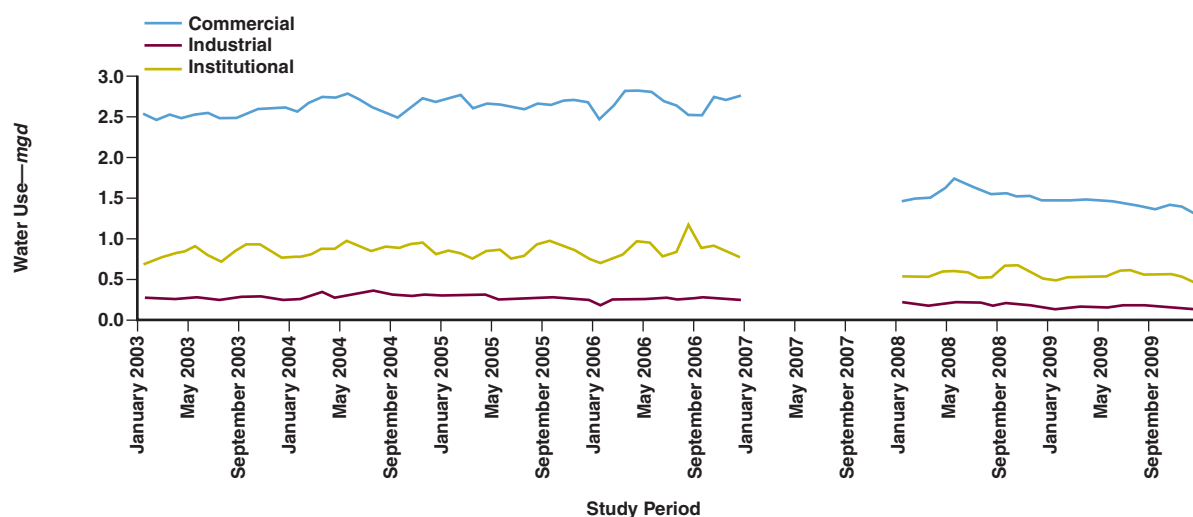
$$\bar{q}_j = \frac{\sum_{i=1}^n Q_{ij}}{\sum_{i=1}^n HA_{ij}} / AD \quad (4)$$

in which \bar{q}_j is the heated area weighted average water use coefficient for subsector j in gfd of heated area, Q_{ij} is the average monthly water use of parcel i in subsector j in gal per month, HA_{ij} is the heated square footage of all buildings on parcel i in subsector j in sq ft, AD is the average number of days in months billed, and n is the number of parcels in subsector j .

The average water use coefficients shown in Table 4 demonstrate the variability of water use intensities within the CII subsectors. For example, restaurants (FDOR 21) use water at eight times greater intensity than one-story stores (FDOR 11). The May peak (Table 5) provides a good indication of the extent to which a sector affects the utilitywide peak. The May peak is caused primarily by irrigation needs during the spring dry season in Florida. CII use may be lower in May because significant numbers of winter residents have left Florida (and although establishments remain open, intensity of use likely decreases). In this case, the CII users may not be significant contributors to the May peak given the minimal subsector peak-to-average ratios shown in Table 5.

The total CII and overall CII coefficients shown in Tables 2, 4, and 5 are area-weighted averages of the subsectors that make up these aggregate categories. Thus, these coefficients depend on the CII subsector land use mix for a given utility. In the case of the water use coefficients, a weighted average based on the total heated area of the two-digit FDOR subsectors was used, whereas for the area conversion coefficients, the total effective area was used in the weighting. In Tables 2, 4, and 5, the weighting was carried out using the sample building area

FIGURE 3 Time series plots of monthly water use for CII parcels in HCWRS (January 2003 through December 2006) and GRU (January 2008 through December 2009)



CII—commercial, industrial, and institutional, HCWRS—Hillsborough County Water Resources Services, GRU—Gainesville Regional Utilities

statistics from HCWRS and GRU. If the same subsector water use coefficients were applied to another utility in a region where only the heated area was known, the area-weighted average for the aggregate CII sectors would reflect the relative importance of the CII subsectors that make up that aggregate category. The area weighting offers a significant improvement in the accuracy of CII estimates because the sizes of the various activities are included directly in the calculations.

For measuring the variability in the water use coefficients, Tables 4 and 5 include the mean, COV, and three percentiles of coefficients within the CII subsectors. Just as heated area varies among the different subsectors (Table 2) so too does water use coefficient homogeneity. Certain subsectors, such as hotels/motels (FDOR 39), have a high homogeneity in terms of water use coefficients of the individual establishments for which this study had water use data. Other CII subsectors, such as one-story stores (FDOR 11), have much more heterogeneous water use coefficients. The measures of homogeneity provide valuable insight into the

uncertainty associated with the use of specific two-digit water use coefficients to estimate water use.

Application of water use coefficients. Because the FDOR database provides standardized land use information for all parcels in the state, the coefficients shown in Tables 4 and 5 can be applied to estimate the total statewide contribution of each CII subsector to public water use, as shown in Table 6 (Morales & Heaney, 2010). The 16 CII subsectors that are shown in Table 6 account for more than 75% of the state's CII public water use. The complete water use and heated area statistics for the available 55 FDOR CII subsectors are available on the Conserve Florida Water Clearinghouse (CFWC) website at conservefloridawater.org. The top CII water use subsectors are hotels/motels (FDOR 39), which account for 13.0% of the state's total CII public water use, and community shopping centers (FDOR 16), making up 6.4% of the state's public supply CII water demand.

At the state level, the commercial sector dominated CII water use, with 63.5% of CII public water demand. The industrial and institutional sectors accounted for

TABLE 4 Estimated average water use coefficients and associated statistics for CII sectors

FDOR Code	Description	Sample Size	Weighted Average Water Use Coefficient*	Average Water Use Coefficient*	Coefficient of Variation	25th Percentile*	50th Percentile*	75th Percentile*
11	Stores (one-story)	286	0.0979	0.246	5.529	0.026	0.065	0.159
16	Community shopping centers	235	0.0960	0.143	1.319	0.038	0.088	0.168
17	Offices (one-story)	380	0.1289	0.176	4.331	0.031	0.063	0.142
18	Offices (multistory)	73	0.0692	0.074	0.840	0.026	0.047	0.108
19	Medical offices	260	0.1562	0.143	1.210	0.049	0.092	0.182
21	Restaurants	119	0.7417	0.677	0.688	0.291	0.632	0.964
22	Fast food restaurants	103	0.6369	0.707	0.731	0.403	0.579	0.863
23	Financial institutions	96	0.3705	0.461	3.290	0.047	0.243	0.393
27	Auto sales, repair	172	0.1238	0.203	1.764	0.035	0.061	0.168
39	Hotels, motels	49	0.2286	0.249	0.452	0.183	0.233	0.305
	Other commercial	418	0.0981	0.279	1.626	0.058	0.130	0.281
	Total commercial	2,191	0.1304	0.262	2.821	0.044	0.111	0.261
41	Light manufacturing	32	0.0545	0.134	2.458	0.015	0.021	0.082
48	Warehousing, distribution	221	0.0335	0.140	9.410	0.010	0.022	0.046
49	Open storage	19	0.1520	0.262	1.223	0.113	0.148	0.240
	Other industrial	27	0.1196	3.138	4.957	0.018	0.045	0.107
	Total industrial	299	0.0496	0.417	11.522	0.011	0.026	0.065
71	Churches	337	0.0492	0.075	1.435	0.023	0.042	0.086
74	Homes for the aged	12	0.1007	0.232	0.616	0.081	0.291	0.328
83	Public schools	52	0.0684	0.072	0.913	0.040	0.054	0.081
	Other institutional	281	0.1053	0.797	7.004	0.065	0.136	0.225
	Total institutional	682	0.0781	0.375	9.594	0.032	0.070	0.157
	Total CII	3,172	0.1015	0.301	7.668	0.035	0.086	0.213

CII—commercial, industrial, and institutional, FDOR—Florida Department of Revenue

*Coefficients are based on data of water use and building heated area as measured in gallons per square foot of heated area per day.

17.5 and 19.0%, respectively, of total CII public water use in the state. These industrial water use statistics only accounted for industries served by the public water supply system, however, and many larger industries are self-supplied. In terms of both parcel count and heated building area, the largest industrial subsector was warehousing/distribution (FDOR 48), despite its relatively small average water use coefficient. Given that the water use calculation is a product of a sector's size (total heated building area) and water use coefficient, it is not surprising that warehousing/distribution was by far the largest industrial water user, with 6.1% of total CII water use. Throughout the industrial subsectors, large average heated areas and small water use coefficients were prevalent. In light of this fact, it seems reasonable to infer that these customers likely do not use their potable water connections for industrial processes.

The largest institutional water user was the public county school system (FDOR 83). Though this subsector had a relatively small average water use coefficient of 0.068 derived from gallons per flush per day of heated

area, public county schools have a large heated building area average of 126,588 sq ft, and there are many of them. Throughout the institutional subsectors, average water use coefficients were relatively small, indicating the existence of several possibilities in terms of end uses, such as use of private wells for irrigation.

The two-digit FDOR code breakdown in Tables 2–6 facilitates identification of the subsectors that are the most important as determined by the combination of their water use rate and size and as measured by heated area. If a utility seeks water conservation in the commercial sector, for example, the level of disaggregation in these tables can justify targeting a specific class of customers. Restaurants (FDOR 21) had the highest rate of water use per square foot of heated area (Table 4). Though their heated area accounts for just 0.8% of the heated area for CII sectors in the state, the overall water use of restaurants totaled 5.8% of Florida's estimated CII public water use (Table 6). Hotels/motels (FDOR 39) had a relatively high water use rate and were the single largest CII water user in the state. Such subsectors could be

TABLE 5 Estimated May peak water use coefficients and associated statistics for CII sectors

FDOR Code	Description	Sample Size	Weighted Peak Water Use Coefficient*	Peak/Average Ratio	Average Peak Water Use Coefficient*	COV	25th Percentile*	50th Percentile*	75th Percentile*
11	Stores (one-story)	286	0.1062	1.08	0.257	5.326	0.025	0.072	0.174
16	Community shopping centers	235	0.0995	1.04	0.146	1.320	0.038	0.089	0.185
17	Offices (one-story)	380	0.1405	1.09	0.194	4.230	0.030	0.064	0.165
18	Offices (multistory)	73	0.0781	1.13	0.082	0.895	0.030	0.049	0.122
19	Medical offices	260	0.1692	1.08	0.160	1.297	0.050	0.101	0.209
21	Restaurants	119	0.7718	1.04	0.708	0.680	0.322	0.615	0.975
22	Fast food restaurants	103	0.6701	1.05	0.736	0.756	0.400	0.611	0.952
23	Financial institutions	96	0.3999	1.08	0.497	3.394	0.047	0.249	0.448
27	Auto sales, repair	172	0.1290	1.04	0.224	1.785	0.034	0.066	0.203
39	Hotels, motels	49	0.2473	1.08	0.284	0.527	0.168	0.263	0.355
	Other commercial	418	0.1035	1.05	0.307	1.666	0.059	0.129	0.316
	Total commercial	2,191	0.1383	1.06	0.282	2.773	0.043	0.112	0.283
41	Light manufacturing	32	0.0569	1.04	0.148	2.653	0.017	0.025	0.077
48	Warehousing, distribution	221	0.0368	1.10	0.159	9.502	0.009	0.020	0.051
49	Open storage	19	0.1724	1.13	0.285	1.165	0.116	0.189	0.274
	Other industrial	27	0.1171	0.98	3.227	4.959	0.013	0.045	0.123
	Total industrial	299	0.0520	1.05	0.443	11.256	0.011	0.026	0.068
71	Churches	337	0.0559	1.14	0.088	1.366	0.025	0.046	0.103
74	Homes for the aged	12	0.1102	1.09	0.261	0.634	0.085	0.334	0.362
83	Public schools	52	0.0757	1.11	0.075	0.760	0.045	0.056	0.100
	Other institutional	281	0.1087	1.03	0.840	6.814	0.064	0.136	0.234
	Total institutional	682	0.0842	1.08	0.400	9.224	0.033	0.078	0.162
	Total CII	3,172	0.1080	1.06	0.322	7.392	0.035	0.092	0.231

CII—commercial, industrial, and institutional, COV—coefficient of variation, FDOR—Florida Department of Revenue

*Coefficients are based on data of water use and building heated area as measured in gallons per square foot of heated area per day.

analyzed further to determine end uses and evaluate water conservation potential.

Comparison of heated area coefficients with other CII studies. Other researchers have also developed CII water use coefficients based on heated area. Dziegielewski and colleagues (2000) analyzed the water use patterns of five major CII subsectors: supermarkets, office buildings, restaurants, hotels, and schools. Colorado WaterWise (2007) presented water use coefficients or benchmarks for restaurants, hotels, schools, and homes for the aged. Comparison across the coefficients presented in this article and those developed in these previous studies can be carried out by mapping the FDOR subsectors used here, i.e., supermarkets (FDOR 14), office buildings (FDOR 17 and 18), restaurants (FDOR 21), hotels (FDOR 39), schools (FDOR 83), and homes for the aged (FDOR 74). Table 7 compares CII coefficients from the current study with previous studies. For the most part, the coefficients are comparable. Large discrepancies in the coefficients can be attributed to the fact that the other

studies were specific to the southwestern region of the United States where factors such as varied climatic conditions may affect water use. For example, the largest coefficient difference across studies was within schools. In the research by Dziegielewski and co-workers (2000), the water use coefficient for schools was of a much greater intensity because it included irrigation; in contrast, schools in the Florida sample examined here were likely to irrigate from private wells, and therefore that end use was outside the scope of public water supply.

Incorporation of results into a water planning tool. By using a measure of size that is standard and reliable across the CII subsectors, along with default water use coefficients, any Florida utility can estimate the subsectoral breakdown of CII water use within its service boundary with this methodology. This database can be queried to determine those parcels are within the service boundaries of a given utility. Using the unique parcel ID related to the FDOR database, any utility can find the attributes for the parcels being analyzed within the utility service area.

TABLE 6 Florida application of CII water use coefficients

FDOR Code	Description	Sample Size	HA/EA	\bar{q}_j^*	State Parcel Count	State Total HA acres	State Total Water Use mgd	Percentage CII HA in Florida	Percentage CII Water Use in Florida
11	Stores (one-story)	286	0.924	0.0979	41,049	6,398	27.29	6.23	6.13
16	Community shopping centers	235	0.951	0.0960	8,164	6,818	28.50	6.64	6.40
17	Offices (one-story)	380	0.963	0.1289	39,400	4,145	23.28	4.04	5.23
18	Offices (multistory)	73	0.969	0.0692	16,311	7,503	22.63	7.31	5.08
19	Medical offices	260	0.970	0.1562	21,976	2,773	18.86	2.70	4.24
21	Restaurants	119	0.962	0.7417	8,091	803	25.94	0.78	5.83
22	Fast food restaurants	103	0.965	0.6369	4,521	323	8.96	0.31	2.01
23	Financial institutions	96	0.897	0.3705	4,994	781	12.61	0.76	2.83
27	Auto sales, repair	172	0.865	0.1238	15,807	2,412	13.01	2.35	2.92
39	Hotels, motels	49	0.945	0.2286	22,633	5,803	57.80	5.65	12.98
	Other commercial	418	0.929	0.0981	47,935	10,251	43.80	9.98	9.84
	Total commercial	2,191	0.941	0.1304	230,881	48,009	282.68	46.75	63.48
41	Light manufacturing	32	0.902	0.0545	19,109	6,227	14.78	6.06	3.32
48	Warehousing, distribution	221	0.946	0.0335	44,419	18,464	26.96	17.98	6.06
49	Open storage	19	0.971	0.1520	12,589	2,852	18.88	2.78	4.24
	Other industrial	27	0.946	0.1196	17,147	3,309	17.24	3.22	3.87
	Total industrial	299	0.942	0.0496	93,264	30,851	77.87	30.04	17.49
71	Churches	337	0.946	0.0492	23,275	4,538	9.73	4.42	2.19
74	Homes for the aged	12	0.922	0.1007	4,898	3,251	14.26	3.17	3.20
83	Public schools	52	0.980	0.0684	5,685	7,962	23.71	7.75	5.32
	Other institutional	281	0.966	0.1053	73,995	8,075	37.03	7.86	8.32
	Total institutional	682	0.963	0.0781	107,853	23,826	84.72	23.20	19.03
	Total CII	3,172	0.948	0.1015	431,998	102,686	445.27	100.00	100.00

CII—commercial, industrial, and institutional, EA—effective area, FDOR—Florida Department of Revenue, HA—heated area

*Total water use is derived by multiplying the weighted average water use coefficient \bar{q}_j , as measured in gallons per square foot of heated area per day by the measure of size in square footage of heated area.

CFWC has created a water-planning tool to assist utilities in developing their water conservation plans. EZ Guide 2.0 is currently a spreadsheet-based model that uses the coefficients presented here to estimate CII water use for any utility in Florida. These coefficients are applied within the water budget section of the guide. By estimating the individual water use for each CII subsector, EZ Guide 2.0 allows any utility or planning agency to develop a conservation strategy according to the relative importance and water use intensity of its subsectors. Using the guide, utilities can take a similar data-driven measure-of-size approach to estimate the amount of water use for the single- and multifamily residential sectors. The beta version of EZ Guide 2.0 is available free of charge online (conservefloridawater.org/ez_guide.asp), and the CFWC can assist water utilities and water management districts in generating the necessary information.

SUMMARY AND CONCLUSIONS

The method of estimating CII water use described in this article should represent a significant improvement over existing methods for estimating CII water use because it combines water billing records with parcel-level land use databases, principally FDOR. These databases allow for the size of subsectors and their activity coefficients to be developed by parcel-level data, which is a finer resolution than TAZ or census-block data. The databases also provide a standardized classification system to categorize various land uses across the state of Florida. The 55 CII FDOR land use subsectors allow water users to be classified within various degrees of

This methodology can be applied outside of Florida using water use coefficients and land parcel information from property appraisers specific to a region.

disaggregation based on the level of homogeneity desired in a sector. The FDOR database is public information and can be linked to any utility billing records through the parcel ID number. Water use coefficients presented in this article were calculated from historical billing records from HCWRS and GRU and heated area values from the FCPA. Because of space constraints, only the top CII water use subsectors in the state are presented here; complete water use and heated area statistics for the available CII subsectors are available on the CFWC website (conservefloridawater.org).

Directions for future research. Future work should include estimates on the number, efficiency, and frequency of use of water-using devices in the CII subsectors. Such estimates should include indoor domestic uses such as toilets, urinals, and faucets as well as outdoor uses such as irrigation application rates based on estimates of irrigable area and cooling water use for CII subsectors where applicable. End-use estimates should be linked with available best management practices and incorporated with cost-benefit data to optimize for the best blend of water conservation controls. Future research should also include a study to analyze the accuracy of the water use estimates described in this article and the reliability of savings with conservation efforts. Estimates of water use should be compared with actual CII water use outside the analyzed data. Such a study would allow for a greater measure of uncertainty to be associated with these estimates. In addition, more utilities should be incorporated into the analysis to account for regional differences in water use as well as to increase the sample size for the various water use subsectors.

TABLE 7 Comparison of water use coefficients from current and previous studies on CII water use

FDOR Code	Description	Current Study Coefficients*	AwwaRF Study† Coefficients*	Difference—%	Colorado WaterWise Study‡ Coefficients*	Difference—%
14	Supermarkets	0.270	0.223	-17	NA	NA
17, 18	Office buildings	0.099	0.103	4	NA	NA
21	Restaurants	0.742	0.845	14	0.526	-29
39	Hotels, motels	0.229	0.248	8	0.329	42
83	Public schools	0.068	0.306	348	0.042	-39
74	Homes for the aged	0.101	NA	NA	0.219	117

AwwaRF—Awwa Research Foundation, CII—commercial, industrial, and institutional, FDOR—Florida Department of Revenue, NA—not applicable

*Coefficients are based on data of water use and building heated area as measured in gallons per square foot of heated area per day.

†Dziegielewski et al, 2000

‡Colorado WaterWise, 2007

The availability of the FDOR database provides a major advance in the ability to estimate CII water use. The CFWC is expanding its database of water use coefficients and heated area statistics and will make them available to interested utilities. Given that this research found seasonal components of water use across CII subsectors to be minimal, estimates of average water use should be applicable outside of Florida except in those regions where landscape irrigation is a significant component of water use.

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FOOTNOTE

¹StatTools, Palisade, Ithaca N.Y.

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