EVALUATION OF RESTROOM AND IRRIGATION BEST MANAGEMENT PRACTICES IN THE COMMERCIAL AND INSTITUTIONAL SECTORS

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INTRODUCTION

A true benefit-cost analysis of water conservation best management practices (BMPs) requires an end use inventory of water using devices, along with estimates of their water use efficiency and frequency of use. Most studies regarding commercial and institutional (CI) water use have focused on presenting baseline usage for a select number of sectors. Dziegielewski et al. (2000) carried out a detailed analysis on five CI sectors of interest: schools, hotels/motels, office buildings, restaurants, and food stores. They developed water use coefficients for these sectors using a variety of measures of size, and through submetering, disaggregated total water use down to the general end uses (e.g., domestic, cooling, landscaping). Also, they presented benchmarks for efficiency based on the 25th percentile of customers sampled. This approach allows for comparison of water use across customers, but provides little insight into the effectiveness of actual BMPs.

The Pacific Institute's *Waste Not, Want Not: The Potential for Urban Water Conservation in California* (2003) also documented baseline water use for eight CI sectors and end use breakdowns. This study provided sector estimates of potential savings associated with various BMPs. Their methodology relied on survey data regarding the efficiency distribution of water end-use devices within a given sector. For example, toilets in the commercial sector were found to use an average of 3.0 gallons per flush (gpf). By retrofitting to a 1.6 gpf toilet, the potential savings for the sector is 1.4 gpf. By multiplying this end-use potential savings by estimates of frequency of use (total number of annual flushes per sector based on employment and visitors), the annual potential savings of BMPs for various sectors were quantified. This study provides a means by which to quantify a BMPs potential impact on water use, but provides limited insight into which sector BMPs are most cost effective to implement.

In order to overcome gaps in CI BMP end-use evaluations, this paper presents a methodology by which to estimate the number of domestic restroom fixtures, their water use efficiency, and frequency of use at the parcel level for 28 commercial and 16 institutional sectors. In addition, sector-specific water use coefficients will be reported to estimate how much of a sector's water use is attributable to sprinkler systems. Estimating how much water is used by a given end-use device allows cost and water saving data to be incorporated into the BMP optimization model that is part of EZ Guide (www.conservefloridawater.org).

DATA-DRIVEN APPROACH

Bottom-up estimates of end use devices require parcel-level information. For this methodology, the Florida Department of Revenue (FDOR) provides parcel-level data. FDOR maintains a database of legal, physical and economic property-based information, which is publicly available free of charge from the FDOR file transfer protocol site (ftp://sdrftp03.dor.state.fl.us/), and is audited and updated annually. FDOR provides data for each of the 9 million parcels of land in the state of Florida, of which 215,000 are commercial and 42,000 are institutional. The State’s 67 Florida County Property Appraisers (FCPAs) provide the parcel information to FDOR annually, allowing for a statewide land-use database with a consistent definition of terms. The following attributes from the FDOR database are of interest: parcel identification (ID) number, land use code, effective year built, effective building area, and parcel area.

The parcel ID number is a unique identifier to a plot of land, and serves as the link between 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 28 commercial and 16 institutional sectors in this study are determined using FDOR land use codes. Effective year built is defined as the effective or actual year built of major improvements for 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 to weight the various building area types found within a parcel differently. Unlike, effective area, heated area is a true area of a building, defined as all areas under climate control. Parcel-level heated area data is available from FCPA. Previous studies (Morales et al. 2011, Palenchar 2009) have investigated the relationship between effective and heated building area. These results indicate that effective and heated building areas are highly correlated across all CI sectors. Hence, effective area to heated area conversion coefficients were developed using the ratio of the means approach at the 2-digit FDOR sector level. These area conversion coefficients are used to estimate water use per heated area.

Parcel area is a derived field from the FDOR database, which provides polygon shapefiles delineating every parcel in the State. Using standard GIS tools, the area of each parcel can thus be calculated, and joined to the other parcel information provided in the FDOR attribute data. Besides parcel dimensions, these polygon shapefiles also 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. South Florida Water Management District (WMD), St. Johns River WMD, Southwest Florida WMD, and Suwannee River WMD provide the water service area boundaries of utilities in their districts as polygon shapefiles available on their respective websites to be viewed in GIS. The parcels are identified by a unique parcel identification number which can be related to the FDOR database to find the attributes for the parcels in the utility being analyzed.

RESTROOM END USES

Fixture Count

The heterogeneous nature of CI facilities makes it difficult to account for and estimate the number of end-use devices. A methodology by which to estimate the number of toilets, urinals, faucets and showers in each of the 28 commercial and 16 institutional FDOR sectors is presented in this section. This methodology uses Florida building and plumbing code information on minimum floor area and plumbing fixtures required per occupant for various facility types (Florida Building Commission 2007). The Florida building and plumbing codes used in this study are directly derived from the International Code Council, a non-profit organization whose mission is to develop national standardized construction codes. The International Code Council was founded in 1994 by the Building Officials and Code Administrators International, Inc., International Conference of Building Officials, and Southern Building Code Congress International, Inc., as a means to develop one set of comprehensive codes. Most states have adopted the construction codes of the International Code Council.

The Florida plumbing code provides minimum toilet, faucet, and shower fixture requirements for 24 building types. The normalization parameter for the derived coefficients is building occupancy, except for hotels/motels where the coefficients are in terms of the number of rooms. In order to relate these coefficients to FDOR, fixture count coefficients require normalization based on heated building area. The Florida building code provides the conversion from occupancy to square footage for 42 building types. By linking the FDOR land use codes to the appropriate facility type categories in the Florida building and plumbing codes, fixture count estimates per square foot of heated building area can be developed for the 46 CI FDOR sectors. Morales et al. (2011) indentified the top CI sectors in the state of Florida in terms of water use. The fixture count coefficients for these sectors are presented in Table 1. The hotel/motel (FDOR 39) coefficient assumes that the average hotel room is 250 ft^2, with a gross-to-net ratio of 1.1, where gross area is the total area of a building, and net area is the “usable” area of a building. Hence, this coefficient assumes that an average room accounts for 275 ft^2 in a hotel/motel.

The Florida building code’s minimum floor areas per occupant are based on means of egress. For the most part, these square foot per occupant values are based on gross area, though certain building types are presented per net square footage. For assembly tables and chairs, a gross-to-net ratio of 1.11 was assumed. The educational gross-to-net ratio was taken to be 1.20 (NIBS 2010). The coefficients of certain FDOR sectors in Table 1 are limited to facilities below a certain square footage as described in the table footnotes.

The fixture per square footage coefficients are intended to be applied at the parcel level, allowing for estimates of fixture counts to be rounded up to the nearest integer. This application also ensures a minimum of two toilets and faucets per establishment, one for male and one for female use. To estimate the number of urinals, the Florida plumbing code states that a maximum of 67% of male toilets for assembly or educational establishments are replaceable by urinals; all other facility types are allowed a 50% maximum replacement. The coefficients presented in Table 1 provide estimates of fixture counts based on minimum construction codes. These coefficients can be refined by surveying facilities in the major sectors of CI water use.

Table 1. Number of restroom fixture coefficients normalized using heated area for the top 10 commercial and 3 institutional sectors in Florida (Florida Building Commission 2007).

FDOR	Description	Building Code Land Use Description	Plumbing Code Function of Space	Toilets per 10,000 ft^2	Male Toilets per 10,000 ft^2	Female Toilets per 10,000 ft^2	Faucets per 10,000 ft^2	Showers per 10,000 ft^2
11[a]	Stores, One-Story	Mercantile, basement and grade floor areas	M; Retail stores, service stations, shops	1.33	0.67	0.67	0.89	
16[a]	Community Shopping Centers	Mercantile, basement and grade floor areas	M; Retail stores, service stations, shops	1.33	0.67	0.67	0.89	
17[b]	Office, One-Story	Business areas	B; Transaction of business	4.00	2.00	2.00	2.50	
18[b]	Office, Multi-Story	Business areas	B; Transaction of business	4.00	2.00	2.00	2.50	
19[b]	Medical Office	Business areas	B; Transaction of business	4.00	2.00	2.00	2.50	
21[a]	Restaurant	Assembly w/o fixed seats, unconcentrated (tables and chairs)	A-2; Restaurants	16.16	8.08	8.08	6.06	
22[a]	Fast-Food Restaurants	Assembly w/o fixed seats, unconcentrated (tables and chairs)	A-2; Restaurants	16.16	8.08	8.08	6.06	
23[b]	Financial Institutions	Business areas	B; Transaction of business	4.00	2.00	2.00	2.50	
27[b]	Auto Sales / Repair	Business areas	B; Transaction of business	4.00	2.00	2.00	2.50	
39	Hotels / Motels	Institutional areas, sleeping areas	R-1; Hotels, motels	36.36	18.18	18.18	36.36	36.36
71	Churches	Assembly w/o fixed seats, unconcentrated (tables and chairs)	A-3; Places of worship	6.06	2.02	4.04	3.03	
74	Homes for the Aged	Institutional areas, sleeping areas	I-2; Hospitals, ambulatory nursing home	16.67	8.33	8.33	16.67	5.56
83	Public County Schools	Educational, shops and other vocational room areas	E/D; Educational facilities/Day care	3.33	1.67	1.67	3.33	

[a] Assumes twice the minimum fixtures required by Florida plumbing code (Brubaker 2010).
[b] Toilet and faucet coefficients limited to a building's first 5,000 ft^2 and 8,000 ft^2, respectively. For building area over these limits use: 2 toilets per 10,000 ft^2 (one male, one female) and 1.25 faucets per 10,000 ft^2.

Frequency of Use

The proposed method for approximating how often restroom fixtures are used is presented in this section. This determination is made possible given that restroom frequency of use is driven by people. By estimating how many, and for how long, people are in a building, one can arrive at an estimate of frequency of use. This estimate is complicated by the fact that CI facilities have arrival and departure rates that vary widely depending on the mix and type of customers and employees. To overcome these challenges, functional population coefficients are proposed.

Functional population is a building's population normalized to 24 hours per day, and 7 days per week (Nelson and Nicholas 1992). For example, if 24 people visit a store for an hour each day, this corresponds to a functional population of one. Functional population coefficients are available for many facility types from impact fee studies specific to Florida (Nicholas 2010, Tindale-Oliver 2007, Duncan 2007). These coefficients are derived from transportation modeling statistics on employment, visitor trips, and length of stay, and can be mapped to FDOR (Table 2). These coefficients are normalized by heated building area, and thus apply directly to FDOR parcel-level data.

Since functional population is a standardized measure across all land uses, regardless of the land use dependent variability in employment/transient population, this allows for the application of generic human frequency of restroom use estimates. Mayer et al. (1999) gathered data indicating that the average person in a single family residence flushes a toilet 5.1 times per day. Assuming this statistic is based on a 16-hour period, its 24-hour equivalent would be 7.65 flushes per person per day. Following this procedure, Table 3 presents male and female frequency of use coefficients per restroom end-use fixture. The male coefficients assume that when applicable, urinal use occurs thrice as frequently as toilet use. Faucet use is arrived by assuming 10 seconds of faucet use following every toilet or urinal event. Toilet and urinal coefficients are expressed in flushes per person per day, while faucet and shower use is in minutes per person per day.

Fixture Water Use Efficiency

The final piece of information required to estimate the water use for restroom end uses is fixture water use efficiencies. The previous section described a method by which to arrive at total daily frequency of use in a building using functional population, and estimates of uses per person per day. The uses presented in Table 3 are flushes for toilets and urinals, and minutes for faucets and showers. To arrive at estimates of water use, gallons per fixture use are required. Florida's plumbing code mandates water use efficiencies. Through this regulatory information, a fixture's efficiency is thus a function of a building's year built and a fixture's service life. The historical water use efficiencies for toilets, urinals, faucets, and showers, required by the Florida plumbing code are provided in Table 4 (Friedman et al. 2011, NCDENR 2009). For CI establishments the service life of toilets and urinals is estimated to be 20 years based on valve life cycle analysis, while faucets and showerheads are taken to have a service life of 5 years (Scheuer et al. 2003, Santa Clara Valley Water District 2008). A Lagrangian approach to estimating service lives is used since it is important to retain the identity of the fixtures over time. The alternative approach of estimating fixture replacement using replacement rates (e.g., 5% of the urinals are replaced each year) causes the identity of an individual fixture to be lost. For example, a CI establishment built in 1983 would replace its toilets and urinals in 2003, and thus have toilet and urinal water use efficiencies corresponding to the 1995-present fixture efficiency group.

The methodology described in the previous sections allows for the estimation of water use per end-use device at the parcel level. Knowing how much water a given device currently uses, it is possible to derive the water saved through retrofitting such a device. The calculation to estimate water use per end-use device is shown in Equation 1.

$$\left(\frac{functional\,population}{ft^2}\right)\left(\frac{uses}{person*day}\right)\left(\frac{gallons}{use}\right)\left(\frac{ft^2}{fixtures}\right)=\frac{gallons}{fixture*day} \qquad (1)$$

Table 2. Functional population coefficients normalized on heated area for the top 10 commercial and 3 institutional sectors in Florida (Nicholas 2010, Tindale-Oliver 2007, Duncan 2007).

FDOR	Description	Functional Population per 1,000 ft^2
11[a]	Stores, One-Story	3.44
16[a]	Community Shopping Centers	3.44
17[b]	Office, One-Story	1.64
18[b]	Office, Multi-Story	1.64
19	Medical Office	1.70
21	Restaurant	7.43
22	Fast-Food Restaurants	7.90
23	Financial Institutions	1.94
27	Auto Sales / Repair	0.49
39	Hotels / Motels	1.27
71	Churches	0.53
74	Homes for the Aged	0.67
83	Public County Schools	0.98

[a] Only applicable to buildings of 50,000 ft^2 or less. For buildings between 50,001 and 100,000 ft^2 use 2.74, between 100,001 and 200,000 ft^2 use 2.76, and greater than 200,000 ft^2 use 2.32 functional population per 1,000 ft^2.

[b] Only applicable to buildings of 50,000 ft^2 or less. For buildings greater than 50,000 ft^2 use 1.19 functional population per 1,000 ft^2.

Table 3. Male and female frequency of fixture use coefficients per 24-hour period (Adapted from Mayer et al. 1999).

	Male	Female
Toilet (flushes/person/day)	1.91	7.65
Urinal (flushes/person/day)	5.74	0
Faucet (minutes/person/day)	1.28	1.28
Shower (minutes/person/day)	5.6	5.6

Table 4. Fixture water use efficiency coefficients per age group (NCDENR 2009).

Fixture Efficiency Group	Toilets (gal/flush)	Urinals (gal/flush)	Faucets (gal/min)	Showerheads (gal/min)
Pre-1983	5.0	2.5	5.0	6.5
1983-1994	3.5	1.5	2.8	3.0
1995-Present	1.6	1.0	2.2	2.2

SPRINKLER SYSTEM WATER USE

Gainesville Regional Utilities (GRU) provided water billing data for 738 commercial parcels, representing the ten largest commercial sectors of water use (Morales and Heaney 2010). Estimating which of these parcels irrigate with a sprinkler system can be carried out by using Alachua County Property Appraiser (ACPA) data, which identifies accounts with sprinkler systems. Water billing time series information for the top ten commercial sectors can thus be split into parcels with and without sprinkler systems. This analysis was confined to the top commercial sectors given sample size limitations within the smaller sectors.

Water billing time series information normalized by heated square footage for the 186 one-story office buildings (FDOR 17) in GRU is presented in Figure 1. It is clear that those parcels tagged with sprinkler systems consistently use more water than those without sprinkler systems. The discrepancy between water users with and without sprinkler systems is narrowing over time. This trend is possibly attributable to a decreased use of sprinkler systems due to climatic conditions and/or a weaker economy.

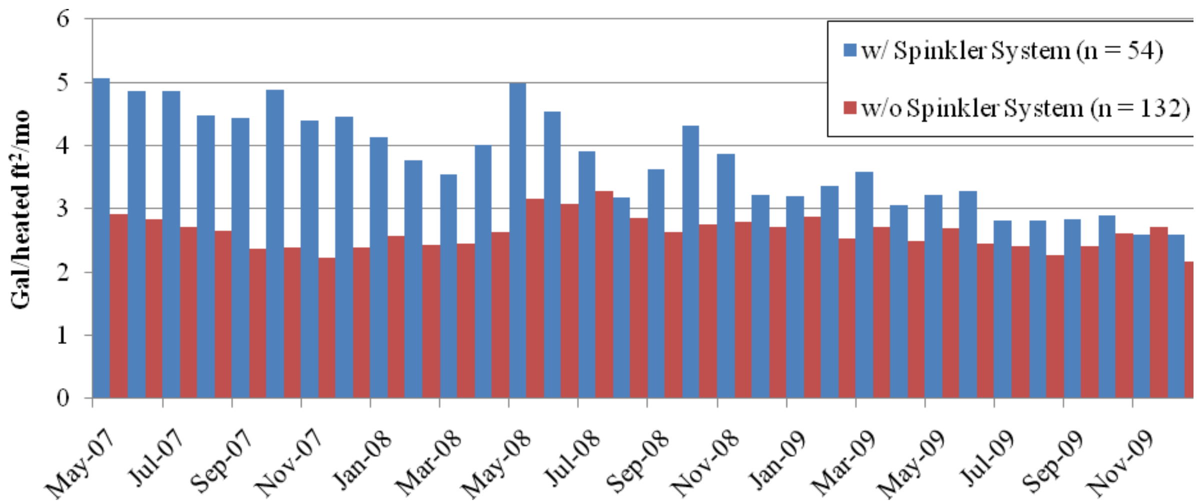

Figure 1. Sprinkler and non-sprinkler one-story office buildings (FDOR 17) water use (normalized by heated area) in Gainesville Regional Utilities.

In order to model sprinkler irrigation, it is crucial to use water billing data that is representative of normal system conditions. GRU provided two complete years of water billing from January 2008 through December 2009. Given the considerable downward trend of water use attributable to sprinkler systems within FDOR 17 parcels (Figures 1), it is important to determine which year, if either, is most representative.

Each utility in the state of Florida reports their monthly average and peak daily water produced to the Florida Department of Environmental Protection (FDEP). FDEP compiles this data and makes it available online. Ten years of data from January 2000 through December 2009, was used to determine GRU's average monthly water use as shown in Figure 2. Comparing GRU's average monthly water use to that of years 2008 and 2009 provides clear evidence that 2008 is more representative of normal water use in the system. Given this fact, in order to carry out water use evaluations for typical conditions, water billing from 2008 is used in this study.

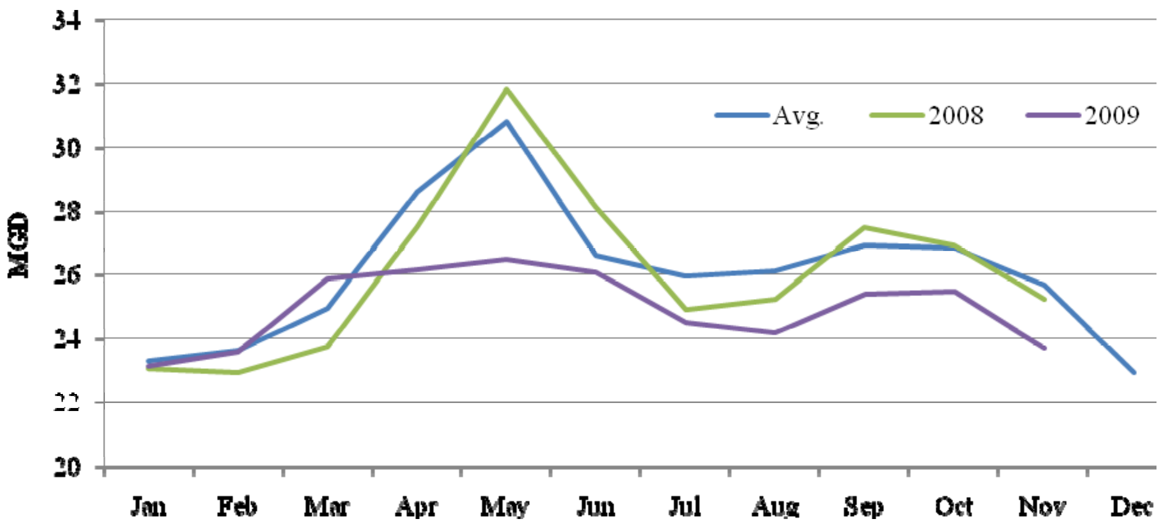

Figure 2. Average monthly for 2000 to 2009, 2008, and 2009 public water supplied by Gainesville Regional Utilities.

Average water use coefficients normalized by heated area are determined for FDOR parcels with sprinkler systems and those without via GRU billing, and associated ACPA data (Equation 2). This method of calculating water use coefficients results in a weighted average, accounting for the skewed nature of CI water use (Dziegielewski et al. 2000).

$$AWU = [\sum_{i=1} Q_i / \sum_{i=1} HA_i] \quad (2)$$

Where:

AWU = average weighted water use coefficient (monthly gallons/heated ft^2)
Q_i = average monthly water use of parcel i (gallons/month)
HA_i = heated square footage of all buildings on parcel i (ft^2)

Similarly, the base weighted water use coefficients (BWU) can be calculated using the total sector minimum water use month. The seasonal water use (SWU) coefficient is then obtained by subtracting the base water use (BWU) coefficient from the average water use (AWU) coefficient to arrive at the seasonal water use coefficient as shown in Equation 3.

$$SWU = AWU - BWU \qquad (3)$$

The difference between the sprinkler and non-sprinkler seasonal water use coefficients, as shown in Equation 4, is taken to be water use attributable to sprinkler systems. The average and seasonal water use coefficients for the top ten commercial sectors with and without sprinkler systems are presented in Tables 5 and 6, respectively, along with the associated water use coefficient attributable to sprinkler systems (Table 6).

$$WU_{sprk} = SWU_{ws} - SWU_{wos} \qquad (4)$$

Where:

WU_{sprk} = average water use coefficient attributable to sprinkler systems (monthly gallons/heated ft^2)
SWU_{ws} = seasonal water use coefficient for customers with sprinkler systems (monthly gallons/heated ft^2)
SWU_{wos} = seasonal water use coefficient for customers without sprinkler systems (monthly gallons/heated ft^2)

This method of calculating water use attributable to sprinkler systems is directly dependent on the hydrograph signature of sprinkler and non-sprinkler parcels in each sector. Unlike the residential sector, the commercial sector is often prone to other seasonal drivers besides irrigation. By taking into account the seasonality associated with the non-sprinkler parcels, this better ensures that other seasonal components such as those associated with fluctuations in population and tourism are not included in the estimate of water use attributable to sprinkler systems.

By utilizing the water use coefficient attributable to sprinkler systems, and assuming an annual application rate, one can estimate irrigated area using Equation 5. A typical application rate for sprinkler systems in the state of Florida is 25 inches per year (Palenchar 2009). Since FDOR also provides the parcel area for each of the 9 million parcels in the State, Table 6 presents the average irrigated area for top commercial sectors with sprinkler systems as a percentage of parcel area. The percent area irrigated calculation facilitates cross sector sprinkler irrigation comparisons. Following this calculation, it is clear that sprinkler irrigation is a minimal driver of water use for the commercial sectors analyzed. For the most part, the percent of the parcel irrigated is less than or equal to 5 percent. Medical offices (FDOR 19), financial institutions (FDOR 23), and one-story stores (FDOR 11), represent the largest sprinkler irrigators in terms of percent of parcel irrigated, with 14%, 12%, and 10%, respectively.

$$IA = WU_{sprk} * \frac{231 in^3}{gallon} * HA * \frac{1}{AR} * \frac{ft^2}{144 in^2} \quad (5)$$

Where:

IA = irrigated area (ft^2)

WU_{sprk} = average water use coefficient attributable to sprinkler systems (gallons/heated ft^2 /month)
HA = heated building area (ft^2)
AR = irrigation application rate (inches/month)

Table 5. Average and seasonal water use coefficients from Gainesville Regional Utilities for parcels without sprinkler systems in the top ten commercial sectors.

FDOR	**Description**	**Sample size**	**% of total**	**Avg. water use (gal/ft^2/mo)**	**Seasonal water use (gal/ft^2/mo)**	**Avg. heated area (ft^2)**	**Avg. parcel area (ft^2)**
11	Stores, One-Story	137	82%	3.31	0.33	7,111	43,114
16	Community Shopping Centers	71	66%	2.49	0.27	21,959	113,307
17	Office, One-Story	186	71%	2.78	0.36	5,301	33,506
18	Office, Multi-Story	28	29%	0.81	0.18	12,544	26,016
19	Medical Office	115	50%	3.67	0.44	5,838	24,915
21	Restaurant	41	61%	15.60	1.41	3,562	23,494
22	Fast-Food Restaurants	41	41%	16.38	1.48	2,033	25,193
23	Financial Institutions	30	13%	9.46	2.99	4,956	22,592
27	Auto Sales / Repair	52	79%	3.39	1.08	5,529	70,835
39	Hotels / Motels	37	70%	6.93	1.02	28,171	101,899

Table 6. Average, seasonal, and water use attributable to sprinkler system coefficients from Gainesville Regional Utilities for parcels with sprinkler systems in the top ten commercial sectors.

FDOR	Description	Sample size	% of total	Avg. water use (gal/ft^2/mo)	Seasonal water use (gal/ft^2/mo)	Avg. heated area (ft^2)	Avg. parcel area (ft^2)	Water use attributable to sprinkler systems (gal/ft^2/mo)	% water use attributable to sprinkler systems	% of parcel area irrigated
11	Stores, One-Story	137	18%	6.23	1.20	7,925	54,135	0.87	14%	10%
16	Community Shopping Centers	71	34%	1.62	0.27	73,712	346,706	0.00	0%	0%
17	Office, One-Story	186	29%	3.92	0.75	10,813	67,891	0.39	10%	5%
18	Office, Multi-Story	28	71%	1.82	0.57	25,108	157,675	0.39	21%	5%
19	Medical Office	115	50%	6.94	1.31	11,993	58,394	0.86	12%	14%
21	Restaurant	41	39%	23.65	1.70	7,110	56,306	0.29	1%	3%
22	Fast-Food Restaurants	41	59%	23.16	2.09	3,200	37,494	0.61	3%	4%
23	Financial Institutions	30	87%	16.44	4.35	6,460	54,935	1.36	8%	12%
27	Auto Sales / Repair	52	21%	4.58	1.36	8,079	81,603	0.27	6%	2%
39	Hotels / Motels	37	30%	7.52	1.15	34,326	98,504	0.12	2%	3%

Apart from contributing little to total water use, parcels with sprinkler systems also only make up a fraction of the total parcels within a given sector. This percentage of parcels with sprinkler systems largely influences the relative sector importance of this end-use device. In order to better estimate and forecast the water use attributable to sprinkler systems, it is crucial to investigate the time series trends for the prevalence of this end-use device over time using the information presented in Table 7. Given sample size limitations, Table 7 uses year built categories to present the trends for prevalence of sprinkler systems and average heated area. From this table, it is clear that over time both the heated area and the prevalence of sprinkler systems are increasing with a few notable exceptions. Similar trends in the popularity of in-ground sprinklers have been documented for single-family residences (Palenchar 2009).

BMP EVALUATIONS

Water use and end-use device estimates, along with economic data on total cost of retrofits and water, allow for evaluation of water conservation BMPs. The cost-effectiveness of a retrofit will increase the less water efficient an end-use device is, and with increased utilization of the device. For example, a 3.0 gpf toilet flushed 20 times a day will be more cost effective to retrofit than a similar toilet flushed 5 times a day. The coefficients and methodology described in this study indicate that indoor domestic end-use devices in the commercial and institutional sectors generally have a higher utilization rate, and thus are more cost-effective to retrofit than those same devices in the residential sector. Indoor restroom end-use device calculations and BMP evaluations are illustrated for a restaurant (FDOR 21) in GRU (Example 1).

Table 7. Sprinkler system and average heated area trends for top ten commercial sectors in Gainesville Regional Utilities.

	Sample size			**Average heated area (ft^2)**			**% with sprinkler systems**		
FDOR	**Pre 1983**	**1983-1994**	**1995-2008**	**Pre 1983**	**1983-1994**	**1995-2008**	**Pre 1983**	**1983-1994**	**1995-2008**
11	68	40	28	4,985	6,812	13,211	7%	18%	46%
16	28	27	15	27,820	46,600	48,637	7%	44%	67%
17	98	47	41	5,414	7,865	9,351	14%	36%	56%
18	9	15	4	32,352	13,742	26,306	67%	67%	100%
19	31	33	51	8,108	10,021	8,631	45%	58%	47%
21	18	12	11	3,645	5,544	6,424	6%	58%	73%
22	10	19	11	2,402	2,682	2,903	30%	68%	64%
23	4	9	15	6,902	7,224	5,667	100%	78%	93%
27	25	20	7	5,091	7,723	4,828	4%	35%	43%
39	19	12	5	21,489	27,723	67,026	16%	42%	60%
Sample size weighted avg.				9,174	13,277	13,749	17%	44%	58%

Example 1:
Attributes of restaurant in GRU:
Heated area = 4,304 ft^2 Effective year built = 1993

Fixture count
From Table 1:
Male toilets = 8.08/10,000 ft^2 Urinals = up to 67% of male toilets
Female toilets = 8.08/10,000 ft^2 Faucets = 6.06/10,000 ft^2

Fixture count = (Heated area)(coefficient from Table 1)

Male toilets = (4,304 ft^2)(8.08/10,000 ft^2) = 3.48 = 4 toilets
Knowing that up to 67% can be urinals => 2 toilets, 2 urinals
Similarly, female toilets = 4 toilets; faucets = 3 faucets

Functional population (24-hr, 7-day standardized population)
From Table 2: 7.43 people/1,000 ft^2

Functional population = (Heated area)(coefficient from Table 4) = 32 people
Assuming 50% male => 16 male, 16 female

Fixture water use:
From Table 3: Men flush toilets 1.91 times per day, and urinals 5.74 times per day.
Women flush toilets 7.65 times per day. Faucet use is 1.28 minutes per person per day
From Table 4: Property built in 1993, with 20-year replacement rate, fixture efficiency group is 1983-1994 efficiency group.
End-use water use = (fixture uses/person/day)(functional population)(gallons/fixture use)
Male toilets: (1.91 fpd)(16 men)(3.5 gpf) = 107 gallons/day (gpd)
Similarly, male urinals = 138 gpd; female toilets = 428 gpd; faucets = 115 gpd
Total restroom water use = 788 gpd

BMP Evaluation
Retrofitting to 0.8 gpf toilets
Assume utility rebate: total retrofit cost per toilet = $150
Retrofit cost effectiveness:
Annualizes cost of retrofit per water saved ($/kgal) = (total retrofit rebate cost / fixture service life) / kgal water saved per year
Male toilets = ($150/20 years) / [(107 gpd)(365 days/yr) / (1,000 gal/kgal) = $0.19/kgal
Similarly, cost/1,000 gallons for female toilets = $0.05/kgal

The ease by which BMP evaluations can be carried out using the proposed methodology is illustrated in Example 1. With two simple bits of information, heated area and effective year built, both available through FDOR, water use per end use device was calculated and an example BMP evaluated for cost effectiveness. The end result of the example is that female toilets are more cost effective to retrofit than male toilets. With the assumed cost of retrofit per toilet, it was calculated that the annualized cost of retrofitting male and female toilets in this example is $0.19/kgal and $0.05/kgal, respectively. With the cost of certain alternative water supplies exceeding $5/kgal, water conservation options in the CI sectors can prove to be attractive alternatives to meet water demands. The restroom end uses for the 46 CI sectors addressed in this study allow for the evaluation of 1,554 BMPs given three current fixture efficiencies and available retrofit types (Table 8). This methodology can be applied so that these 1,554 CI BMPs can be analyzed for cost effectiveness at the parcel level for any utility in the State.

Table 8. Best management practices for restroom end uses in the 28 commercial and 16 institutional sectors of water use.

	Applicable CI Sectors	**Current Water Use Efficiency***	**Possible Retrofits Types***	**Number of BMPs**
Male Toilets	46	5, 3.5, and 1.6 gpf	1.28, 1.0, and 0.8 gpf	414
Female Toilets	46	5, 3.5, and 1.6 gpf	1.28, 1.0, and 0.8 gpf	414
Urinals	46	2.5, 1.5, and 1 gpf	0.5 and 0.0 gpf	276
Faucets	46	5, 2.8, 2.2 gpm	1.5, 1.0, 0.5 gpm	414
Showerheads	6	6.5, 3, and 2.2 gpm	2.0 and 1.5 gpm	36
Total	-	-	-	1,554

*gpf = gallons per flush; gpm = gallons per minute

SUMMARY, CONCLUSIONS, AND FUTURE WORK

This paper presents a methodology by which to estimate the number, efficiency, and frequency of use, of indoor restroom end-use devices for each of the 28 commercial and 16 institutional sectors classified by FDOR. Additionally, sprinkler irrigation water use coefficients for the top commercial sectors in the State were calculated per heated building area. This approach is also readily expandable to the industrial sectors of water use. By estimating water use at the end-use level, this methodology offers a major improvement over past studies by addressing a large number of CI sectors and allowing for the evaluation of water conservation BMPs for cost effectiveness.

Future work in this area should validate the use of minimum fixture requirements by using survey data of a representative sample of establishments. In addition, increased sample sizes across the CI sectors, would not only improve the current estimates of water use attributable to sprinkler systems, but also expand the estimates to other sectors and allow for the accounting of regional effects. Furthermore, this end-use device methodology should be expanded to include other end uses such as cooling towers, hotel/motel clothes washers, and restaurant spray valves.

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