METHODS FOR ESTIMATING COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WATER USE

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INTRODUCTION

Municipal water use is commonly measured in gallons per capita per day (gpcd) to compare use between utilities and across water use sectors. Gpcd can be defined as net gpcd, which is water use by the residential sector only, or as gross gpcd, water use by all sectors. Gross gpcd includes total water use and water loss, and should be evaluated by a water budget to better understand the relative use by different sectors of customers. The Conserve Florida Water Clearinghouse (CFWC) Guide is a tool that is used to develop a water budget for a utility (www.conservefloridawater.org). The major sectors profiled in the Guide are: single family residential (SF), multi-family residential (MF), commercial, industrial, institutional, and other (Friedman and Heaney 2009). The water use estimates for the commercial, industrial, and institutional (CII) sectors are addressed in this paper.

This paper presents a new methodology to estimate CII water use based on databases of parcel-level customer attributes and water use billing. The Florida Department of Revenue (FDOR) and County Property Appraiser (CPA) databases provide the classification of customer and heated building area for every parcel of land in the state of Florida. Linking these parcel-level attributes with parcel-level water use billing data provides a major improvement in our ability to estimate CII water use. The customer classifications in these databases allow the user of the Guide to define the level of disaggregation within the CII sector. The sum of the heated area of a sector is the size used to estimate its water use.

The calculation used to estimate CII water use is a production function combining a coefficient of water use for the sector with the heated area estimate of the sector's total size. The water use coefficient is the total of the average monthly water use for all customers in a sector standardized by their total heated area. These activity coefficients are developed by linking the attribute database with the water billing records. The default values for the coefficients of the CII sectors are based on an analysis of the Hillsborough County Water Utility (HCWU) from 2003 to 2006. This utility provides a relatively large sample of 1,857 CII parcels, of which 65% are commercial, 8% are industrial, and 27% are institutional.

Access to this level of data improves on existing models of estimating CII water use. Existing models typically use the number of employees as the best single indicator of the size of the CII sector. Employee data is available periodically through the U.S. Census or private surveys. The finest resolution of Census data is the block level, not the parcel level, and while survey data is at the parcel level, the data are expensive to collect. Census data are only available every five years and surveys are typically done only once.

In order to determine the heated area of different sectors in a utility, the user must access the FDOR, water management district and CFWC databases. The FDOR database provides the classification code and the effective area for every parcel. These values are standardized across the state and the database is available by download from the FDOR website. The user can query the database for the parcels in a utility based on the service area delineations provided by the water management districts. The results of this query provide the effective areas for every parcel and the means to separate customers into CII sectors. The CFWC provides a conversion factor in an online database (www.conservefloridawater.org) to determine the heated area from the effective area. Converting the effective area to heated area may be easier than finding the heated area directly in the CPA database because the data fields and formats in the CPA databases vary by county and may not be available to download.

The CII activity coefficients were developed by linking the parcel level attribute data with the water billing data of HCWU. Because the FDOR database identifies the classification of land use for each parcel, this database provides the means to aggregate or disaggregate the water use activity coefficients for sectors by different levels of specification. The most aggregated coefficients are for the general CII sectors. These coefficients can be disaggregated into 57 sectors based on the FDOR two-digit land use categories. These sectors may be further disaggregated to more specific four-digit CPA land use categories if the water use by a sector needs to be investigated further. The FDOR database has standard two-digit economic codes to classify parcels across the state, and the local CPA database has the option to expand upon these codes with more detail with their classification system. By this method, every utility in the state of Florida can determine the relative water use by different sectors of customers in their service area. The relative use of each sector can be calibrated with known total water use in order to identify how the water is used at present and which sectors are the more significant water users.

LITERATURE REVIEW

Water use models typically forecast water use for supply planning purposes. Estimates to forecast water use include having a rate of water use for a sector and a measure of its size throughout the planning period. The rate of water use, or activity water use coefficient, is the total water use by all customers within that sector standardized by the total measure of its size. Some models may provide default coefficients for sectors of varying levels of customer disaggregation or require the user to develop their own. Total water use over n sectors is calculated using Equation 1.

$$Q_{Total} = \sum_{k=1}^{n}(\alpha_k * x_k) \tag{1}$$

Where: Q_{Total} = water use for n sectors
α_k = water use coefficient of sector k
x_k = size of sector k
n = number of sectors

The historically predominant water use model was the Institute of Water Resources Municipal and Industrial Needs model (IWR-MAIN). It was the first model to estimate CII water use empirically and disaggregate the general sector into more distinct categories. IWR-MAIN was created by Hittman Associates, Inc. in 1969, developed under the Institute of Water Resources of the U.S. Army Corps of Engineers and further refined by Planning and Management Consulting, Ltd (PMCL, now a subsidiary of CDM). IWR-MAIN was a public domain model and transitioned into being a proprietary model after IWR financial support ended in the 1980s. The original IWR-MAIN is no longer available and water use estimates are done using spreadsheets that replicate many of the features in the original model. In IWR-MAIN, the size of each CII sector is estimated by total employment and CII water use is estimated based on Standard Industrial Classifications (SIC) sectors as developed by the Department of Commerce (Opitz et al. 1998).

IWR-MAIN version 5.1 (1988) was used to estimate the demand for water and the intensity of water use within a sector. The water use coefficients were determined by regression analysis and the explanatory variables are the number of employees, the price of water and sewer services, and the presence of conservation programs (Boland 1997). The coefficients in Version 5.1 were developed from the weighted average of water use rates found in a nationwide survey of 3,448 commercial and institutional establishments, as well as from surveys of manufacturers by the U.S. Census Bureau and the California department of Water Resources (Dziegielewski and Boland 1989).

The survey to develop the Version 5.1 activity coefficients was large, random and parcel-specific to produce stable national averages, but the model could not be adjusted to a specific region's climate. The model depended on the user to input local employment data, which is available from the U.S. Economic Census or from private surveys (Dziegielewski et al. 2000). The U.S. Census is available only in five year increments and the employment data is aggregated to a geographical block. Each Census block is assigned one North American Industry Classification System (NAICS) code (which recently replaced the SIC classification system) and a corresponding level of employment. The size, density and composition of parcels within a Census block vary widely and the precision of total employment estimates for each sector by U.S. Census is limited because of this aggregation. Commercial surveys are more thorough and precise because data is collected at the customer level, but the accuracy depends on the diligence of the respondent and this data must be purchased.

The latest release of the IWR-MAIN model was Version 6.1 in 1995. Version 6.1 had a more sophisticated demand forecast procedure. The employment data used to estimate the water use coefficients were based on surveys over a ten year period of over 7,000 CII establishments across the United States and were developed by regression to account for the elasticity of CII water demand to economic and climatic independent variables. Users could choose from a library of default coefficients or input their own estimates (Opitz et al. 1998).

This model had activity coefficients for the eight major industry groups (n = 8 disaggregated CII sectors), all of the 65 two-digit SIC sectors (n = 65) and all of the 417 three-digit SIC sectors (n = 417). Because the sample was collected over a period of time, the forecasts of water use were able to provide daily-demands and summer and winter, or annual periods (Baumann et al. 1998; Opitz et al. 1998). These coefficients were a major improvement because they were developed from a larger cross-section of customers over a longer period of time. The accuracy of the model was still limited by the quality of the input data. If a user relied on the government Census for employment data, the sectoral and temporal components of the model were restricted by the resolution of that data. If the user relied on survey data, their forecast was restricted by the amount of historic data they could afford.

The traditional IWR-MAIN model with default coefficients is no longer supported and the coefficients are antiquated. In 1999, PMCL released the IWR-MAIN Water Demand Management Suite. This spreadsheet model removed the default water use coefficients and required the user to develop their own coefficients (CDM 2008). This software provided a different approach to modeling where the user could tailor the model to their region of implementation.

Hazen and Sawyer and PMCL (2004) developed a utility-wide model for Tampa Bay Water (TBW), a wholesale distributor. This model was used to estimate SF, MF and non-residential (NR) water use for seven different member government planning areas. The model has an equation to estimate the NR water use coefficient based on historical usage, composition of the NR sector, local affluence and climate. A commercial vendor provided the historical employment and income data for the years 1999 to 2002 by survey. The study included 39,727 NR parcels and linked the parcel data to their billing records. The values were averaged per Traffic Analysis Zone (TAZ) and combined with rainfall data to run a regression and develop the monthly water use coefficients (Hazen & Sawyer and PMCL 2004). Total employment is the size of the NR sector used to estimate water use.

TBW found that its macro-scale NR model explained only two percent of the variation in water use (Hazen & Sawyer and PMCL 2004). The modelers attribute this low explanatory power to the typically heterogeneous nature of NR water use. If more specific customer classifications were developed for the NR sector, then each group of customers could be more homogeneous in their application of water. The coefficients also came from two years of severe drought (SWFWMD 2006) and likely do not describe average water use during a normal year.

The models of the IWR-MAIN tradition are tools for forecasting water use. These models develop their water use projections from a regression analysis of explanatory variables and have been developed differently over time. Table 1 highlights their progression.

As forecasting tools, these models do little to evaluate present water use or indicate conservation potential. TBW has a rich spatial and temporal dataset for water use by each parcel, and a more sophisticated CII model could have been developed if the water use coefficients were standardized by a measure of size that can be related more directly to water use processes.

Maddaus and Maddaus (2004) have pioneered the end-use approach with a Least Cost Planning Demand Management Decision Support System (DSS) model. This forecasting model calibrates total water use with an estimate of fixtures in a building based on its age, the frequency of each end-use by an employee, and the fixture’s natural replacement rate. Studies like the AWWARF Commercial/Institutional End Uses of Water Study (Dziegielewski et al. 2000) and EBMUDs Watersmart Guidebook (EBMUD 2008) provide the documentation of baseline water use by end use devices and water-saving technologies that are applicable in the different CII sectors. Maddaus and Maddaus (2004) rely on employment data for the measure of CII water use in the DSS model and can only disaggregate into C, I and I.

Item	Version 5.1	Version 6.1	TBW
Measure of sector size	Employment	Employment	Employment
Data used to develop water use coefficients	National survey	National survey	Regional survey
Number of survey points	3,448	7,000	39,727
Level of data aggregation	Census block	Census block	TAZ
Time span of historic data	1 year	10 years	3 years
Explanatory variables	• number of employees • price of water and sewer services • presence of conservation programs	• number of employees • marginal price of water • average productivity of labor • number of cooling degree days	• total number of employees • fraction of employment in commercial, institutional, industrial customers • residential income • total rainfall
Default CII coefficients	• 23 commercial and institutional • 198 industrial	Aggregated • 8 major industrial groups Disaggregated • 65 two-digit SIC Most disaggregated • 417 three-digit SIC	• 1 non-residential

Table 1. Comparison of models in the IWR-MAIN tradition (Dziegielewski and Boland 1989; Opitz et al. 1998; Hazen & Sawyer and PMCL 2004).

Similar to the 1999 IWR-MAIN release, the Water Evaluation and Planning model (WEAP) also requires the user to develop the water use coefficients. The WEAP software, developed by the Stockholm Environmental Institute (2009), is a water forecasting tool for utility supply planning and demand management. This model utilizes a system of modules that characterize the physical water demand-supply network and estimate water demands for various water uses as defined in the study. The activities are standardized per production output for CII and sectors determined by the quality of the input data. A notable feature of this demand management program is that a hierarchic branching data infrastructure is used to manage water use data by the sector, subsector, end-use and device. The model incorporates demand estimates into the distribution program to simulate supply allocations on a spatial and temporal basis to provide a sophisticated planning tool (Wurbs 1995). This model allows for greater flexibility and accuracy in water supply planning but has an extensive requirement of user inputs. Such data requirements also increase the amount of time and resources required to run such a model.

Many of the models reviewed standardize CII water use by the total number of employees in order to compare the efficiency and variance of different sectors. Other variables have been investigated. Mercer and Morgan (1974) developed water use coefficients based on number of employees and this study cites that employee data has historically been readily available compared to other parameters such as acreage. Kim and McCuen (1979) studied retail stores and the results showed that the best two predictors of water use were gross area and sales area, the only two measures of area analyzed, followed by average number of daily man-hours and employees. Dziegielewski et al. (2000) investigated five different commercial and institutional water users and only building area was found to be a significant indicator of water use across all customer categories.

In order to create a bottom-up approach, a model needs more accurate, frequent and robust database. Employment data are averaged per Census block, available periodically and do not provide a means to classify customers. Because this metric is so widely used and a better substitute has not been developed, no CII water forecasting model is appropriate for evaluating conservation options. A new approach is needed. Our proposed method is described in the next section.

METHODOLOGY

Given the limitations of past models, including access to reliable data and that many of these models are no longer available, we propose a new methodology to estimate CII water use based on parcel-level land use and water billing databases. Parcel-level land use characteristics from the FDOR database were linked with historic water billing data for CII customers in Hillsborough County Water Utility (HCWU) to develop water use coefficients normalized by heated building area. Heated building area is a consistent and well-defined measure of size, as well as good estimator of water use. The FDOR database, in conjunction with the CPA, provides the heated building areas for every parcel in the state along with their land use classification, allowing for sector specific water use coefficients. By applying the water use coefficients presented in this paper, any utility in the State, by utilizing publicly available databases, can carry out a water budget at the parcel-level. The following section will describe the databases used to develop this model, as well as the databases required to apply it.

UTILITY BILLING DATA

Water billing data vary widely in both content and availability depending on the policies of the individual utilities. Without standardized databases, these differences make water use comparisons across utilities very difficult. In order to develop the water use coefficients for this study, water billing records from HCWU were utilized. HCWU provided four complete years (2003-2007) of monthly water billing for a relatively large sample of 1,857 CII water users, as well as the crucial link to FDOR via a parcel ID. Parcel ID is the common identifier which allows parcel attributes from FDOR to be related to water use.

HCWU data also provides valuable time series information about the nature of water use in the CII sectors. By using FDOR land use codes, CII water customers can be aggregated into either the commercial, industrial, or institutional sector. The time series plots of these sectors, presented in Figure 1, show the lack of any significant trends or monthly variability among the sectors. The peaking factors corresponding to these time series plots are 1.10, 1.27, and 1.30 for the commercial, industrial and institutional sectors, respectively. Such small peaking factors, along with insignificant trending or seasonal variability, indicate that point estimates of water use coefficients are reasonable for the CII sectors.

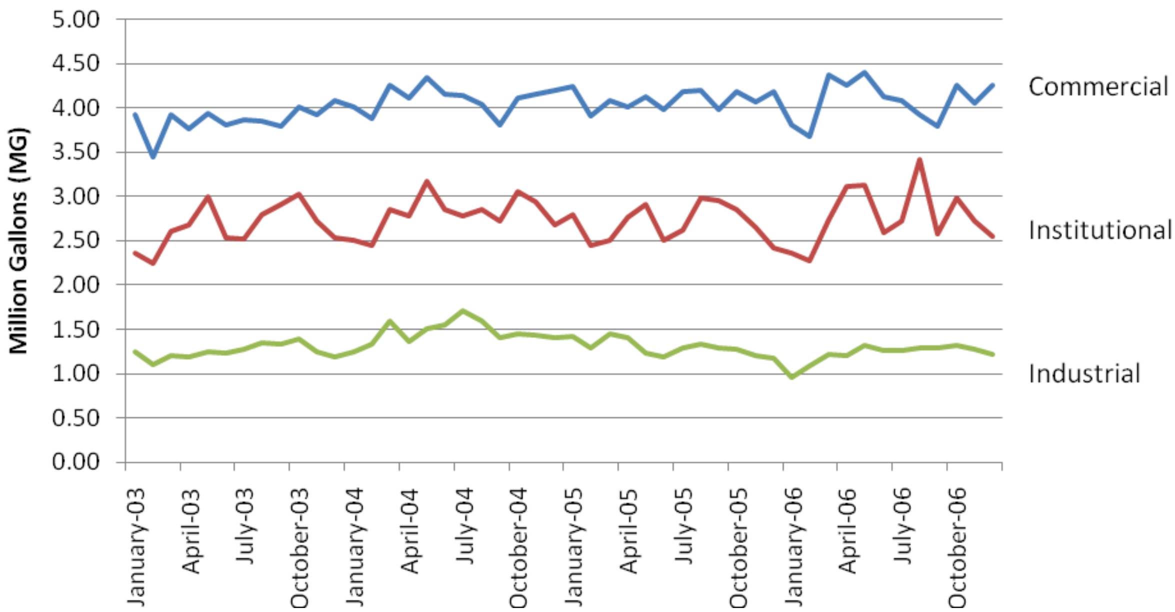

Figure 1. Time series plots of monthly water use for the commercial, industrial, and institutional sectors in HCWU.

FDOR DATABASE

The Florida Department of Revenue (FDOR) maintains a database of legal, physical and economic property-based information for every parcel of land in the state of Florida. This database is publicly available free of charge from the FDOR website, and is carefully audited and updated annually. Parcels are partitioned based on their land use into 100 sectors using two-digit FDOR codes. FDOR codes are standardized across the state, providing consistent definitions of terms. The parcel information in this database is provided by the state's 67 County Property Appraisers (CPAs) to FDOR for a statewide land-use database. The FDOR has also joined forces with other state agencies and water management districts to capture and share data for a more thorough database (FDOR 2009). The following attributes of interest are provided by the FDOR database:

- Parcel ID number
- Land use code
- Effective building 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 coefficients in this study were developed at the parcel level, requiring the data in all the databases be adjusted to this level of aggregation.

The FDOR land use code is a two-digit classification system that identifies the primary use of the land by its economic activity. CII sectors in this study were determined using FDOR land use codes. The FDOR land use classification system allows for various degrees of disaggregation following the hierarchical structure presented in Figure 2. In broadest terms, urban land use can be broken up into residential and CII sectors based on groups of FDOR codes. Disaggregation is possible by allocating the residential codes into either SF or MF, and CII codes into commercial, industrial, and institutional. The greatest level of disaggregation that can be derived from the FDOR database comes from the two-digit land use code. Through the use of FDOR alone, the relative importance of sectors can be quantified by simply summing total effective areas of parcels within sectors.

Effective building area is not a physical area, but rather a calculated value which incorporates econometric factors of the structures within a parcel. For this reason, water use coefficients in this study were developed using heated building area, a physical area not prone to misinterpretation and available from CPA. In order to allow application of water use coefficients directly with FDOR requires coefficients to convert the effective building area to heated building area. The use of these coefficients is reasonable given that effective area is very highly correlated with the heated area. This correlation is shown in Figure 3.

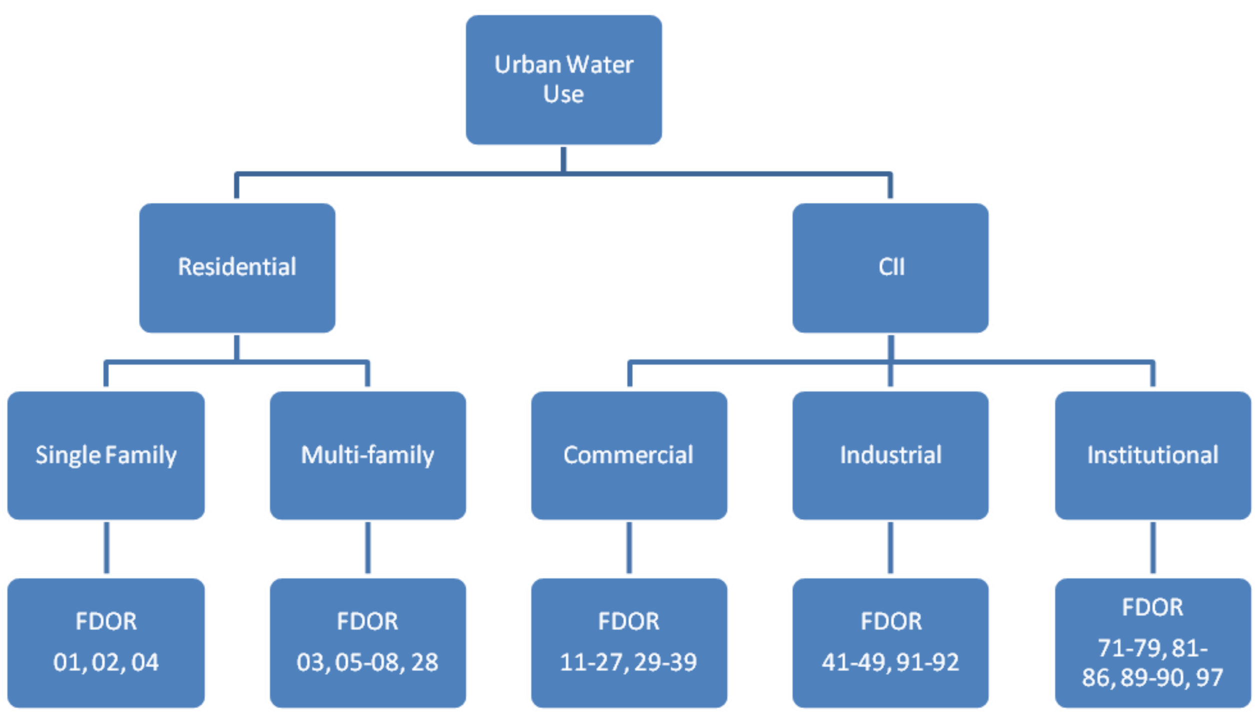

Figure 2. Levels of FDOR land use disaggregation into 9 residential and 57 CII sectors.

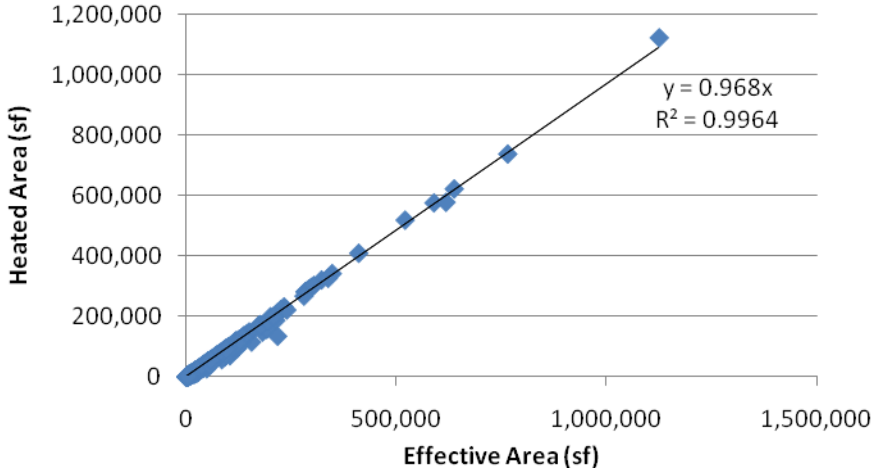

Figure 3. Heated and effective area correlation for 1,857 CII parcels in HCWU.

CPA DATABASES

Each of the 67 counties in Florida maintains a CPA database that contains the same information as the FDOR database, along with additional attributes varying from county to county. Though exact fields and formats by each CPA vary across the State, the FDOR's Tax Oversight Program is providing training to property appraisers to increase their efficiency with digital data (FDOR 2009). These databases are public information, must be obtained from each county individually, and their availability and extent of additional information has not been fully investigated. Attributes of interest in the CPA databases include:

- Parcel ID number
- Heated building area
- CPA land use code

CPA provides the heated areas of buildings in a parcel, defined as all building area under climate control. Unlike effective building area, provided by FDOR, heated area is a physical building area. The local CPA may have the same two-digit land use code as FDOR, or subdivide the land use further with a four-digit code. In the case of the four-digit code, the first two digits are consistent with the original FDOR classification system and the second two break the sector down into further land use detail. Four-digit CPA land use codes allow for greater disaggregation of customers, but since these codes are neither required nor standardized across the State, this paper solely addresses two-digit FDOR codes.

WATER MANAGEMENT DISTRICT GIS UTILITY BOUNDARIES

The state of Florida is comprised of five water management districts: Northwest Florida Water Management District (NWFWMD), Suwannee River Water Management District (SRWMD), St. Johns River Water Management District (SJRWMD), South Florida Water Management District (SFWMD) and Southwest Florida Water Management District (SWFWMD). SJRWMD, SFWMD and SWFWMD provide the water service area boundaries of utilities in their Districts as shapefiles available in their respective websites to be viewed in GIS. These maps are provided for the analysis of public water supply and identify the parcels that are supplied potable water through a utility. The delineations are polygons in GIS and the parcels identified as being in the service area are ones with their centroids in the polygon. In GIS, the user can query for the parcels in a particular service area and then export the list to a spreadsheet. The parcels are identified by a unique Parcel ID number which can be related to the FDOR database to find the attributes for the parcels in the utility being analyzed. SRWMD and NWFWMD do not provide utility delineations, but their parcels can be estimated by the city served by a utility or the zip codes in the service areas. With all of these methods to acquire the parcels in a utility, the water budget will need to be calibrated with total water use for improved accuracy.

FDEP WATER USE DATABASE

The Florida Department of Environmental Protection (FDEP) provides a database on their website of maximum day flow and average daily flow per month for every potable water plant in the State. This monthly data are available since 1999, and includes the design capacity and population served of each plant. This database can be used once an initial water budget has been carried out using the water use coefficients to ensure an accurate estimate. If the estimated water use does not match the reported flow in the FDEP database, then the reported flow can be used as a means of calibrating the model.

DEVELOPMENT OF CII COEFFICIENTS BASED ON SPECIAL STUDIES

Activity water use and area conversion coefficients in this study were developed at the parcel level for the CII customers of HCWU. The three databases used, along with their attributes of interest are presented in Table 2.

Database	Attributes of Interest	Period of Record
HCWU	• Monthly Water Use	2003 - 2006
FDOR	• Land Use Code • Effective Area	2008
HCPA	• Heated Area • Land Use Code	2008

Table 2. Databases and parcel attributes used to develop water use and area conversion coefficients.

CFWC CII WATER USE COEFFICIENT CALCULATION

To develop the water use coefficients, the HCWU water billing records were adjusted so that all customer records on a single parcel in a given month were summed. This procedure aggregated the water billing to the parcel level, and accounted for customers with multiple water use entries for a given month. Multiple entries are common to billing records, where a utility seeks to correct for a billing over/under-charge with a separate billing entry. This method of aggregating the billing records maintains the water use in a time series for each parcel, and allows for parcel land use classification via FDOR. Since the activity coefficients developed in this study are point estimates, the average water use throughout the four year period was computed for each parcel. Only parcels reporting water use through the entirety of the study period were included in the analysis.

The adjusted billing records were then linked to FDOR and HCPA via the parcel ID. FDOR provided the two-digit land use codes for each parcel, allowing for their classification. The hierarchical structure presented in Figure 2 was used to develop water use coefficients for the various degrees of aggregation, as well as for each of the 28 commercial, 11 industrial, and 18 institutional sectors. The measure of size used to normalize the water use data and develop the activity coefficients is heated area from the HCPA. Similarly to the billing records, the heated areas were aggregated to the parcel level by summing all the heated areas of establishments within a given parcel. The water use coefficients were developed by summing the average monthly water use of all parcels within a given sector and dividing by their total heated area. This method of calculating the coefficients provides a weighted average which compensates for the skewness often found in the distribution of CII water users.

CFWC CII AREA CONVERSION COEFFICIENT CALCULATION

Since the water use coefficients were developed based on the heated area of buildings, this study also derived coefficients to convert effective area, found in the FDOR database, to heated area. These conversion coefficients allow users to apply the CFWC water use coefficients directly to the FDOR database, without having to obtain the corresponding CPA database. As shown previously on Figure 3, heated and effective areas are highly correlated for the CII sector; hence the application of conversion factors only introduces a minor loss of accuracy. Since the FDOR database is much more easily accessible and standardized across the state, these area conversion coefficients greatly facilitate the application of the CFWC water use coefficients.

COMMERCIAL SECTOR

As described previously, water use and area conversion coefficients were developed for various degrees of disaggregation. In order to more specifically pinpoint CII water use, this study carries out the greatest disaggregation based on two-digit FDOR codes. The developed water use coefficients for the commercial sector of HCWU are shown in Table 3. The area conversion coefficients to convert from effective area to heated area are presented under the subheading of HA/EA. This table includes the sample sizes from which the coefficients were derived, and the total heated areas of all the buildings and total monthly water use of all customers within each sector. Also included in this table is the percent of total heated area and water use in each sector, these columns allow for a measure of the relative importance of each sector when it comes to CII land use and water use.

FDOR Code	Description	n	HA/EA	Weighted Water Use Coef. (gal/hsf/mo)	Total Heated Area (sf)	% Heated Area in Sector	Total Water Use (mg/mo)	% Water Use in Sector
11	Stores, One-Story	114	0.95	2.18	1,100,896	5.2%	2.40	2.8%
12	Mixed Use	97	0.92	2.78	1,344,553	6.4%	3.73	4.4%
13	Department Stores	22	0.97	1.78	3,006,401	14.2%	5.34	6.3%
14	Supermarkets / Conv. Stores	121	0.95	7.92	800,947	3.8%	6.34	7.4%
15	Regional Malls	2	0.88	2.80	1,641,102	7.8%	4.59	5.4%
16	Community Shopping Centers	165	0.95	3.49	6,508,188	30.8%	22.74	26.7%
17	Office, One-Story	153	0.96	5.39	846,254	4.0%	4.56	5.3%
18	Office, Multi-Story	44	0.98	2.39	1,590,795	7.5%	3.80	4.5%
19	Medical Office	110	0.96	3.98	739,322	3.5%	2.94	3.4%
20	Transit Terminals	5	0.96	10.62	53,348	0.3%	0.57	0.7%
21	Restaurant	70	0.96	25.52	359,323	1.7%	9.17	10.8%
22	Fast-Food Restaurants	59	0.96	20.95	182,456	0.9%	3.82	4.5%
23	Financial Institutions	64	0.87	7.64	281,706	1.3%	2.15	2.5%
24	Insurance Company Offices	-	-	-	-	-	-	-
25	Service Shops	20	0.90	12.47	55,477	0.3%	0.69	0.8%
26	Service Stations	-	-	-	-	-	-	-
27	Auto Sales / Repair	118	0.86	3.84	1,152,746	5.5%	4.42	5.2%
29	Wholesale Outlets	-	-	-	-	-	-	-
30	Florist / Greenhouses	-	-	-	-	-	-	-
31	Drive-in Theaters/Open Stadiums	-	-	-	-	-	-	-
32	Enclosed Theaters / Auditoriums	1	0.92	4.04	97,632	0.5%	0.39	0.5%
33	Nightclubs / Bars	7	0.94	8.19	24,102	0.1%	0.20	0.2%
34	Bowling Alleys / Skating Rinks	1	0.98	1.21	30,784	0.1%	0.04	0.0%
35	Tourist Attractions	1	0.80	17.54	3,576	0.0%	0.06	0.1%
36	Camps	-	-	-	-	-	-	-
37	Race Tracks	1	0.98	1.40	576,364	2.7%	0.81	0.9%
38	Golf Courses / Driving Ranges	22	0.87	9.14	383,725	1.8%	3.51	4.1%
39	Hotels / Motels	10	0.95	8.20	368,746	1.7%	3.02	3.5%
	Total Commercial	1,207	0.94	4.03	21,148,443	100.0%	85.31	100.0%

Table 3. Average monthly water use coefficients based on a sample of 1,207 commercial parcels and four years of monthly water use data from HCWU.

The area weighted water use coefficient for HCWU depends heavily on the commercial land use mix for this utility. Thus, if these same water use coefficients are applied to another utility where only the heated area is known, then the area weighted average for the commercial sector would reflect the relative importance of the commercial subsectors. Indeed, the area weighting provides an important improvement in the accuracy of CII estimates since the sizes of the various activities are included directly in the calculations. Also, the two digit breakdown allows us to evaluate which two digit users are the most important as judged by the combination of their water use rate and their size as measured by heated area.

If a utility was to pursue water conservation in the commercial sector, for example, the water budget could achieve this level of disaggregation to target a class of customers. Restaurants (FDOR 21) have the highest rate of water use per facility. Though their heated area only accounts for 1.7% of the heated area for the commercial sector, their overall water use totals 10.8% of the commercial water use. Supermarkets/convenience stores (FDOR 14) have many customers in that class and a relatively high water use rate. Such sectors could be analyzed through further disaggregation for water conservation potential.

INDUSTRIAL SECTOR

The industrial sector, just like the commercial sector, can be broken up into more disaggregated sectors using FDOR land use codes. The 11 FDOR industrial sectors, along with their water use and area conversion coefficients are presented in Table 4. Like the commercial sector, the total industrial water use coefficient as shown in Table 4 is a calculated heated area weighted average of the 11 FDOR codes that make up that sector.

FDOR Code	Description	n	HA/EA	Weighted Water Use Coef. (gal/hsf/mo)	Total Heated Area (sf)	% Heated Area in Sector	Total Water Use (mg/mo)	% Water Use in Sector
41	Light Manufacturing	9	0.85	0.87	338,341	5.0%	0.30	3.4%
42	Heavy Industrial	2	0.96	1.20	88,864	1.3%	0.11	1.2%
43	Lumber Yards	-	-	-	-	-	-	-
44	Packing Plants	-	-	-	-	-	-	-
45	Bottler / Canneries	-	-	-	-	-	-	-
46	Food Processing	-	-	-	-	-	-	-
47	Mineral Processing	7	0.97	5.14	813,158	12.1%	4.18	47.4%
48	Warehousing / Distribution	122	0.89	0.76	5,346,038	79.5%	4.06	46.0%
49	Open Storage	6	0.93	6.18	14,811	0.2%	0.09	1.0%
91	Utility, Gas & Elec.	8	0.95	0.69	125,713	1.9%	0.09	1.0%
92	Mining / Petroleum	-	-	-	-	-	-	-
	Total Industrial	154	0.90	1.31	6,726,925	100.0%	8.82	100.0%

Table 4. Average monthly water use coefficients based on a sample of 154 industrial parcels and four years of monthly water use data from HCWU.

The industrial sector at 154 customers accounts for the least amount of water users in the CII sector of HCWU. With a total weighted water use coefficient of 1.31 gallons per square foot of heated building area per month, this sector also presents the smallest rate of water use amongst the CII sectors, and accounts for only 6.9% of total CII water use. Given the large average heated areas and small water use coefficients prevalent in the FDOR industrial sectors, it seems fair to infer that these customers likely do not utilize their potable water connections for industrial processes.

INSTITUTIONAL SECTOR

The institutional sector is disaggregated into 18 FDOR user groups. The water use and area conversion coefficients for these disaggregated institutional sectors are presented in Table 5. With nearly half of the total water use, private and public schools are by far the largest water users for HCWU. Other significant water users include orphanages/non-profits and churches, which account for 21.9% and 10.7% of the total institutional water use, respectively.

FDOR Code	Description	n	HA/EA	Weighted Water Use Coef. (gal/hsf/mo)	Total Heated Area (sf)	% Heated Area in Sector	Total Water Use (mg/mo)	% Water Use in Sector
71	Churches	216	0.95	1.26	2,850,880	23.2%	3.58	10.7%
72	Private Schools & Colleges	63	0.96	4.57	460,943	3.8%	2.11	6.3%
73	Private Hospitals	2	0.97	2.62	849,831	6.9%	2.23	6.6%
74	Homes for the Aged	-	-	-	-	-	-	-
75	Orphanages / Non-profits	75	0.91	9.49	772,864	6.3%	7.33	21.9%
76	Mortuaries / Cemeteries	7	0.88	1.92	52,921	0.4%	0.10	0.3%
77	Clubs / Union Halls	16	0.83	5.16	168,259	1.4%	0.87	2.6%
78	Sanitariums / Convalescents	-	-	-	-	-	-	-
79	Cultural Organizations	-	-	-	-	-	-	-
81	Military	-	-	-	-	-	-	-
82	Parks and Recreation	-	-	-	-	-	-	-
83	Public County Schools	52	1.00	2.07	6,636,925	54.1%	13.71	40.9%
84	Colleges	-	-	-	-	-	-	-
85	Hospitals	-	-	-	-	-	-	-
86	County Owned	59	0.91	7.18	460,307	3.8%	3.31	9.9%
89	Municipal	6	0.88	15.19	20,055	0.2%	0.30	0.9%
90	Gov. Leased Interests	-	-	-	-	-	-	-
97	Outdoor Recreational	-	-	-	-	-	-	-
	Total Institutional	496	0.97	2.73	12,272,985	100.0%	33.54	100.0%

Table 5. Average monthly water use coefficients based on a sample of 496 institutional parcels and four years of monthly water use data from HCWU.

AGGREGATED CII COEFFICIENTS

The general CII and the more aggregated C, I and I sector coefficients for HCWU are shown in Table 6. These coefficients are directly dependent on the land use mix within a given service area boundary. A weighted average of the coefficients in the previous tables is simply carried out based on the total heated area of the two-digit FDOR sectors, in the case of the water use coefficients, and total effective area in the case of the area conversion coefficients. Following this methodology, by querying for the total areas in the various two-digit FDOR codes, any utility in the State is able to derive CII aggregated coefficients specific to their service area.

	n	Avg. Heated Area (sf)	HA/EA	Avg. Monthly Water Use (gal)	Weighted Water Use Coef. (gal/hsf/mo)	Total Heated Area (sf)	% Heated Area in Sector	Total Water Use (mg/mo)	% Water Use in Sector
Commercial	1,207	17,521	0.94	70,678	4.03	21,148,443	52.7%	85.31	66.8%
Industrial	154	43,681	0.90	57,260	1.31	6,726,925	16.8%	8.82	6.9%
Institutional	496	24,744	0.97	67,630	2.73	12,272,985	30.6%	33.54	26.3%
Total CII	1,857	21,620	0.94	68,751	3.18	40,148,353	100.0%	127.67	100.0%

Table 6. Commercial, industrial, and institutional average water use coefficients based on a sample of 1,857 CII parcels and four years of monthly water use data from HCWU.

In the case of HCWU, the CII sector uses an area weighted average of 3.18 gallons of water per square foot of heated building area per month. This point estimate was determined from summing the water use and heated building values over the 1,857 CII parcels in HCWU. Commercial customers use water at a higher rate than industrial or institutional customers. Commercial customers also account for most of the heated area and water use in CII, as well as dominate in terms of the total number of customers in a sector. Industrial parcels are much larger than the commercial and institutional parcels, but account for the least amount of water use.

APPLYING COEFFICIENTS TO A WATER BUDGET

By estimating the individual water use for each customer sector, a utility or planning agency can plan a conservation strategy according to the relative efficiency among the sectors. To estimate the amount of water use for a sector, the size of the sector is combined with the average water use coefficient. Equation 2 demonstrates how the size of the sector is combined with the coefficient to estimate CII water use.

$$(\#\ of\ accounts)\left(\frac{avg.\ effective\ area}{account}\right)\left(\frac{HA}{EA}\right)\left(\frac{gallons}{sf\ of\ HA * month}\right) = \begin{matrix} Avg.\ Monthly\ CII \\ Water\ Use \end{matrix} \qquad (2)$$

This calculation parallels the estimated water use by residential customers, shown in Equation 3.

$$(\#\ of\ accounts)\left(\frac{people}{account}\right)\left(\frac{gallons}{person * day}\right)\left(\frac{30.4\ days}{month}\right) = \begin{matrix} Avg.\ Monthly\ Residential \\ Water\ Use \end{matrix} \quad (3)$$

The measure of size in the CII sectors is the total heated area, and for residential customers it is the average density of people in a household. The total heated area is determined by multiplying the number of accounts in that sector by the average heated area of the buildings for that type of customer. The activity coefficient in the CII sectors is the gallons per square foot of heated area per month, and for residential customers it is gallons per person per day.

The number of accounts in a service area can be estimated in different ways depending on the sophistication of the utility. If the utility boundary is delineated in GIS, then the associated parcels can be queried in the FDOR land use database. If the exact boundary of the utility is unknown, the utility can query the parcels in the city or zip codes served by the utility to get a representative sample of the composition of its customer base. The water use calculation is done this way in order to calibrate water use in a sector by the number of accounts. For example, if the query results in fewer than the known number of accounts, the query can be taken to be a representative sample, and the number of accounts in each sector scaled up to produce the total known number of accounts.

The ‘people per account’ in the residential water use calculation is the average people per household as found in the U.S. Census Bureau and the water use coefficient is found in the CFWC database. The ‘average effective area per account’ in the CII water use calculation is found from querying the accounts in the FDOR database. The effective area is converted to heated area through the HA/EA ratio for that specific sector found in Tables 3-5. By combining the size of a sector with its activity water use coefficient, a utility can estimate the relative water use by different customer groups and prioritize water conservation programs.

CONCLUSIONS AND FUTURE WORK

This CII water use estimating method should offer a significant improvement over traditional methods of estimating CII water use by combining water billing records with parcel-level land use databases, principally FDOR. These databases allow for the size of sectors and their activity coefficients to be developed by parcel-level data, which is a finer resolution than TAZ or Census block data. They also provide a standardized classification system to categorize land uses across the State. The 57 CII FDOR land use categories allow water users to be classified within various degrees of disaggregation based on the level of homogeneity desired in a sector. The FDOR database is public information and is capable of being linked to any utility billing records through the Parcel ID number.

Existing utility linkages between the FDOR and water billing records are available for only a few utilities in the State. This paper develops CFWC default activity water use coefficients and presents a methodology to carry out water budgets regardless of this link. By employing a measure of size that is standard and reliable across the CII sectors, along with default water use coefficients, any utility within the State is able to develop a water budget. The water budget is an essential tool to investigate the gross gpcd of a utility by sectors. It also allows a utility to estimate how the water in their service boundary is being used. This information about water users is crucial to develop an accurate forecast for water use or in planning and evaluating conservation efforts.

Water use coefficients presented in this paper were calculated from four years of historical billing records from HCWU and heated areas from HCPA. HCWU provided for a relatively large cross-section of customers and long time series. More utilities from across the State should be incorporated into the analysis to account for regional differences in water use, as well as increase the sample size for the various water use sectors.

The extensive amount of data available from FDOR/CPA allow for substantial amounts of future refinements. The available data can be used to improve the accuracy of water estimates, as well as further disaggregate water use to the end use or process level. For example, FDOR incorporates year built in its database. This information can be used to carry out time series analysis and find trends for both heated areas and activity water use coefficients over time. This analysis improves the accuracy of water use estimates and forecasts, and could provide insight into end uses. Also, by estimating irrigated area and analyzing the billing records for seasonal components, it should be possible to break down water use into outdoor and indoor, whereby outdoor could be further disaggregated into irrigation and cooling. Future work should also include a study to analyze the accuracy of the water use estimates described in this paper and the reliability of savings with conservation efforts. Such a study would allow for a measure of uncertainty to be associated with these estimates.

The availability of the FDOR database provides a major improvement in our ability to estimate CII water use. The Conserve Florida Water Clearinghouse (www.conservefloridawater.org) is developing these water use coefficients and heated area statistics and will make them available to interested utilities. These coefficients should provide good estimates for CII users outside of Florida except where landscape irrigation is a significant component of water use. Utilities may link their billing data with the FDOR/CPA databases and share this information with us so that these estimates can be improved over time.

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