Prepared in cooperation with the
St. Johns River Water Management District

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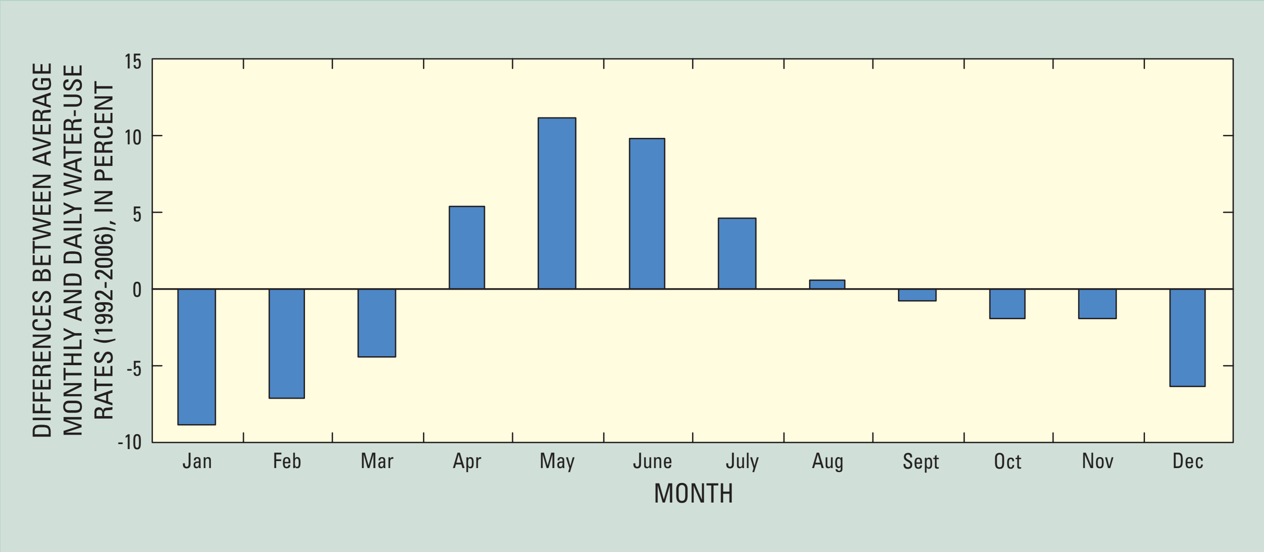

Scientific Investigations Report 2009-5010

U.S. Department of the Interior
U.S. Geological Survey

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By Louis C. Murray, Jr.

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Conversion Factors, Datums, and Acronyms

Multiply	By	To obtain
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04381	cubic meters per second

Acronyms and Abbreviations

AWC	Available water content
COV	Coefficient of variation
gpdm	gallon per day per metered connection
GRU	Gainesville Regional Utilities
JEA	Jacksonville Electric Authority
OCU	Orange County Utilities
OUC	Orlando Utilities Commission
NOAA	National Oceanic and Atmospheric Administration
PDSI	Palmer Drought Severity Index
SCU	Seminole County Utilities
SF	Sensitivity factor
SPI	Standardized Precipitation Index
STA	City of St. Augustine
USGS	U.S. Geological Survey
VIF	Variance Inflation Factor
WTP	Water-treatment plant

Meteorological Parameters

P	Precipitation
PET	Potential evapotranspiration
P-PET	Available water
R^2	Coefficient of determination
T	Mean air temperature

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929).

Relations between Municipal Water Use and Selected Meteorological Parameters and Drought Indices, East-Central and Northeast Florida

By Louis C. Murray, Jr.

Abstract

Water-use data collected between 1992 and 2006 at eight municipal water-supply utilities in east-central and northeast Florida were analyzed to identify seasonal trends in use and to quantify monthly variations. Regression analyses were applied to identify significant correlations between water use and selected meteorological parameters and drought indices. Selected parameters and indices include precipitation (P), mean air temperature (T), potential evapotranspiration (PET), available water (P-PET), monthly changes in these parameters (ΔP, ΔT, ΔPET, Δ(P-PET)), the Palmer Drought Severity Index (PDSI), and the Standardized Precipitation Index (SPI). Selected utilities include the City of Daytona Beach (Daytona), the City of Eustis (Eustis), Gainesville Regional Utilities (GRU), Jacksonville Electric Authority (JEA), Orange County Utilities (OCU), Orlando Utilities Commission (OUC), Seminole County Utilities (SCU), and the City of St. Augustine (STA). Water-use rates at these utilities in 2006 ranged from about 3.2 million gallons per day at Eustis to about 131 million gallons per day at JEA.

Total water-use rates increased at all utilities throughout the 15-year period of record, ranging from about 4 percent at Daytona to greater than 200 percent at OCU and SCU. Metered rates, however, decreased at six of the eight utilities, ranging from about 2 percent at OCU and OUC to about 17 percent at Eustis. Decreases in metered rates occurred because the number of metered connections increased at a greater rate than did total water use, suggesting that factors other than just population growth may play important roles in water-use dynamics. Given the absence of a concurrent trend in precipitation, these decreases can likely be attributed to changes in non-climatic factors such as water-use type, usage of reclaimed water, water-use restrictions, demographics, and so forth. When averaged for the eight utilities, metered water-use rates depict a clear seasonal pattern in which rates were lowest in winter months and greatest in late spring. Averaged water-use rates ranged from about 9 percent below the 15-year daily mean in January to about 11 percent above the daily mean in May.

Water-use rates were found to be statistically correlated to meteorological parameters and drought indices, and to be influenced by system memory. Metered rates (in gallons per day per active metered connection) were consistently found to be influenced by P, T, PET, and P-PET, as well as changes in these parameters that occurred in prior months. In the single-variant analyses, best correlations were obtained by fitting polynomial functions to plots of metered rates versus moving-averaged values of selected parameters (R^2 values greater than 0.50 at three of eight sites). Overall, metered water-use rates were best correlated with the 3- to 4-month moving average of ΔT or ΔPET (R^2 values up to 0.66), whereas the full suite of meteorological parameters was best correlated with metered rates at Daytona and least correlated with rates at STA. Similarly, metered rates were substantially better correlated with moving-averaged values of precipitation (significant at all eight sites) than with single (current) monthly values (significant at only three sites). Total and metered water-use rates were positively correlated with T, PET, ΔP, ΔT, and ΔPET, and negatively correlated with P, P-PET, Δ(P-PET), PDSI, and SPI. The drought indices were better correlated with total water-use rates than with metered rates, whereas metered rates were better correlated with meteorological parameters.

Multivariant analyses produced fits of the data that explained a greater degree of the variance in metered rates than did the single-variant analyses. Adjusted R^2 values for the "best" models ranged from 0.79 at JEA to 0.29 at STA and exceeded 0.60 at five of eight sites. The amount of available water (P-PET) was the single parameter most common to the best models (six of eight sites), whereas ΔT or ΔPET were included at five of eight sites. The moving average of at least one parameter was present in seven of the eight best models, indicating the influence of water-use memory to changing climatic conditions. Monthly P and ΔP were better correlated with metered water-use rates in the multivariant regression analyses (significant at six of eight sites) than in the single-variant analyses (significant at only three sites). This contrast can be attributed to the fact that the multivariant analyses better isolate the effects of precipitation on water use by factoring out the offsetting effects of other parameters, such as temperature, which are directly (and not inversely) related to water use.

The best model equations determined from the multi-variant analyses were used to predict metered water-use rates for 2007, a relatively dry year. The average error between predicted and measured results, an indication of model bias, ranged from -53 gpdm (gallons per day per active metered connection) at OCU (overpredicted rates) to 42 gpdm at GRU (underpredicted rates). These biased results are likely due, in part, to factors not considered in the analyses such as increased usage of reclaimed water and changes in the ratio of commercial-to-residential users in 2007. Based collectively on the error and regression statistics developed for the predicted results, the best predictions were made at Eustis while the poorest predictions were made at GRU.

Introduction

Ground-water withdrawals in east-central and northeast Florida have the potential to adversely affect sensitive water resources, such as the amounts of water being discharged at springs, wetland ecosystems, and canal and lake levels. Ground-water withdrawal rates, in turn, are largely dependent on municipal water-supply demands required to meet residential, commercial and industrial usages. The amount of water used for municipal supply, and changes in usage from one month or year to the next, is influenced by numerous factors that include changes in population, climatic conditions, water-use types, socio-economic conditions, availability of reclaimed water, water-conservation practices, and water pricing (Marella, 1992a). While municipal water withdrawals are known to vary seasonally, little or no research has been conducted in east-central and northeast Florida to quantify how these withdrawals vary from one month to the next and how changes in meteorological conditions may affect usage. Similarly, little or no research has been done to determine if commonly referenced drought indices, such as the Palmer Drought Severity Index (PDSI) or Standardized Precipitation Index (SPI), can be related to the amounts of water being withdrawn and used for municipal supply. Drought indices provide potentially useful tools for associating predicted water-use rates with quantifiable drought conditions of interest.

The U.S. Geological Survey, in cooperation with the St. Johns River Water Management District, conducted a study to examine the relations between water use and selected meteorological parameters and drought indices. Statistically relating water use to variations in commonly measured parameters and/or indices may provide resource managers an improved tool for predicting the potential effects of climate, and perhaps climate change, on associated demands. Additionally, scientists tasked with developing transient ground-water flow models can more confidently quantify ground-water withdrawal rates subject to a broad range of climatic conditions.

Purpose and Scope

The purposes of this report are to: (1) document seasonal (monthly) variations in municipal water withdrawals for selected utilities in east-central and northeast Florida, and (2) quantify the relations between water use and commonly measured meteorological parameters and drought indices. Parameters of interest include precipitation (P), air temperature (T), potential evapotranspiration (PET), and available water (P-PET). Drought indices of interest include the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI), both of which are commonly referenced across the country for assessing the severity of droughts. Because the scope of this report examines just the relation between water withdrawals and climate, and does not account for other influential factors mentioned above, the results discussed herein are somewhat limited for accurately predicting future water use. However, results do provide an indication of the relative influence of climate in assessing changes in short-term (monthly) use.

The analyses are conducted for eight municipal water-supply utilities dispersed across east-central and northeast Florida (fig.1) and include the City of Daytona Beach (Daytona), the City of Eustis (Eustis), Jacksonville Electric Authority (JEA), Gainesville Regional Utilities (GRU), Orange County Utilities (OCU) for the southern service area, Orlando Utilities Commission (OUC), Seminole County Utilities (SCU) for the northeast and northwest service areas, and the City of St. Augustine (STA). Each utility provided at least 1 Mgal/d of treated water to respective service areas in 2006 and is located near a National Oceanic and Atmospheric Administration (NOAA) rainfall station. The largest of these utilities, JEA and OUC, serve large metropolitan areas with numerous and dispersed water-treatment plants (WTPs). The smaller utilities (Daytona, Eustis, GRU, and STA) operate single plants.

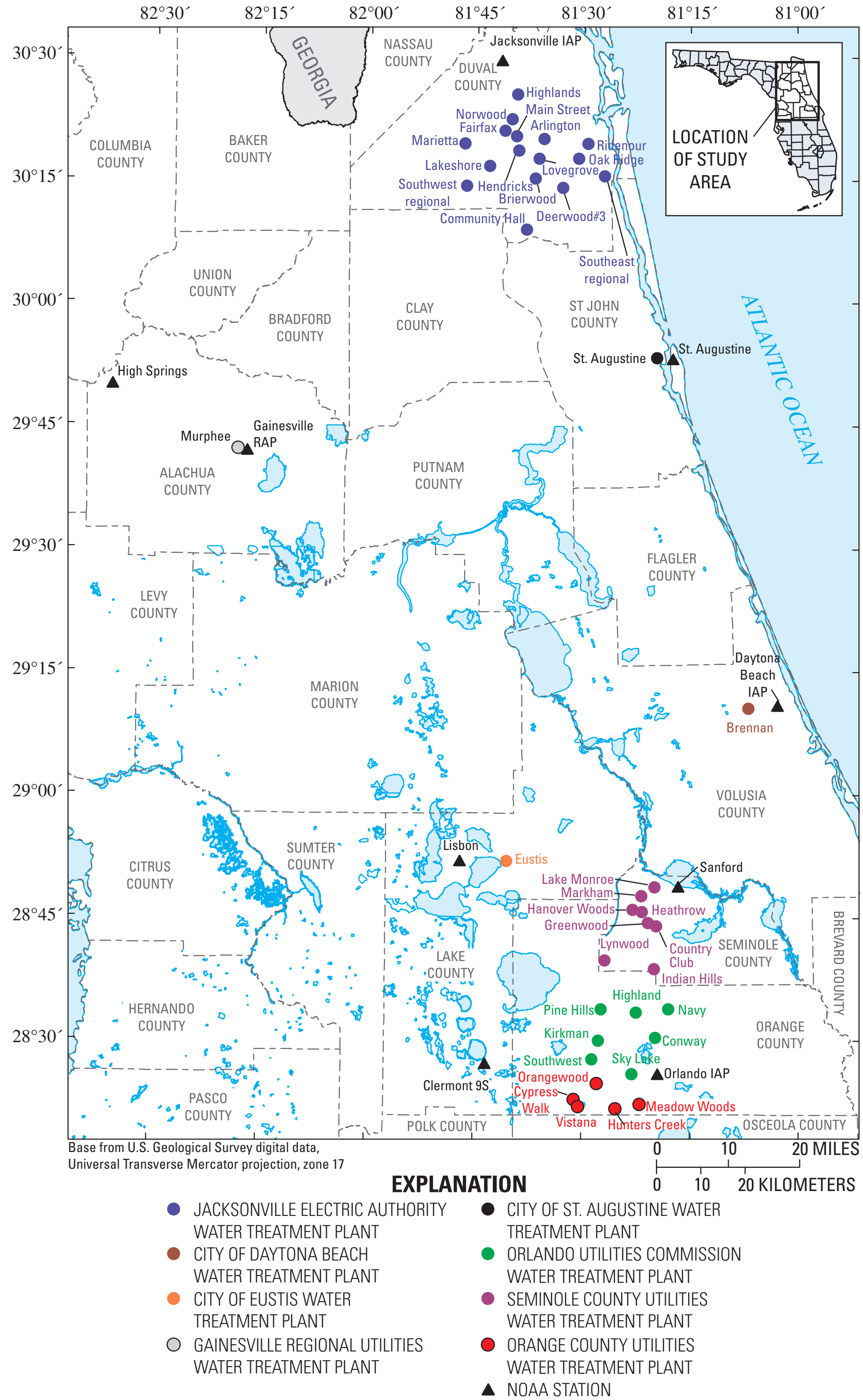

Figure 1. Locations of selected municipal water-treatment plants and National Oceanic and Atmospheric Administration rainfall stations in east-central and northeast Florida. IAP is International Airport. RAP is Regional Airport.

Acknowledgments

The author would like to thank several individuals for their assistance in obtaining the water-use information required for this study. These individuals include Robert Briggs and Robert Dehler (Seminole County Environmental Services Department); Melanie Abbott, Pat Divecchio, and Jacqueline Torbert (Orange County Utilities); Greg Dobbins and Erwin Gajentan (City of Eustis); Richard Hutton (Gainesville Regional Utilities); Richard Lott and Blanca Rodriguez (Florida Department of Environmental Protection); Brad Russell (Jacksonville Electric Authority); Chris Russell and Robert Teegarden (Orlando Utilities Commission); James Thurrott (City of Daytona Beach); and Tom Wallace (City of St. Augustine).

Methods of Investigation

The subsequent sections describe the data-collection methods and statistical techniques that were applied in this study. The analyses were performed on a monthly basis for consistency with time frames commonly used in transient ground-water flow models.

Data Collection and Analyses

Water-use data collected for this study include the treated flow rates from the selected WTPs and the associated number of active service (metered) connections for each WTP (table 1). Average daily flows converted to monthly flows or total monthly flows can be considered a reasonable approximation of the amounts of water withdrawn from ground-water sources at nearby well fields. Treated flow rates were used in place of ground-water withdrawals because these data were more readily available, and the difference between raw water withdrawals and treated flow is typically minimal for municipal ground-water systems in east-central and northeast Florida. Only those plants that rely on ground water as the source were included in this study. The number of service connections was used as a surrogate to offset the effects of population growth. In addition, the populations served by municipal WTPs are most often estimated, whereas the number of service connections are recorded from billing records and maintained monthly by the utility. The appendix provides the amounts of water treated and number of metered connections at the selected municipal water-treatment plants (service areas) between 1992 and 2006.

The analyses discussed in this report ideally would be applied to a period spanning several decades to quantify long-term average conditions and to account for repeated occurrences of unusually wet and dry periods and climatic extremes. Acquiring long-term data, however, particularly for service area connections, was problematic. Data on service area connections were difficult to obtain beyond the past few years. Based on the best available information, a 15-year period of record (1992-2006) was selected for analyses. Although this period is shorter than would have been desired, it does include both wet and dry climatic extremes that are representative of longer-term conditions.

Water Use

Treated flows from the WTPs meet a variety of needs, including residential, commercial, irrigation, industrial, fire protection, and so forth, and the amount of water required from one use type to the next can vary considerably. With the exception of GRU, however, information provided by the utilities on the total number of active metered connections did not explicitly distinguish between use type—a condition which unavoidably introduces some level of uncertainty in identifying factors contributing to changes in metered rates. At GRU, where the total amount of water used for residential applications exceeds that for commercial applications, the amount of residential use per metered connection is considerably less than that used per commercial connection (fig. 2). Additionally, water use at GRU is heavily influenced by about 50,000 university students, who live and use water in Gainesville. As such, not only can water-use rates vary by type, but the ratios of these use types can vary spatially from one utility to the next and with time. In Orange County, for example, the percentage of water used for residential supply decreased from about 63 percent in 1990 to about 56 percent in 2000, whereas the amount of water used for commercial supply increased from about 19 to 26 percent (Marella, 1992b; 2004). Because metered water-use rates vary considerably by use type, the ratios of which are likely to vary from one utility to the next and to change with time, such dynamics invariably introduce some scatter (variance) in the data that cannot be accounted for in a regression analyses, such as that used in this study, which treats all connections “equally.” Only the data provided by SCU grossly accounts for varying use types by assigning a multiplicative factor, based on meter size, to each active connection.

Meteorological Parameters

Monthly precipitation and temperature data were collected from eight NOAA stations located near the selected utilities (fig.1). These stations include Clermont (for the OCU southern service area), Daytona Beach International Airport (for Daytona Beach), Gainesville Regional Airport (for GRU), Jacksonville International Airport (for JEA), Lisbon (for Eustis), Orlando International Airport (for OUC), the Sanford Experiment station (for the SCU northeast and northwest service areas), and St. Augustine Airport (for STA).

Precipitation data collected between 1992 and 2006 were statistically contrasted with data collected between 1959 and 2006 to provide some measure of how representative the

Table 1. Listing of selected utilities, associated municipal water-supply treatment plants, and National Oceanic Atmospheric Administration (NOAA) rainfall stations used in this study.

[Mgal/d, million gallons per day; IAP, International Airport]

Utility (service area)	Water-treatment plant	Treated flows, Mgal/d (total all plants)		Nearest NOAA station providing data
		1992	2006	
City of Daytona Beach	Brennan	12.3	13.1	Daytona Beach IAP
City of Eustis	Eustis	2.5	3.2	Lisbon
Gainesville Regional Utilities	Murphee	17.6	22.8	Gainesville/High Springs
Jacksonville Electric Authority	Arlington	67.7	131.3	Jacksonville IAP
	Brierwood			
	Community Hall			
	Deerwood#3			
	Fairfax			
	Hendricks			
	Highlands			
	Lakeshore			
	Lovegrove			
	Main Street			
	Marietta			
	Norwood			
	Oak Ridge			
	Ridenour			
	Southeast regional			
	Southwest regional			
Orange County Utilities	Cypress Walk	4.9	16.5	Clermont 9S
(southern service area)	Hunters Creek			
	Meadow Woods			
	Orangewood			
	Vistana			
Orlando Utilities Commission	Conway	72.3	91.1	Orlando IAP
	Highland			
	Kirkman			
	Navy			
	Pine Hills			
	Sky Lake			
	Southwest			
Seminole County Utilities[1]	Hanover Woods	4.7	13.3	Sanford Experiment Station
(northeast, northwest service areas)	Country Club			
	Greenwood			
	Heathrow			
	Indian Hills			
	Lynwood			
	Lake Monroe			
	Markham			
City of St. Augustine	St. Augustine	1.8	3.3	St. Augustine

[1]Total flows include water purchases from cities of Casselberry (Sunshadow, Tanglewood) and Sanford (Chase Groves, Five Points).

selected 15-year period of record was of long-term climatic conditions. Monthly averages computed for the two periods were relatively close (fig. 3), and the two driest years in the 15-year record (2000 and 2006) were also the driest years on record between 1959 and 2006 at four of the eight NOAA stations, and among the two or three driest years at the other stations (table 2). Similarly, the wettest years between 1992 and 2006 occurred in 2002, 2004, and 2005 and were exceeded by less than 10 percent of the long-term record at six of the eight NOAA sites.

PET was estimated by the Thornthwaite (1948) method based on a set of formulas that relate PET with monthly mean air temperature and length of daylight hours, and which are indexed or “calibrated” to the long-term record of mean monthly temperatures for a given location. Because of its limited input data requirements, the method has been widely applied in climatic and hydrologic studies and, given adequate historical record, can provide reasonable estimates of PET (Hagan and others, 1967). In the present study, a computer program developed by McCabe and others (1985) was used to calculate monthly PET values at each of the eight NOAA stations. Input data included the monthly temperatures for the investigated period of record, latitude of the station, and long-term historic monthly temperature values averaged from 1959 to 2006. The difference between P and PET is considered a gross measure of available water, another of the explanatory variables considered in this study.

Drought Indices

The Palmer Drought Severity Index (PDSI) is a meteorological drought index developed by Palmer (1965) to quantify the severity of drought and wet periods. The index uses temperature, precipitation, and the available water content (AWC) of the soil in a water-budgeting formulation that determines the relative wetness or dryness of soils. The index is standardized to the local climate so comparisons of soil-moisture conditions can be made among varying locations. A given value of the PDSI, which ranges from -4 (extreme drought) to +4 (extreme wet conditions), is a combination of the current condition and previous PDSI values, so it is somewhat representative of trends whether a drought or wet period. The index is best applied in determining relatively long-term drought, such as occurred in Florida in 1998-2000.

The “Self-Calibrated” PDSI applied in this study is a modified version of the PDSI that is calibrated to the climate of the selected location by replacing the empirical constants used in the water-budget equation with dynamic values that are based on the historical climate of that location. As such, the Self-Calibrating PDSI provides more consistent and reliable results for specific locations than does the PDSI. The Self-Calibrating PDSI is also designed so that index values at or below -4.0 and at or above +4.0 each occur 2 percent of the time. Thus, for every 50 years, there will be about 12 months of “extreme” drought and 12 months of “extreme” wetness, which serves to better define the drought classification system

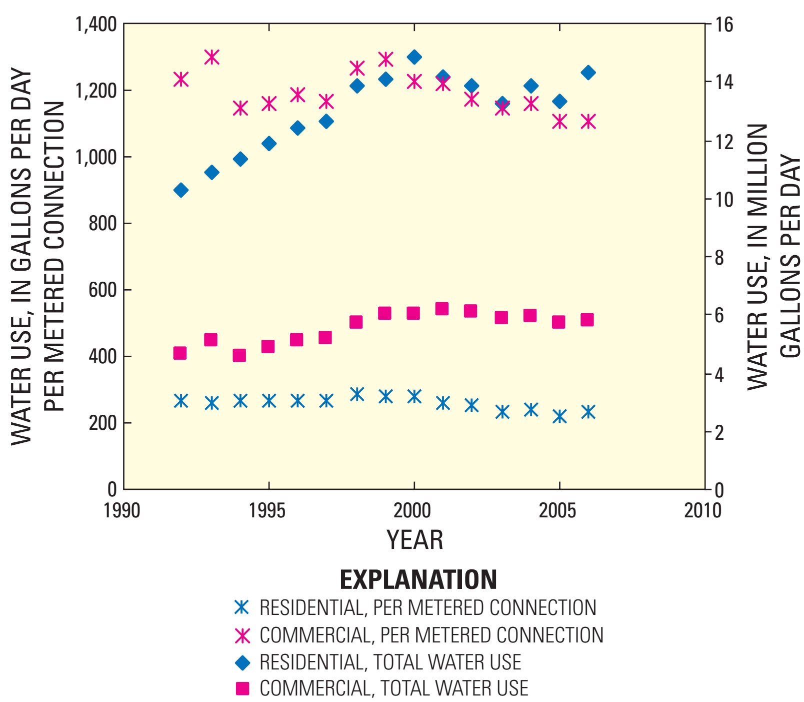

Figure 2. Residential and commercial water uses at Gainesville Regional Utilities, 1992-2006.

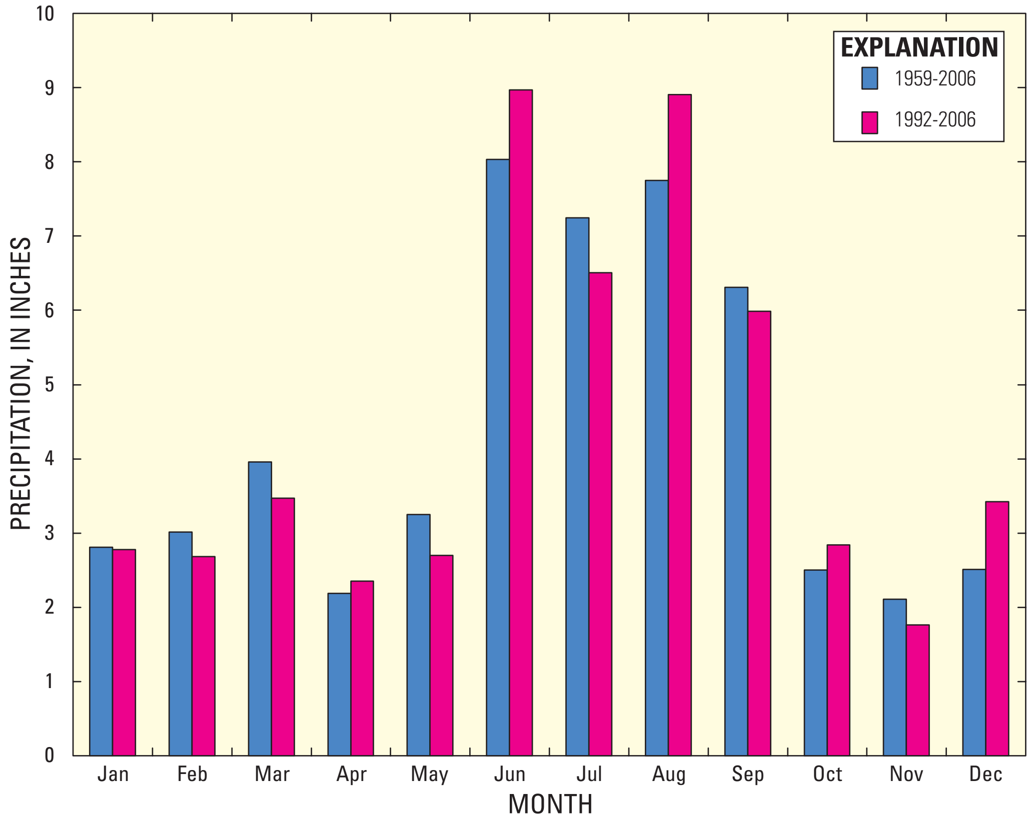

Figure 3. Monthly precipitation for 1959-2006 and 1992-2006 (averaged from eight project NOAA sites).

Table 2. Precipitation statistics for selected National Oceanic and Atmospheric Administration (NOAA) rainfall stations, 1959-2006 and 1992-2006.

[IAP, International Airport]

NOAA station	Annual average precipitation (inches)		Driest year	Precipitation (inches)	Percent greater than[1]	Wettest year	Precipitation (inches)	Percent less than[2]
	1959-06	1992-06						
Clermont	51.7	52.4	2000	28.9	100	2002	86.7	0
Daytona IAP	50.0	52.1	2006	31.4	100	2005	65.8	8
Gainesville	50.5	47.8	2000	34.4	98	2004	58.4	21
Jacksonville IAP	52.9	53.9	2006	38.1	96	2004	69.5	4
Lisbon	48.7	50.7	2000	29.3	100	2005	58.7	10
Orlando IAP	50.3	52.6	2000	30.4	100	2002	66.4	4
St. Augustine	51.2	51.5	2006	37.1	94	2005	70.1	4
Sanford	51.6	54.6	2000	32.8	100	2002	66.5	6
Average (all stations)	50.9	51.9						

[1]Percent of years in the long-term (1959-2006) record with precipitation equal to or greater than the driest year between 1992-2006.

[2]Percent of years in the long-term (1959-2006) record with precipitation equal to or less than the wettest year between 1992-2006.

and improve spatial comparability. A step-by-step formulation for the PDSI and the Self-Calibrating PDSI can be found at the National Agricultural Decision Support System web site maintained for NOAA by the University of Nebraska-Lincoln Department of Computer Science and Engineering.

Problems associated with the PDSI are summarized by Alley (1984) and Karl and Knight (1985). Some of the more important issues are as follows: (1) because the index is sensitive to the AWC of a given soil type, applying it to a climate division that contains multiple soil types may be too general; (2) the natural lag that occurs between precipitation and the resulting runoff is not considered in the water budget; and (3) PDSI values may lag emerging droughts by several months and may not be representative of most current conditions. Notwithstanding these limitations, many Federal and State government agencies rely on PDSI to initiate drought relief programs.

The Standardized Precipitation Index (SPI) also quantifies deficit or excess moisture conditions at a desired location and time interval (McKee and others, 1993). The SPI is based on fitting the long-term precipitation record for a given location and time interval to a probability distribution which is transformed into a normal distribution, such that the mean SPI for the desired location and time interval is zero. Thus, the value computed for the index represents the number of standard deviations that the measured precipitation deviates from the long-term mean. SPI values range from -2 (extremely dry) to +2 (extremely wet) and can be calculated for varying time scales to reflect the impact of drought on the availability of the different water resources. For the purposes of this study, SPI values calculated on a single monthly basis were used because it is assumed that the majority of municipal water use is directed for irrigation needs, both residential and commercial, which are sensitive to soil-moisture conditions. The procedure for calculating SPI can be found at the National Agricultural Decision Support System web site.

Statistical Methods

Statistical methods described by Helsel and Hirsch (2002) for trend testing and for single- and multivariant regression analyses were applied in this study. The Durbin-Watson statistic (Durbin and Watson, 1951) was used to determine if the temporal sequence of monthly water-use rates were serially correlated. A Kolmogorov test (Conover, 1999) was applied to determine if monthly water-use and meteorological parameter values were normally distributed about respective means to help select appropriate tools for subsequent trend and correlation tests. The Kolmogrov-Smirnov test serves as a goodness-of-fit test in which the frequency distribution of a given dataset is compared against a theoretical distribution, in this case, a Gaussian normal distribution. The test calculates a p-value to determine whether or not the null hypothesis can be accepted. P-values of less than 0.05, which were quantified for virtually every meteorological dataset, indicate that the null hypothesis can be rejected. While the water-use data were found to be normally distributed, the meteorological data were not. Accordingly, the parametric ANOVA test was used to determine whether significant differences existed between the 15-year mean daily water-use rate and average monthly rates, while Tukeys (1977) multiple comparison test was applied to identify all of the significant pairwise differences. Kendall's tau (Helsel and Hirsch, 2002) was used to analyze temporal variations in water use for trends and to quantify the relations between water use and selected meteorological variables and drought indices. The Kendall test is a nonparametric procedure that measures the strength of a monotonic relation, whether linear or nonlinear, between the dependent and explanatory variables and, as a ranked-based method, its results are not affected by outliers in the data. A probability level of 5 percent (p-value of less than 0.05) was used in all tests as the criterion for significance; that is, a p-value of less than 0.05 indicates that the probability of a detected correlation or difference not being real is less than 5 percent.

Commercially available spreadsheet software was used to plot the data. A commercially available statistical software package, used throughout the USGS, was applied to test the data for normality and serial correlation, detrend the water-use data for seasonal analyses, and conduct the regression analyses and trend tests.

Relations between Water Use and Meteorological Parameters/Drought Indices

Water-use data were analyzed to identify significant seasonal trends, quantify differences in use, and determine interrelations with meteorological parameters and drought indices measured at eight NOAA stations in east-central and northeast Florida from 1992 to 2006. Both single-variant and multivariant regression analyses were applied to quantify these relations. Additionally, best model equations determined from the multivariant analyses were used to predict metered water-use rates for 2007, a relatively dry year.

Trends

While no significant temporal trends were detected in precipitation between 1992 and 2006 at any of the eight NOAA stations, total water-use rates increased significantly at all utilities, from about 4 percent at Daytona to greater than 200 percent at OCU and SCU (table 3). When normalized per metered connection, however, which serves to reduce the influence of population increases, water-use rates in gallons per day per metered connection decreased significantly at five of the eight utilities (Daytona, Eustis, GRU, JEA, and OCU), while increasing at SCU and STA (table 3). No significant change in metered rates were seen at OUC.

Table 3. Results of trend tests on total and metered water-use rates and on precipitation at selected National Oceanic and Atmospheric Administration (NOAA) rainfall stations, 1992-2006.

[Percent change in water use calculated from the difference between LOWESS curve values for Jan-92 and Dec-06. Mgal/d, million gallons per day; gpdm, gallons per day per metered connection; Tau, Kendalls tau value; significant trends shown by p-values equal to or less than 0.05]

Rainfall stations	Total water use (Mgal/d)					Metered water use (in gpdm)					Precipitation		
	Jan-92	Dec-06	Change	Tau	p-value	Jan-92	Dec-06	Change	Tau	p-value	NOAA station	Tau	p-value
City of Daytona Beach	12.24	12.76	4	0.19	<.001	533	501	-6	-0.02	0.01	Daytona IAP	-0.020	0.69
City of Eustis	2.47	3.02	22	.16	<.001	377	314	-17	-.26	<.001	Lisbon	-.081	.11
Gainesville Regional Utilities	17.0	23.1	36	.38	<.001	409	343	-16	-.43	<.001	Gainesville	-.049	.33
Jacksonville Electric Authority	66.3	132	99	.64	<.001	464	436	-6	-.26	<.001	Jacksonville	-.061	.22
Orange County Utilities (Southern)	4.70	16.3	247	.79	<.001	1,002	983	-2	-.14	.007	Clermont	-.001	.99
Orlando Utilities Commission	73.1	90.0	23	.47	<.001	666	655	-2	-.05	.33	Orlando IAP	-.041	.41
Seminole County Utilities (NE, NW)	4.41	13.3	202	.64	<.001	352	440	25	.12	.019	Sanford	-.067	.18
City of St. Augustine	1.88	3.41	81	.73	<.001	280	340	21	.42	<.001	St. Augustine	.006	.91

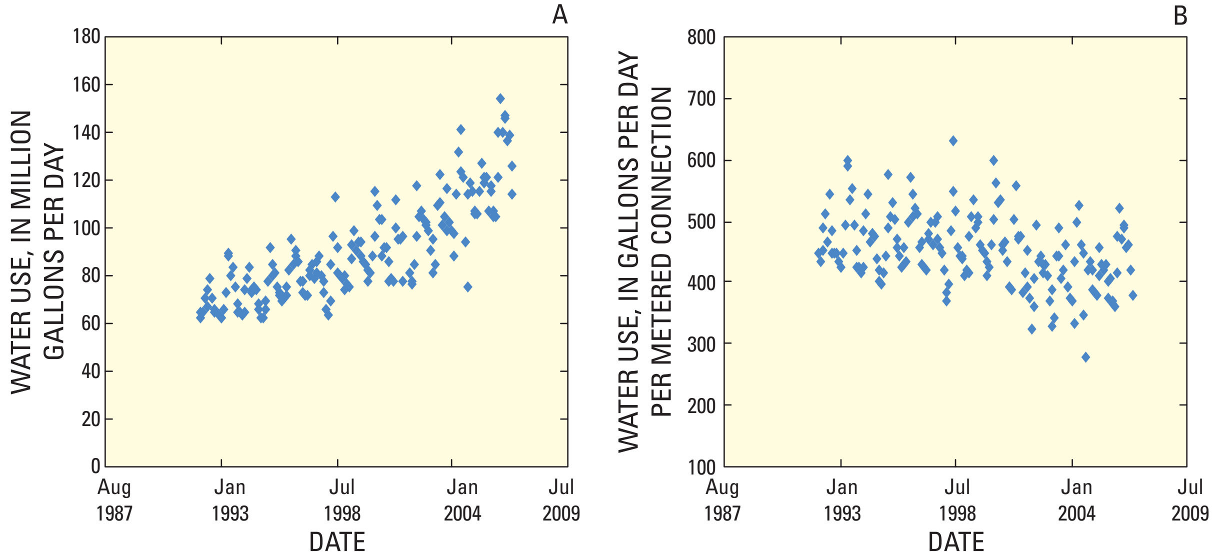

Figure 4. Total and metered water-use rates for Jacksonville Electric Authority, 1992-2006.

Given the absence of coincident trends in precipitation, these reductions can likely be attributed to variables not considered in this study, such as changes in service area demographics and water-use type, conservation measures, increased use of reclaimed water, and changes in the ratio of single- to multi-family metered connections.

The plots shown for JEA in figure 4 contrast the trends seen between total and metered water-use rates and also depict the shorter term and more erratic monthly fluctuations characteristic of all utilities. While the longer 15-year trend in total water-use rates can be associated with population increases, these shorter term fluctuations are more affected by changes in meteorological conditions and thus more suitable for seasonal (monthly) analyses.

Metered water-use rates, such as those depicted for JEA in figure 4B, were detrended to better isolate the shorter term fluctuations for seasonal analyses. This was performed by fitting the data with LOWESS smooth curves (smoothing factor = 5), calculating residuals, and adding the value of the LOWESS curve at the end of the period of record to the residual values. By doing so, the data were adjusted to better represent current (end of 2006) conditions.

Average metered water-use rates were calculated at each site for each calendar month of the year and compared with the respective 15-year daily means (table 4). Given that public-supply water-use rates are indicative of ground-water withdrawals, and that average monthly climatic conditions between 1992 and 2006 are representative of long-term (1959-2006) conditions, the 15-year daily mean may be associated with a steady-state hydrologic stress against which transient monthly variations can be quantified. At Daytona, for example, the average metered rate in January (464 gpdm) was about 7.3 percent lower than the 15-year daily mean of 500 gpdm, whereas the average rate in August (517 gpdm) exceeded the daily mean by about 3.3 percent. Although results vary considerably from one utility to the next, the largest positive differences generally occur in the spring months (April, May, and June), while the greatest negative differences occur in the winter months (December, January, and February).

When spatially averaged across the eight utilities for each calendar month, the departures depict a well-defined seasonal pattern in which metered water-use rates tended to be least in the winter and greatest in the late spring (fig. 5). In January, for example, water use averaged about 9 percent below the 15-year daily mean, whereas water use in May averaged about 11 percent above the daily mean. Because of the considerable scatter in the monthly departures from one utility to the next, Tukey's (1977) test was applied to determine if the monthly mean departures were significantly different from one another. Results in table 5 indicate, for example, that the mean January departure is significantly different from those of April, May, June, July, and August, while not significantly different from those of September, October, November, December, February, and March. These results can provide guidance for quantifying seasonally variant ground-water withdrawals rates in predictive transient flow models.

Table 4. Average monthly metered water-use rates (1992-2006) and differences between monthly rates and 15-year daily means.

[Daytona, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area) ; OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (northeast, northwest service areas); and STA, City of St. Augustine; Avg. diff., average difference between daily and monthly mean]

Month	Daytona	Eustis	GRU	JEA	OCU	OUC	SCU	STA	Avg. diff.
				Metered water-use rates, in gallons per day per metered connection					
Jan	463.7	333.1	311.2	386.3	878.1	593.8	397.6	326.4	--
Feb	487.2	345.0	317.0	376.4	889.9	601.3	404.7	333.8	--
Mar	517.0	372.9	295.1	405.8	951.9	637.2	378.5	341.2	--
Apr	519.3	429.1	342.0	458.8	1,063	698.1	443.3	344.3	--
May	521.7	461.7	363.5	514.4	1,088	744.3	482.5	346.1	--
June	523.7	397.2	417.7	475.5	1,049	691.1	538.7	343.1	--
July	538.1	375.5	351.9	474.6	1,047	683.7	445.7	350.1	--
Aug	517.1	369.2	311.3	457.9	1,009	670.3	440.1	340.9	--
Sept	493.3	359.6	371.7	428.7	916.9	635.1	445.1	334.5	--
Oct	488.7	362.7	344.8	425.3	975.5	655.1	406.6	332.8	--
Nov	479.8	359.9	349.2	421.5	960.8	641.5	434.1	331.7	--
Dec	455.3	343.1	331.7	393.7	888.9	606.0	440.3	322.3	--
Daily mean	500.4	375.8	342.3	434.9	976.5	654.8	438.1	337.3	--
				Difference between monthly and daily means, in percent					
Jan	-7.3	-11.4	-9.1	-11.2	-10.1	-9.3	-9.2	-3.2	-8.9
Feb	-2.6	-8.2	-7.4	-13.5	-8.9	-8.2	-7.6	-1.0	-7.2
Mar	3.3	-.8	-13.8	-6.7	-2.5	-2.7	-13.6	1.2	-4.5
Apr	3.8	14.2	-.1	5.5	8.9	6.6	1.2	2.1	5.3
May	4.3	22.9	6.2	18.3	11.4	13.7	10.1	2.6	11.2
June	4.7	5.7	22.0	9.3	7.4	5.5	23.0	1.7	9.9
July	7.5	-.1	2.8	9.1	7.2	4.4	1.7	3.8	4.6
Aug	3.3	-1.8	-9.1	5.3	3.3	2.4	.5	1.1	.63
Sept	-1.4	-4.3	8.6	-1.4	-6.1	-3.0	1.6	-.8	-.85
Oct	-2.3	-3.5	.7	-2.2	-.1	.0	-7.2	-1.3	-2.0
Nov	-4.1	-4.2	2.0	-3.1	-1.6	-2.0	-.9	-1.7	-2.0
Dec	-9.0	-8.7	-3.1	-9.5	-9.0	-7.5	.5	-4.4	-6.3

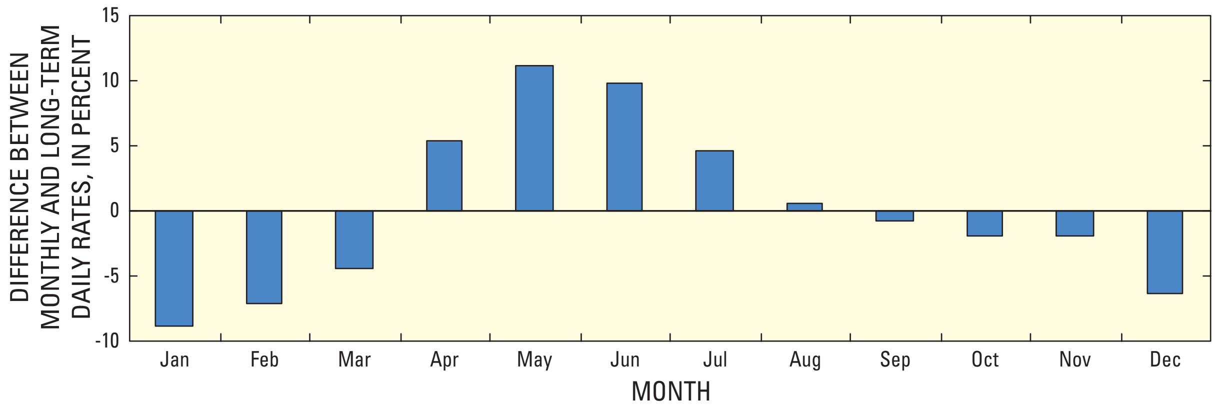

Figure 5. Differences between monthly and long-term (1992-2006) daily mean water-use rates (averaged for the eight utilities).

Table 5. Significant monthly differences in percent departure of monthly water-use rates from the 15-year daily mean (averaged for the eight utilities).

[X, indicates that the difference in percent departure for the two months being compared is significant at the α = 0.05 level]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Jan				X	X	X	X	X				
Feb				X	X	X	X					
Mar				X	X	X	X					
Apr												X
May								X	X	X	X	X
June								X	X	X	X	X
July												X
Aug												
Sept												
Oct												
Nov												
Dec												

Single-Variant Regression Analyses

Both single- and multivariant least squares regression analyses were used to evaluate the relations between municipal water use and selected meteorological parameters and drought indices which included P, T, PET, P-PET, ΔP, ΔT, ΔPET, Δ(P-PET), PDSI, and SPI. Explanatory variables were regressed against both total and metered water-use rates to determine which form of the dependent variable was best correlated with meteorological conditions. The same sets of metered water-use data analyzed for seasonal trends in the previous section were used in these analyses. Total water-use rates were also regressed against the number of metered connections.

Prior to regression analyses, the Durbin-Watson (d_L) statistic (Durbin and Watson, 1951) was used to determine if the temporal sequence of monthly water-use rates was serially correlated. Regression analyses using serially correlated data will yield erroneous values for the coefficient of determination (R^2) and standard error, which can result in too easily rejecting the null hypothesis; that is, there is no significant relation between the explanatory and dependent variables. Results indicated that, at a 5-percent significance level, monthly water-use rates were serially correlated at all utilities ($d_L < 1.80$ for N = 180 observations). Accordingly, and in line with an approach suggested by Helsel and Hirsch (2002) of using a regularly sequenced subset of a serially correlated dataset, water-use rates measured for every other calendar month were used (for example, January, March, May, July, September, and November). This approach reduced serial correlation effects to acceptable levels ($d_L > 1.5$ for N = 90 observations) while still accounting for seasonal variability in meteorological parameters and drought indices.

Results of the single-variant regression analyses are summarized in table 6 on the basis of R^2 values and sensitivity factors (SFs). Only those R^2 values determined from linear regressions with statistically significant slopes ($p < 0.05$) are quantified. The SF is calculated as the product of the geometric mean of the R^2 values—determined from the plots of water use relative to the explanatory variables—by the number of variables found to be significantly correlated with the dependent variable. At Daytona, for example, where metered water-use rates are significantly correlated with T, PET, P-PET, ΔT, and ΔPET, the product of the geometric mean of the R^2 values (0.258) times the number of significantly correlated parameters (5) is equal to 1.290 (table 6). The SF provides a basis for determining: (1) which of the eight utilities have water-use rates that are most (or least) sensitive to the suite of selected meteorological parameters and drought induces, and (2) which individual parameter and drought index is best (or least) correlated with water-use rates, all utilities considered. Results given in table 6 are summarized below.

- In general, the correlations between monthly water-use rates (both total and metered) and selected meteorological parameters/drought indices can be described as poor ($R^2 < 0.40$). These poor correlations illustrate the limits of using any single meteorological parameter or drought index for predictive purposes, although some parameters/indices are clearly better than others for estimating water use at the selected utilities.

- Metered water-use rates were better correlated with the suite of meteorological parameters than were total water-use rates. Total water-use rates, however, were better correlated with PDSI and SPI and were best correlated with the number of metered connections, the parameter being used here as a surrogate for population growth.

- Metered water-use rates were best correlated with T, PET, and P-PET (sensitivity factors of 1.552, 1.532, and 1.424, respectively) and least correlated with P and ΔP (sensitivity factors of 0.213 and 0.074, respectively). Precipitation was correlated with metered rates at only three of the eight utilities (Eustis, OCU, and STA). As discussed later, however, this apparent absence of a significant relation between precipitation and water use at most utilities could be considered counterintuitive and misleading.

- Metered water-use rates were best correlated with meteorological parameters at JEA and Daytona (sensitivity factors of 1.290), while least correlated with parameters at SCU and STA (sensitivity factors of 0.445 and 0.504, respectively).

- Both total and metered water-use rates were positively correlated with T, PET, ΔP, ΔT, and ΔPET, while negatively correlated with P, P-PET, and Δ(P-PET).

- The relation between total water-use rates and meteorological parameters is affected by growth rate. As shown in figure 6, sensitivity factors calculated from plots of total water use relative to meteorological parameters decrease logarithmically with a percentage-wise increase in total water use between 1992 and 2006. That is, water-use rates at utilities with the lowest growth rates (Daytona, Eustis, and OUC) were much better correlated with the parameters than were water-use rates at utilities with the highest growth rates (OCU, SCU, and STA). The logarithmic function fitted to the plot explains greater than 80 percent of the scatter in the data. This result is noteworthy because it suggests that metered, as opposed to total, water use is a better choice of the dependent variable for assessing correlations with meteorological parameters over periods of record in which growth is significant. Accordingly, only metered water-use rates were used in the multivariant regression analyses discussed later in this report. However, if total water-use rates are to be used in future analyses (for example, in the absence of adequate data on metered connections), then it may be best to try and a select a period of record over which the growth rate is relatively small and unaffected by changes in population.

Table 6. Results of single-variant linear regression analyses between metered water-use rates and selected meteorological parameters and drought indices, 1992-2006.

[Values are coefficients of determination, R^2. Correlated utilities: The number of the utilities having water-use rates significantly correlated with the given parameter. Correlated parameters: The number of the meteorological parameters significantly correlated with water use rates at the given utility. The sensitivity factor indicated for each utility is calculated by multiplying the geometric mean of significantly correlated parameter R^2 values by the number of parameters found to be significantly correlated with water use at the utility. Similarly, the sensitivity factor for each meteorological parameter/drought indice is calculated by multiplying the geometric mean of significantly correlated R^2 values by the number of utilities found to have water use rates significantly correlated with the parameter or drought indice. P, precipitation; T, temperature; PET, Thornthwaite potential evapotranspiration; P-PET, precipitation minus potential evapotranspiration; ΔP, change in precipitation; ΔT, change in temperature; ΔPET, change in potential evapotranspiration; Δ(P-PET), change in precipitation minus evapotranspiration; PDSI, Palmer Drought Severity Index; SPI, Standardized Precipitation Index; Daytona, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (northeast, northwest service areas); STA, City of St. Augustine]

	Daytona	Eustis	GRU	JEA	OCU	OUC	SCU	STA	Slope	Correlated utilities	Geometric mean	Sensitivity factor
						Regressions against metered water-use rates, in gallons per day per connection						
Meteorological parameter												
P		0.126			0.052			0.054	neg	3	0.071	0.213
T	0.342	.120	0.322	0.357	.186	0.225	0.129	.078	pos	8	.194	1.552
PET	.326	.109	.311	.345	.191	.214	.132	.088	pos	8	.192	1.532
P-PET	.107	.308	.172	.376	.272	.192	.056	.165	neg	8	.178	1.424
ΔP							.074		neg	1	.074	.074
ΔT	.306	.155	.058	.125	.118	.145		.057	pos	7	.119	.833
ΔPET	.313	.227	.026	.199	.158	.183		.074	pos	7	.134	.938
Δ(P-PET)							.077	.041	neg	2	.056	.112
Geometric mean	.258	.162	.121	.258	.145	.190	.089	.072				
Correlated parameters	5	6	5	5	6	5	5	7				
Sensitivity factor	1.290	.972	.605	1.290	.870	.950	.445	.504				
Drought indice												
PDSI		.106	.109	.039	.041	.142	.068	.089	neg	7	.077	.539
SPI	.078	.168	.035	.121	.178	.086		.101	neg	7	.098	.686
Geometric mean	.078	.133	.062	.069	.085	.111	.068	.095				
Correlated indices	1	2	2	2	2	2	1	2				
Sensitivity factor	.078	.266	.124	.138	.170	.222	.068	.190				
						Regressions against total water-use rates, in million gallons per day						
Meteorological parameter												
P		.146		.045					neg	2	.081	.162
T	.240	.089	.211	.107		.146	.046		pos	6	.122	.732
PET	.226	.072	.213	.086		.137	.045		pos	6	.111	.666
P-PET	.087	.314	.118	.189		.174	.063		neg	6	.137	.822
ΔP									neg	0	.000	.000
ΔT	.295	.124	.048	.040		.096			pos	5	.092	.460
ΔPET	.295	.170		.048		.119			pos	4	.130	.520
Δ(P-PET)									neg	0	.000	.000
Geometric mean	.210	.135	.126	.073	.000	.132	.051	.000				
Correlated parameters	5	6	4	6	0	5	3	0				
Sensitivity factor	1.050	.810	.504	.438	.000	.660	.153	.000				
Drought indice												
PDSI	.032	.210	.371	.184		.273	.290	.167	neg	7	.180	1.260
SPI	.076	.248	.042	.156		.104			neg	5	.105	.525
Geometric mean	.049	.228	.125	.169	.000	.169	.290	.167				
Correlated indices	2	2	2	2	0	2	1	1				
Sensitivity factor	.098	.456	.250	.338	.000	.338	.290	.167				
No. metered connections	.092	.131	.294	.691	.849	.104	.705	.849		8	.327	2.616

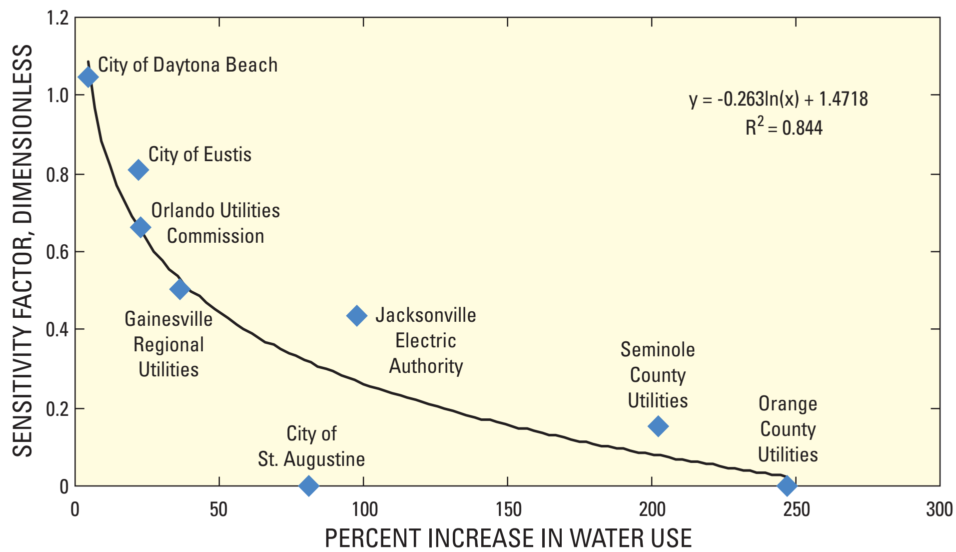

Figure 6. Relation between percent increase in total monthly water-use rates at selected utilities and sensitivity to meteorological parameters, 1992-2006.

Influence of System Memory

Correlations between metered water-use rates and meteorological parameters could be improved by considering the influence of system "memory." In this study, memory refers to the fact that the availability of water to plants is affected by the depth to the underlying water table and by soil-moisture conditions, both of which can be influenced by climatic variables on time scales of greater than a single (current) month. Given that water users will provide their lawns, shrubs, commercial ornamentals, and so forth, as much water as needed to keep them green, users would tend to use more water in a month where the water table and soil-moisture conditions are not as conducive to supplying the plant's need as they would in a month where these conditions have been made more favorable by rainfall and temperature conditions that occurred in preceding months. That is, watering habits may be influenced by the memory of the water table and soil-moisture conditions—and hence plants—to varying climatic conditions.

The duration of each utility's water-use memory to each parameter was examined by plotting monthly water-use rates relative to the moving averages of the given parameter for 1-, 2-, 3-, …and 12-month time periods (12 plots were constructed). The R^2 value obtained from each plot was plotted against the number of months used in the moving average calculation to identify which time frame provided the best correlation between the dependent and explanatory variables. Precipitation proved to be particularly sensitive to the moving average analyses. While correlated with monthly precipitation at only three sites, metered water-use rates were correlated with the moving average of precipitation at all eight sites. At OUC, for example, metered rates were best correlated with the 8-month moving average of precipitation at the Orlando NOAA station (fig. 7). Moving averages below and above this 8-month mark produced poorer fits of the data.

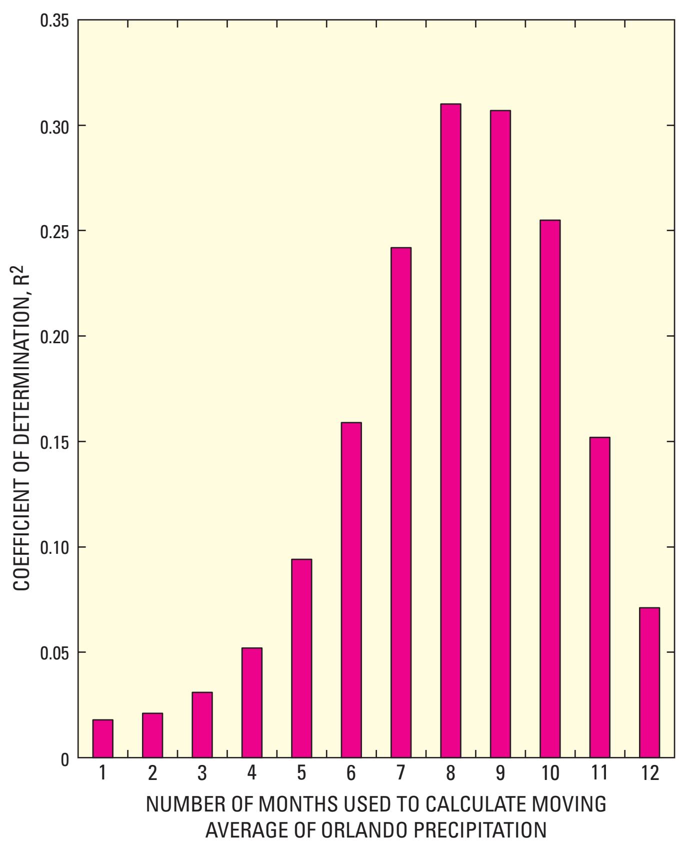

Figure 7. Coefficient of determination R^2 from plots of metered water use at Orlando Utilities Commission relative to the number of months used to calculate moving averages of precipitation at the Orlando NOAA station, 1992-2006.

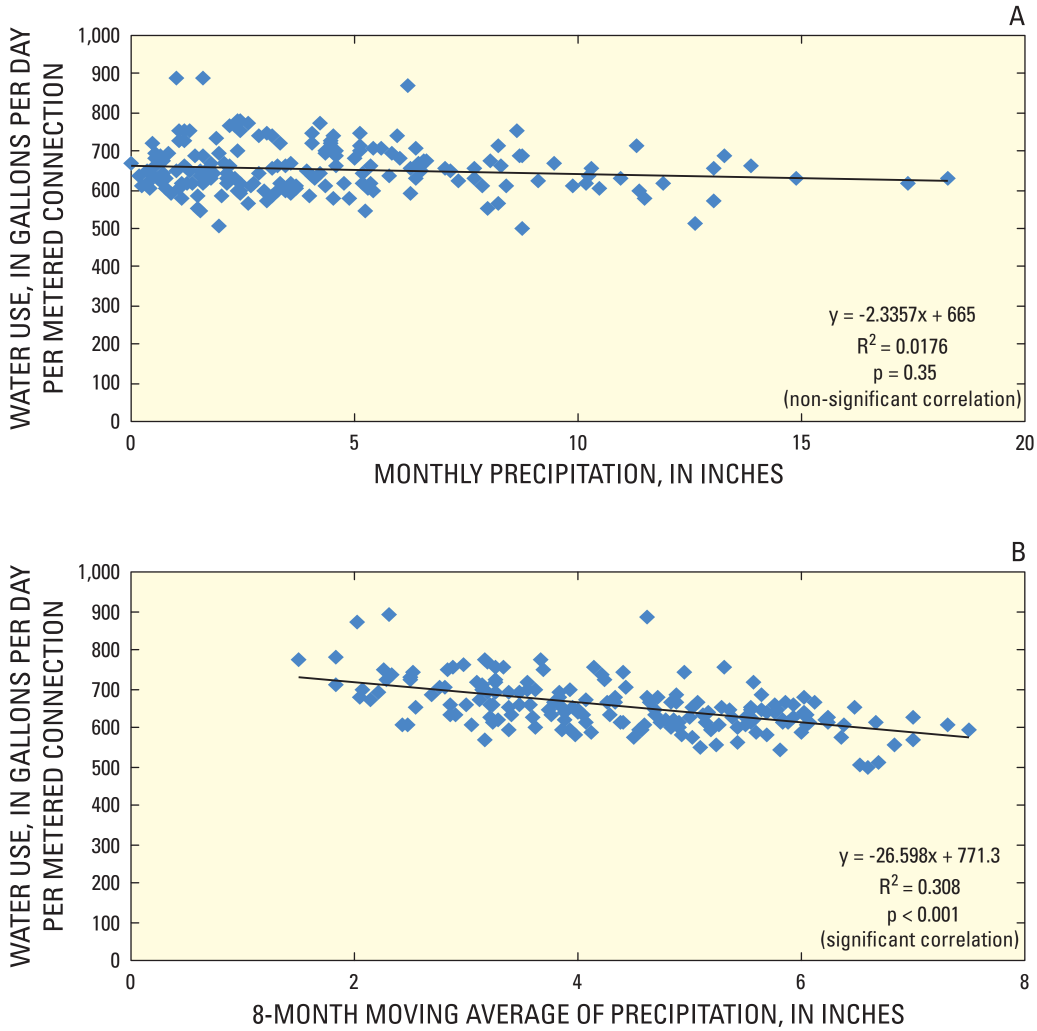

Figure 8. Metered water-use rates at Orlando Utilities Commission versus (A) monthly precipitation and (B) the 8-month moving average of precipitation at the Orlando NOAA station, 1992-2006.

The plots shown in figure 8 depict the improved relation between water use at OUC and precipitation at Orlando when using the moving-averaged value of precipitation ($R^2 = 0.31$, significant correlation) in place of the single (current) monthly value ($R^2 = 0.018$, nonsignificant correlation). Optimal time frames for precipitation at the other utilities ranged from 7 months at Daytona and Eustis to 11 months at GRU.

The monthly moving averages of the other meteorological parameters, particularly those for ΔT and ΔPET, also improved the correlations when plotted against metered rates (table 7). At JEA, for example, regression of metered rates relative to the 4-month moving averages of ΔT and ΔPET improved R^2 values from 0.125 to 0.491 (for ΔT) and from 0.199 to 0.449 (for ΔPET). Accounting for the eight utilities collectively, the sensitivity factor for ΔT increased nearly threefold—from 0.833 to 2.320—while the sensitivity factor for ΔPET increased from 0.938 to 2.320.

The results depicted in table 7 do not necessarily represent a unique or optimal solution, and the true duration of water-use memory to these parameters may be less than the indicated time frames. Each month used to calculate the moving average was equally weighted, whereas the current month or most recent 2 to 3 months may exert more influence on water use than do later months. Nonetheless, results indicate that a current month's water use is affected by P, ΔT, and ΔPET on time scales of greater than 1 month and may be indicative of the cumulative influence of these parameters on the amounts of water required to maintain green vegetative covers.

Table 7. Comparison of single-variant regression analyses for monthly and moving-averaged parameter values, 1992-2006.

[Values are coefficients of determination, R^2; 1-mo, single month result; ma, moving monthly averaged result (number in parentheses is number of months found to provide highest R^2); P, precipitation; T, temperature; PET, Thornthwaite potential evapotranspiration; P-PET, precipitation minus potential evapotranspiration; ΔP, change in precipitation; ΔT, change in temperature; ΔPET, change in potential evapotranspiration; Δ(P-PET), change in precipitation minus potential evapotranspiration; Daytona, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (northeast, northwest service areas); STA, City of St. Augustine]

Meteoro-logical parameter	Daytona		Eustis		GRU		JEA		OCU		OUC		SCU		STA		Geometric mean		Sensitivity factor	
	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma	1-mo	ma
P		0.234 (8)	0.126	0.254 (9)		0.134 (11)		0.435 (8)	0.052	0.244 (8)		0.373 (8)		0.110 (9)	0.052	0.270 (7)	0.071	0.235	0.213	1.880
T	0.342	.342 (1)	.120	.106 (1)	0.313	.322 (1)	0.357	.357 (1)	.186	.186 (1)	0.225	.225 (1)	0.129	.155 (2)	.078	.078 (1)	.194	.196	1.552	1.568
PET	.326	.326 (1)	.109	.109 (1)	.311	.311 (1)	.345	.345 (1)	.191	.191 (1)	.214	.214 (1)	.132	.147 (2)	.088	.088 (1)	.192	.195	1.532	1.560
P-PET	.107	.137 (4)	.308	.347 (2)	.172	.172 (1)	.376	.403 (2)	.272	.272 (1)	.192	.232 (3)	.056	.257 (3)	.165	.165 (1)	.178	.233	1.424	1.864
ΔP													.074	.074 (1)			.074	.074	.074	.074
ΔT	.306	.654 (3)	.153	.332 (3)	.058	.202 (4)	.125	.491 (4)	.118	.358 (3)	.145	.366 (3)		.111 (4)	.057	.159 (3)	.119	.290	.833	2.320
ΔPET	.313	.661 (3)	.227	.300 (3)	.026	.245 (4)	.199	.449 (4)	.158	.359 (3)	.183	.354 (3)		.104 (4)	.074	.174 (3)	.134	.290	.938	2.320
Δ(P-PET)				.156 (2)				.173 (4)		.199 (4)			.077	.077 (1)	.041	.054 (3)	.056	.121	.112	.605
Geometric mean	.258	.340	.162	.202	.121	0.219	.258	.370	.145	.247	.190	.285	.089	.120	.072	.124				
Sensitivity factor	1.290	2.040	.972	1.414	.605	1.314	1.290	2.590	.870	1.729	.950	1.710	.445	.960	.504	.868				

Nonlinear Relations

In most cases, linear functions provided the best (or very nearly so) R^2 values for the single-variant regressions. At several utilities, however, plots between metered water-use rates and the moving averages of ΔT, ΔPET, and P-PET were clearly curvelinear. In such cases, R^2 values could be further improved by fitting the data with nonlinear (polynomial) functions. At Eustis, for example, the R^2 value determined from a linearly regressed plot of metered rates relative to the 3-month moving average of ΔT increased from 0.33 (table 7) to 0.48 for the second-order polynomial function (fig. 9). Results depicted in figure 9 are noteworthy in that water use appears to be relatively insensitive to reductions in the 3-month moving average of ΔT (negative scale values) as water use approaches some constant minimum usage. Positive changes in temperature, however, produce increasingly greater water-use demands. The plot shown for Eustis in figure 9 is similar to those found for the other utilities.

Table 8 quantifies the highest R^2 values determined for each meteorological parameter from the three single-variant regression models discussed above; that is, from either the single monthly linear fit, the moving-averaged linear fit, or the moving-averaged polynomial fit. At OCU, for example, metered water-use rates were best correlated with a linear fit of the single monthly values of PET ($R^2 = 0.19$), while

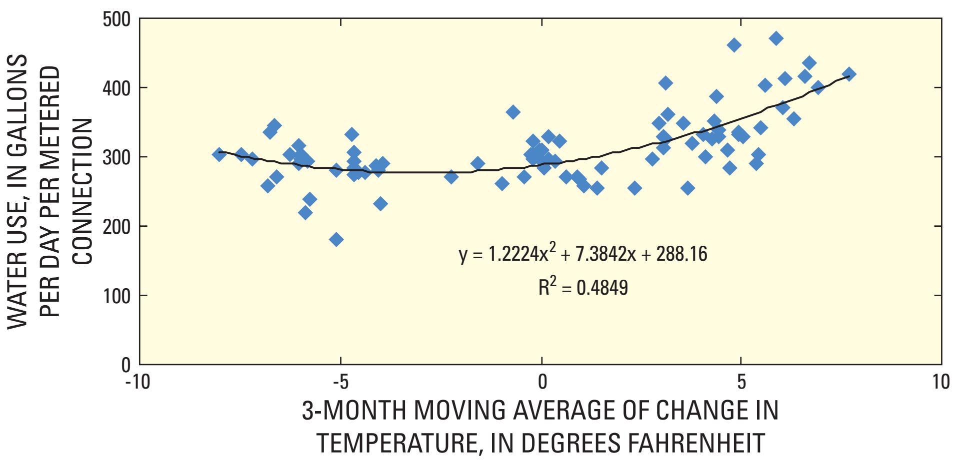

Figure 9. Metered water-use rates at Eustis and the 3-month moving average of change in temperature at the Lisbon NOAA station, 1992-2006.

Table 8. Results of best fit linear and nonlinear single-variant regression analyses, 1992-2006.

[Values are coefficients of determination, R^2; P, precipitation; T, temperature; PET, Thornthwaite potential evapotranspiration; P-PET, precipitation minus potential evapotranspiration; ΔP, change in precipitation; ΔT, change in temperature; ΔPET, change in potential evapotranspiration; Δ(P-PET), change in precipitation minus potential evapotranspiration; a, the best R^2 value was obtained with a single month linear model; b, the best R^2 value was obtained with a moving average linear model; c, the best R^2 value was obtained with a moving average polynomial model; Daytona, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (northeast, northwest service areas); STA, City of St. Augustine. Single parameter best correlated with water use at each utility is in **bold**]

Meteorological parameter	Daytona	Eustis	GRU	JEA	OCU	OUC	SCU	STA
P	0.234 b	0.254 b	0.134 b	0.435 b	0.244 b	0.373 b	0.110 b	**0.270** b
T	.342 a	.120 a	.322 a	.357 a	.186 a	.225 a	.155 b	.078 a
PET	.326 a	.109 a	.311 a	.345 a	.191 a	.214 a	.147 b	.088 a
P-PET	.137 b	.381 c	.172 a	.475 c	.272 a	.232 b	**.257** b	.165 a
ΔP							.074 a	
ΔT	**.661** b	**.485** c	.202 b	**.575** c	.478 c	.476 c	.111 b	.159
ΔPET	.616 b	.415 c	.245 b	.506 c	**.530** c	**.484** c	.104 b	.174 b
Δ(P-PET)		.156 b		.173 b	.199 b		.077 a	.054 b

a polynomial function provided the best fit for the 3-month moving average of ΔPET ($R^2 = 0.53$). Overall, a single explanatory variable could account for greater than 50 percent of the variance in the data at three of the eight sites—Daytona (66 percent), JEA (58 percent), and OCU (53 percent). In general, and when regressed against single meteorological parameters, metered rates appear to be most sensitive to changes in the moving averages of ΔT or ΔPET.

In summary, even though single parameters are significantly correlated with water use, the high variance present in these relations limits the use of single-variant analyses for predictive purposes. However, these results do provide insight into which parameters are most likely to influence water-use rates, the importance of system memory, and the influence of nonlinear relations between water usage and climate.

Multivariant Regression Analyses

Multivariant linear regression models predict the relation between a response (dependent) variable and explanatory (independent) variables as:

$$Y = \beta_0 + \beta_1 x_1 + \ldots B_k x_k + \varepsilon \qquad (1)$$

where

- Y is the dependent variable,
- β_0 is the intercept,
- β_1 is the slope coefficient for the first explanatory variable (x_1),
- B_k is the slope coefficient for the k^{th} explanatory variable (x_k), and
- ε is the error or remaining unexplained “noise” in the data.

Guidelines presented by Helsel and Hirsch (2002) were used to conduct the multivariant analyses and to select the “best” model (regressed equation) for each utility. The data were analyzed as follows:

1. Initial model runs were conducted using all candidate explanatory variables, including those moving-averaged variables found to improve the single-variant results. Residual plots of the dependent variable were examined for linearity, constant variance, and normality. Where required, the dependent variable was log-transformed to conform to these assumptions.

2. Partial plots of the explanatory variables were examined for nonlinearity and log-transformed where necessary.

3. Variables having unacceptable levels of multicollinearity were identified by the Variance Inflation Factor (VIF) and grouped separately in subsequent testing. The VIF (Marquardt, 1970) is an index which measures how much the variance of a coefficient is increased because of colinearity. In this study, variables with VIF >3 are considered to be highly correlated and included those which are mathematically related such as T and PET, P and (P-PET), and P and SPI.

4. The best subsets of models at each utility were identified for each of “n” explanatory variables; the best model was selected as that which minimized Mallows C_p. Mallows C_p is a test statistic designed to achieve a compromise between explaining as much of the variance in the dependent variable as possible by including all relevant explanatory variables, while minimizing the standard error of the resulting estimates by keeping the number of coefficients small (Helsel and Hirsch, 2002). All explanatory variables included in the best models had statistically significant slope coefficients ($p < 0.05$).

Results of the multivariant regression analyses are given in table 9 and summarized below:

- Relative to the single-variant analyses, multivariant regression analyses improved the correlations between metered water-use rates and meteorological parameters at all eight utilities. Adjusted R^2 values for the best models exceeded 0.60 (considered to be an acceptable level of correlation) at five of the eight utilities, ranging from about 0.79 at JEA to about 0.29 at STA. Greatest improvements are seen at GRU (from 0.31 to 0.62), SCU (from 0.26 to 0.48), and JEA (from 0.58 to 0.79). Marginal improvements are seen at Daytona (from 0.61 to 0.69) and STA (from 0.27 to 0.29).

- The number of significant meteorological parameters included in the eight best models ranged from two at STA to four at GRU, JEA, and SCU. The amount of available water (P-PET) was the single parameter most common to the best models (six of eight utilities), while ΔT or ΔPET were present at five of eight sites. Neither of the drought indices, PDSI or SPI, was found to be significantly correlated to metered rates in any of the eight best models;

- The monthly moving average of at least one parameter was present in seven of the eight best models, again reflective of system memory.

- P and ΔP were much better correlated with metered water-use rates in the multivariant analyses (included as significant parameters in six of the eight best models) than in the single-variant analyses (significant at only three of eight utilities). The contrast here is noteworthy. Multivariant results provide a more realistic view of how precipitation is related to water use because the analytical procedure factors out any offsetting effects of other parameters, in this case temperature, on the dependent variable. Partial residual plots developed between metered rates and precipitation and temperature (not shown here) indicate that

Table 9. Results of multivariant regression analyses between metered water-use rates and selected meteorological parameters and drought indices, 1992-2006.

[R^2 adj, adjusted coefficient of determination; Cp, Mallow's statistic; PRESS, PRESS statistic; VIF, variance inflation factor; gpdm, gallons per day per metered connection; P, precipitation, in inches; PET, Thornthwaite potential evapotranspiration, in inches; T, temperature in degrees Fahrenheit; ΔP, change in precipitation, in inches; ΔT, change in temperature, in degrees Fahrenheit; ΔPET_{3ma}, 3-month moving average of change in PET, in inches; lnP, natural log of precipitation; Daytona, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (northeast, northwest service areas); STA, City of St. Augustine]

	Daytona	Eustis	GRU	JEA	OCU	OUC	SCU	STA
Regression statistics								
R^2 adj (R^2 single variant)	69.0 (61.1)	63.8 (48.4)	62.0 (31.3)	78.8 (57.5)	56.9 (53.0)	63.3 (48.4)	48.2 (25.7)	29.2 (27.0)
C_p	3.1	2.6	2.9	4.6	3.0	2.8	3.2	1.9
PRESS	24654	87767	.478	57803	409045	.318	1.11	.205
VIF	<3	<2	<3	<3	<2	<2	<2	<3
Significant parameters (p-value)	ΔPET_{3ma} (<.001)	ΔT_{3ma} (<.001)	T_{3ma} (<.001)	T (<.001)	ΔPET_{3ma} (<.001)	ΔT_{4ma} (<.001)	PET (<.001)	P_{7ma} (<.001)
	ΔPET (.008)	$(P-PET)_{2ma}$ (.001)	ΔP (<.001)	P_{8ma} (<.001)	P-PET (<.001)	$(P-PET)_{4ma}$ (<.001)	ΔP (<.001)	PET (.046)
	P (.010)	P (.002)	P (<.001)	P-PET (<.001)	Δ(P-PET) (.013)	P (.003)	P-PET (<.001)	
			$(P-PET)_{2ma}$ (<.001)	ΔP (.003)			ΔT (<.001)	

"Best" regressed equations		
	Daytona	$gpdm = 508 - 1.40*P - 7.59*\Delta PET + 36.4*\Delta PET_{3ma}$
	Eustis[1]	$gpdm = 784 + 6.79*\Delta T_{3ma} - 147*\ln(P-PET+20)_{2ma} - 19.2*\ln P$
	GRU	$gpdm = \exp(3.27 + .615*\ln T_{3ma} - .0324*\ln P + .00728*\Delta P - .0109*(P-PET)_{2ma})$
	JEA	$gpdm = 353 - 46.3*\ln P_{8ma} + 2.69*\Delta P - 9.95*(P-PET) + 2.35*T$
	OCU	$gpdm = 2137 + 60.0*\Delta PET_{3ma} - 388*\ln(P-PET+20) + 4.94*\Delta(P-PET)$
	OUC	$gpdm = \exp(6.52 + .0191*\Delta T_{4ma} - .0205*(P-PET)_{4ma} - .00746*P)$
	SCU	$gpdm = \exp(6.50 + .0367*PET + .0218*\Delta P - .0266*(P-PET) - .191*\ln(\Delta T+20))$
	STA	$gpdm = \exp(5.89 - .0211*P_{7ma} + .00553*PET)$

[1]Precipitation measured at City of Eustis WTP.

metered rates decrease significantly with increasing precipitation but increase significantly with temperature. Because these two parameters have the opposite effect on metered rates and are seasonally related (for example, highest P and T typically occur together in the summer months while lowest P and T occur together in the winter months), the two parameters tend to dampen or offset the effects of one another on the dependent variable. Based on comparison with the single-variant results, temperature appears to dampen more of the influence of precipitation on metered rates than vice versa.

The effect of using locally measured versus the more distant NOAA-measured precipitation on correlated results was evaluated for the four utilities operating single plants—Daytona, Eustis, GRU, and STA. At Eustis, where the water-treatment plant and associated Lisbon station are farthest apart (about 7 miles), precipitation measured locally at the plant improved the correlation. At Daytona, GRU, and STA, however, where the plants and associated NOAA stations are closer to one another, the correlations were not improved by using locally measured precipitation. These results suggest that the spatial variability of monthly precipitation may affect the relations between water use and precipitation discussed here, particularly for those utilities having multiple and more geographically dispersed water-treatment plants such as JEA, OUC, OCU, and SCU.

Predictive Analyses

The regressed equations given in table 9 were used to predict metered water-use rates for 2007. Results provide some indication of how well these equations may be expected to predict future rates, within the limits of the parameter-value ranges documented in this 15-year study, for hypothetical sets of meteorological conditions that may be of interest to water-resource managers and ground-water modelers. Precipitation in 2007 averaged 45.5 in., a relatively dry year compared with the long-term (1959-2006) average of 50.9 in. Water-use restrictions were in effect in 2007.

Measured versus predicted water-use rates are depicted graphically in figure 10 and summarized statistically in table 10. Overall, some models performed better than others,

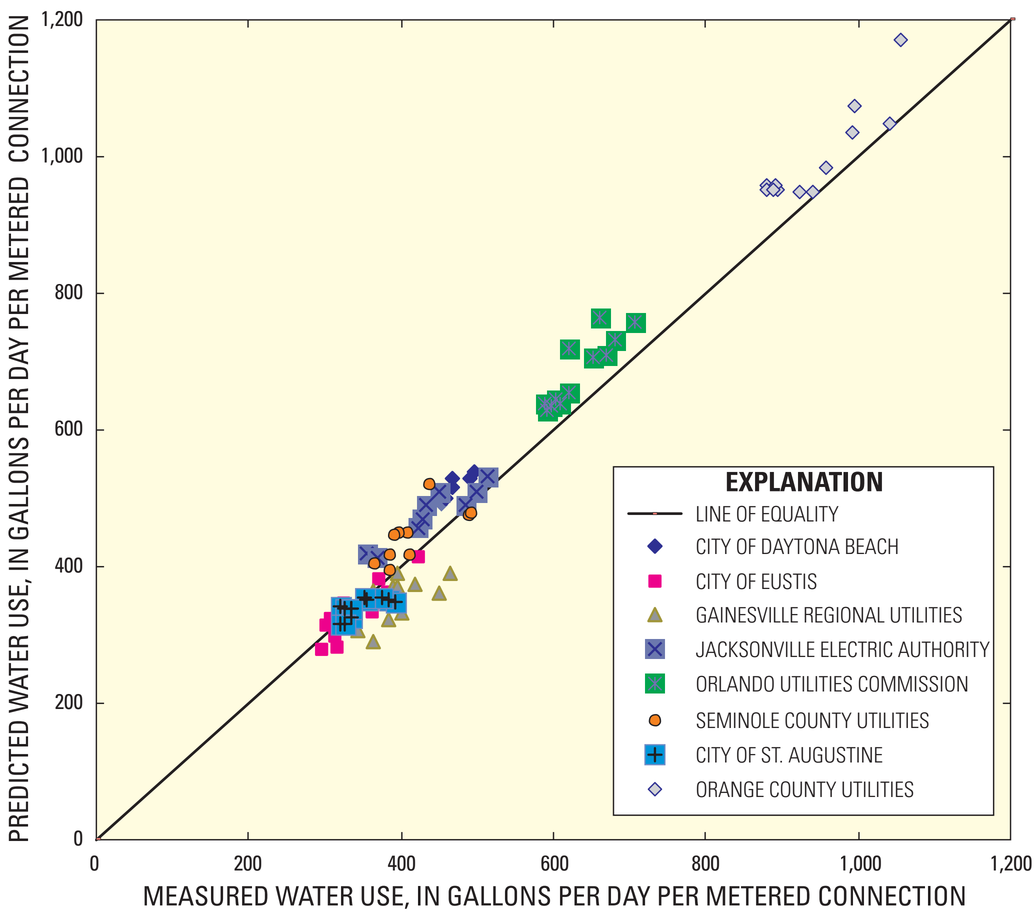

Figure 10. Measured versus predicted water-use rates for the selected utilities, 2007.

Table 10. Summary of descriptive and error statistics for measured and predicted metered water-use rates, 2007.

[gpdm, gallons per day per metered connection; R^2, coefficient of determination; NOAA, National Oceanic and Atmospheric Administration]

Utility	Average annual water use		Average error (gpdm)	Root-mean square error (gpdm)	Coefficient of variation (percent)[1]	Slope line of best fit	R^2
	Measured (gpdm)	Predicted (gpdm)					
City of Daytona Beach	465	507	-42	42.4	9.1	0.92	0.85
City of Eustis[2]	342	333	9	19.9	5.8	.95	.80
City of Eustis[3]	342	326	16	22.4	6.6	.74	.84
Gainesville Regional Utilities	392	350	42	58.9	15.0	.25	.12
Jacksonville Electric Authority	428	464	-36	41.1	9.6	.76	.86
Orange County Utilities	945	998	-53	62.0	6.6	.98	.78
Orlando Utilities Commission	634	686	-52	56.9	9.0	1.15	.79
Seminole County Utilities	418	445	-27	39.8	9.5	.64	.53
City of St. Augustine	346	337	9	20.8	6.0	.32	.46

[1]Calculated as 100*RMSE/measured average annual water-use rate.

[2] Using precipitation measured at water-treatment plant.

[3]Using precipitation measured at Lisbon NOAA station.

but most provided fair-to-good results. The average error between predicted and measured rates, an indication of model bias, ranges from -53 gpdm at OCU (overpredicted rates) to 42 gpdm at GRU (underpredicted rates). The coefficient of variation (COV), an error statistic normalized to allow comparison between utilities having different annually averaged water-use rates, is calculated by dividing the root-mean square error of the differences between measured and predicted rates by the average annual measured rate. The COV values ranged from a low of 5.8 percent at Eustis to a high of 15 percent at GRU. The remaining two statistics given in table 10—the slope of the line-of-best-fit and the coefficient of determination—are regression statistics that describe just the predicted results. Ideally, a regressed slope of 1.0 would indicate that, even though the predicted results may be biased in one direction of another, the rate of change in predicted water-use rates equals that of the measured rates (a desirable attribute). Regressed slopes between 0.90 and 1.10, such as those determined for Daytona Beach, Eustis, and OCU, provide reasonably good approximations of the measured changes in rates. Based collectively on the above-described statistics, the most accurate predictions of metered rates were made at Eustis while the least accurate predictions were made at GRU.

Two factors not accounted for in the regression analyses that probably have significant effects on water use are changes in (1) the ratios of water-use type and (2) reclaimed water usage. At GRU, for example, where metered rates are underpredicted, the ratio of commercial-to-residential service connections increased from 8.4 to 9.7 percent in 2007 (Rick Hutton, Gainesville Regional Utilities, written commun., 2008). Given that the amount of water used per commercial connection at GRU exceeds that used per residential connection (see fig. 2), the increase in the ratio of commercial-to-residential connections in 2007 may be responsible, at least in part, for the biased results at this utility.

Increased usage of reclaimed water likely contributed to the overpredicted results at JEA and OUC. At JEA, the number of metered connections for reclaimed water use remained nearly constant between 2001 and 2006 but increased sharply in 2007 (fig.11A). Volumetrically, reclaimed water usage roughly doubled in 2007 (Brad Russell, Jacksonville Electric Authority, oral commun., 2008). At OUC, reclaimed-water usage has been increasing over the past 10+ years and is estimated to have increased from about 2 Mgal/d in 1996 to 9 Mgal/d in 2007 (fig.11B). In addition to increases in reclaimed water usage, both JEA and OUC service areas were subject to water-use restrictions in 2007 - another factor not accounted for by the models which would tend to contribute to overpredicted rates.

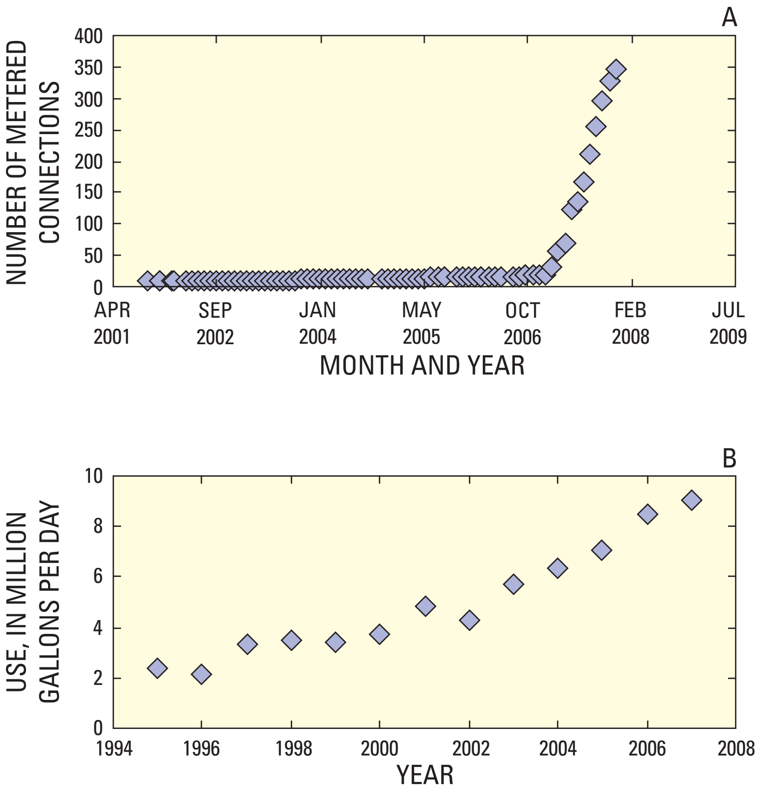

Figure 11. Metered connections for reclaimed water use at Jacksonville Electric Authority, October 2001-December 2006, and reclaimed water use for Orlando Utilities Commission, 1995-2007.

Summary

Future and increased ground-water withdrawals in east-central and northeast Florida have the potential to adversely affect sensitive resources such as springs, lakes, and wetlands. Rates of ground-water withdrawals vary seasonally in response to municipal water-supply demands, which include residential, commercial and industrial usages. Changes in municipal demands are affected by a complex combination of climatological, economic, social, and regulatory factors, not all of which can be accounted for in a statistical examination of cause-and-effect relations. However, if water use can be statistically related to variations in commonly measured meteorological parameters and (or) drought indices, these relations would provide resource managers an improved tool for predicting the potential effects of climate, and perhaps climate change, on associated demands. Additionally, scientists tasked with developing transient ground-water flow models could more confidently quantify ground-water withdrawal rates under varying climatic conditions.

This study examined the relations between municipal water use and several commonly measured meteorological parameters and drought indices. Selected parameters include precipitation (P), air temperature (T), potential evapotranspiration (PET), and available water (P-PET). Drought indices include the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI). Water-use rates were analyzed for seasonal (monthly) variations at eight utilities in east-central and northeast Florida which include the City of Daytona Beach (Daytona), the City of Eustis (Eustis), Gainesville Regional Utilities (GRU), Jacksonville Electric Authority (JEA), Orange County Utilities (OCU) (southern service area), Orlando Utilities Commission (OUC), Seminole County Utilities (SCU) (northeast and northwest service areas), and the City of St. Augustine (STA). The amounts of potable water treated at associated WTPs in 2006 ranged from about 3.2 Mgal/d at Eustis to about 131 Mgal/d at JEA.

The water-use data were analyzed to identify significant seasonal (monthly) trends, quantify differences in use, and determine interrelations. Both single- and multivariant regression analyses were applied to quantify the relations between water use and selected meteorological parameters and drought indices. Results of the multivariant regressions were used to predict monthly rates in 2007. Three types of single-variant regression analyses were conducted: (1) a simple linear regression of both total and metered water-use rates against single (current) monthly parameter values and drought indices; (2) a linear regression of metered rates against monthly moving-averaged parameter values (to account for the influence of system memory); and (3) a nonlinear regression of metered rates against monthly moving-averaged parameters values. Both total and metered water-use rates were used as dependent variables in the single monthly analyses, while just the metered rates were used in the latter two analyses. Because monthly water-use rates were found to be serially correlated, the regression analyses were conducted on a subset of the dependent variable, that is, on those rates measured for every other calendar month (for example, January, March, May, July, September, and November). All trend testing and regression analyses were conducted from 1992 to 2006, with precipitation patterns and extremes similar to those of the longer term (1959-2006) record. Climatological data and drought indice values were obtained from National Oceanic and Atmospheric Administration (NOAA) rainfall stations closest to the utilities.

Total water-use rates between 1992 and 2006 increased at all utilities, from about 4 percent at Daytona to greater than 200 percent at OCU and SCU. Metered rates, however, decreased at six of the eight utilities, from about 2 percent at OCU and OUC to about 17 percent at Eustis. In December 2006, metered water-use rates ranged from about 983 gpdm at OCU to about 314 gpdm at Eustis. Given the absence of significant trends in precipitation, decreases in metered rates can likely be attributed to temporal changes in non-climatic factors that were not considered in this study such as the ratios of water-use types, usage of reclaimed water, effectiveness of water-use restrictions, demographics, water pricing, and so forth.

When averaged for the eight utilities, metered water-use rates depict a clear seasonal pattern in which rates tend to be least in the winter and greatest in the late spring. In January, metered rates averaged about 9 percent below the 15-year daily mean but about 11 percent above the daily mean in May. These results serve to provide guidance for quantifying seasonally variant ground-water withdrawal rates, under average meteorological conditions, for predictive ground-water flow models.

Linear regression of water-use rates versus monthly parameter- and drought-indice values generally produced poor, though still statistically significant, correlations ($R^2 < 0.40$). Metered rates were better correlated with the meteorological parameters while total rates were better correlated with PDSI and SPI. Metered rates were best correlated with T, PET, and P-PET, and least correlated with ΔP and Δ(P-PET). Both metered and total water-use rates were positively correlated with T, PET, ΔP, ΔT, and ΔPET, while negatively correlated with P, P-PET, and Δ(P-PET). Of the eight utilities, metered rates were most sensitive to meteorological parameters at JEA and Daytona while least sensitive to these parameters at SCU and STA.

The relation between total water use and the meteorological parameters is affected by the growth rate in water use. Water-use rates at the utilities with the lowest growth rates (Daytona, Eustis, and OUC) were much better correlated with the parameters than were water-use rates at utilities with the highest growth rates (OCU, SCU, and STA). The logarithmic function that quantifies the relation explains greater than 80 percent of the scatter in the data. This result is noteworthy in that it shows metered water use is a better choice of the dependent variable for assessing correlations with meteorological parameters over periods of substantial growth.

Correlations between metered water-use rates and meteorological variables could be improved by accounting for the influence of system memory. Metered rates were most sensitive to system memory of precipitation where, when averaged for the eight utilities, the sensitivity factor increased from 0.213 (for single monthly regressions) to 1.880 for the monthly moving-averaged regressions. Optimal moving-averaged time frames for precipitation ranged from 7 months at STA to 11 months at GRU. At JEA, regression of metered water-use rates versus the 8-month moving average of P increased R^2 from < 0.10 (insignificant correlation) to 0.44 (highly significant correlation). Similarly, regression of metered rates at Daytona versus the 3-month moving averages of ΔT and ΔPET increased R^2 from 0.30 and 0.31 (for single monthly regressions) to 0.65 and 0.66, respectively. Overall, accounting for system memory improved the sensitivity of metered rates to the full suite of meteorological parameters by greater than 50 percent at all but one utility, and by 100 percent or greater at four of the eight utilities.

In the few cases where plots of metered water use versus the moving-averaged values of ΔT, ΔPET, and P-PET were curvilinear, the R^2 values could be further improved by fitting the data with polynomial functions. At Eustis, for example, R^2 determined from the plot of metered rates versus the 3-month moving average of ΔT increased from 0.33 for the linear plot to 0.49 when fitted with polynomial function. These results are noteworthy in that water use appears to be relatively insensitive to reductions in the 3-month moving average of ΔT (negative scale values) as water use approaches a constant (consumptive) minimum usage rate. Positive changes in the 3-month moving average of ΔT, however, result in increasingly greater water-use demands. The results for Eustis were similar to those found for the other sites. Overall, the highest R^2 value at each utility was achieved by either a linear or nonlinear regression of metered rates against moving-averaged values of the meteorological parameters.

Relative to the single-variant analyses, multivariant regression analyses improved the correlations between metered water-use rates and meteorological parameters at all eight sites. Adjusted R^2 values ranged from 0.79 at JEA to 0.29 at STA and exceeded 0.60 at five of the eight sites. Greatest improvements are seen at GRU (from 0.31 to 0.62), SCU (from 0.26 to 0.48), and JEA (from 0.58 to 0.79). Marginal improvements are seen at Daytona (from 0.61 to 0.69) and STA (from 0.27 to 0.29). The amount of available water (P-PET) was the parameter most commonly included in the best models (six of eight sites), while ΔT or ΔPET were present at five of eight sites. Neither of the drought indices, PDSI or SPI, were significant parameters in any of the eight best models. The moving average of at least one parameter was present in seven of the eight best models, again indicative of the role of memory in water use.

Monthly P and ΔP were much better correlated with metered water-use rates in the multivariant analyses (included as significant parameters at six of eight sites) than in the single- variant analyses (significant at only three of eight sites). This contrast can be attributed to the fact that the multivariant analysis better isolates the effect of precipitation on water use by factoring out any offsetting effects from other parameters, such as T, that are directly (and not inversely) related to water use.

The "best" model equations determined from the multivariant analyses were used to predict metered water-use rates for 2007, a relatively dry year. The average error between predicted and measured results, an indication of model bias, ranged from -53 gpdm at OCU (overpredicted rates) to 42 gpdm at GRU (underpredicted rates). The coefficient of variation (COV), which is the error in predicted results normalized to allow comparison between utilities with varying water-use rates, ranged from a low of 5.8 percent at Eustis to a high of 15 percent at GRU. Regressed slopes between 0.90 and 1.10, such as those determined for Daytona Beach, Eustis, and OCU, provide reasonably good approximations of the measured changes in rates. Based collectively on the error and descriptive statistics, the best predictions were made at Eustis while the poorest predictions were made at GRU. Increased usage of reclaimed water likely contributed to the biased (overpredicted) results at OUC and JEA, while changes in the ratio of commercial-to-residential users in 2007 probably contributed to the underpredicted rates at GRU.

In future work, researchers may want to consider several explanatory variables that were not included in this study. Locally measured precipitation could be used in place of more distant NOAA station data, particularly for the larger utilities having widely dispersed service areas. More highly resolved data are needed to differentiate the types of metered connections to better account for temporal changes in use type. Finally, accounting for changes in reclaimed water use, as well as for periods where water-use restriction are in place, may help improve the predictive capabilities of regression-based models.

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Glossary (adapted from Marella, 2004)

Commercial water use: Water for motels, hotels, restaurants, office buildings, commercial facilities and civilian and military institutions. The water may be obtained from a public supply or be self-supplied.

Industrial water use: Water used for industrial purposes such as fabricating, processing, washing, and cooling, and includes such industries as steel, chemical and allied products, paper and allied products, mining, and petroleum refining. The water can be obtained from a public supply or be self-supplied.

Municipal (public) supply: Water withdrawn by public or private water suppliers and delivered to users who do not supply their own water. Water suppliers provide water for a variety of uses, such as domestic, commercial, industrial, thermoelectric power (domestic and cooling purposes), and public water use. According to the Florida Department of Environmental Protection, any water system that serves more than 25 people or has 15-year-round service connections is considered a community public supplier.

Reclaimed water: Water that has received at least secondary treatment and is reused after leaving a wastewater treatment facility.

Residential water use: Water for normal household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. The water can be obtained from a public supply or be self-supplied.

Water use: (1) In a restrictive sense, the term refers to water that is actually used for a specific purpose such as domestic use, irrigation, or industrial processing; and (2) more broadly, water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements such as water withdrawals, deliveries, consumptive use, wastewater releases, reclaimed wastewater, return flow, and instream use.

Withdrawal: Water removed from the ground or diverted from a surface-water source. The amount of water withdrawn may not equal the amount of water used due to water transfers or the recirculation or recycling of the same water. For example, a power plant may use the same water multiple times but withdraw a significantly different amount.

Appendix. Amounts of water treated and number of metered connections at selected municipal water-treatment plants/service areas, 1992-2007.

(Mgal/d, million gallons per day; conn, number of active metered connections; ERC, equivalent metered connections; Daytona Beach, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (NE, NW service areas); STA, City of St. Augustine]

Month-year	Daytona Beach		Eustis		GRU		JEA		OCU (south)		OUC		SCU (NE, NW)		STA	
	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	ERC	Mgal/d	conn
Jan-92	11.374	22992	2.438	6559	17.810	43135	64.320	142958	4.164	4670	68.800	109699	4.092	12441	1.737	6682
Feb-92	12.172	23000	2.392	6576	16.745	42797	62.130	143434	4.173	4742	66.884	109862	4.486	12584	1.827	6706
Mar-92	13.071	23011	2.479	6586	15.681	42459	64.800	143880	4.684	4786	69.694	110112	3.629	12689	1.896	6241
Apr-92	12.983	23021	2.903	6604	16.449	41662	70.660	144357	5.105	4810	71.899	110200	4.342	12615	1.972	6712
May-92	12.345	23146	3.087	6616	18.218	41086	74.060	144818	5.478	4827	87.011	110381	5.193	12710	1.953	6753
Jun-92	12.397	23067	2.325	6631	19.466	41277	67.430	145294	5.217	4863	78.915	110474	5.307	13358	2.046	6866
Jul-92	13.474	23054	2.562	6648	19.546	40917	78.960	145755	5.771	4887	87.715	110567	5.217	12782	2.066	6864
Aug-92	12.565	23092	2.343	6657	17.848	42299	70.840	146232	5.301	4947	76.582	110680	5.358	12768	1.620	6855
Sep-92	12.090	23060	2.400	6663	18.835	43714	65.720	146708	4.808	5083	73.427	110879	4.741	12798	1.625	6867
Oct-92	11.681	23131	2.392	6671	16.525	43865	64.630	144042	4.707	5219	72.676	110863	4.625	12919	1.667	6949
Nov-92	11.783	23134	2.244	6679	17.327	44659	64.820	145449	4.842	5229	70.185	111045	4.088	12973	1.720	6845
Dec-92	11.119	23136	2.259	6688	16.835	43652	63.680	146424	4.783	5297	67.800	111147	4.902	13020	1.705	6849
Jan-93	11.416	23136	2.223	6703	15.348	44098	62.080	146644	4.687	5321	66.173	111222	4.517	13129	1.711	6651
Feb-93	11.914	23136	2.234	6719	16.373	44644	62.640	147255	4.909	5402	67.538	111353	4.821	13281	1.768	6679
Mar-93	12.874	23164	2.230	6724	15.428	44773	65.680	147424	5.015	5469	68.646	111651	4.154	13266	1.826	6713
Apr-93	12.670	23164	2.537	6738	17.225	44949	72.720	148026	5.637	5486	77.384	111800	4.582	13265	1.698	6699
May-93	12.868	23172	2.817	6757	18.944	45584	87.810	148478	6.044	5488	88.836	111831	5.942	13308	1.752	6741
Jun-93	13.637	23224	3.012	6771	24.252	45509	89.620	149606	6.021	5508	83.044	112056	6.984	13409	1.874	6740
Jul-93	13.968	23251	2.436	6778	20.162	46075	80.280	149742	6.089	5529	76.302	112208	5.796	13490	1.812	6776
Aug-93	14.010	23245	3.009	6787	19.343	49330	83.310	150829	6.364	5586	85.039	112322	6.123	13544	1.791	6799
Sep-93	12.923	23319	2.455	6808	22.581	45783	74.730	151617	5.393	5629	76.287	112391	5.898	13526	1.690	6834
Oct-93	12.419	23319	2.536	6817	20.111	45796	68.430	151666	5.367	5642	76.668	112539	5.428	13545	1.653	6821
Nov-93	11.860	23343	2.397	6826	18.466	45932	65.010	152401	5.291	5690	73.873	112850	5.420	13644	1.580	6645
Dec-93	11.194	23358	2.843	6848	17.707	45732	64.560	152320	5.106	5761	73.362	113015	5.235	13861	1.526	6684
Jan-94	11.171	23373	1.964	6857	16.727	46346	63.340	152732	4.999	5796	68.166	113170	4.488	13751	1.549	6704
Feb-94	12.032	23302	2.420	6863	18.518	46052	64.830	153208	5.047	5846	69.485	113467	4.726	13773	1.614	6736
Mar-94	13.458	23378	2.710	6876	17.172	46323	74.340	152945	5.474	5909	77.689	113760	4.417	13864	1.698	6746
Apr-94	13.597	23385	3.400	6887	20.174	46280	78.640	154005	6.481	5915	87.426	113905	5.647	13915	1.714	6755
May-94	12.932	23409	3.445	6895	19.925	47234	83.950	154627	5.986	5967	86.642	114116	5.589	13960	1.739	6783
Jun-94	12.760	23333	2.543	6910	23.605	46773	72.850	155623	5.935	6051	77.425	114323	6.276	14036	1.650	6758
Jul-94	13.323	23447	2.509	6924	18.392	47033	74.520	155505	6.245	6089	80.608	114533	5.227	14123	1.656	6764
Aug-94	12.552	23464	2.220	6936	17.862	49929	74.890	156223	5.698	6142	77.018	114748	5.325	14460	1.697	6800
Sep-94	12.393	23472	2.293	6956	20.709	47889	74.320	156074	4.869	6197	71.986	114918	5.172	14363	1.688	6805
Oct-94	11.790	23492	2.185	6969	18.127	47360	68.020	155798	5.380	6226	73.120	115089	4.346	14345	1.672	6784
Nov-94	11.500	23495	2.180	6972	18.902	47447	65.490	155559	5.455	6253	74.499	115322	5.115	14385	1.720	6812
Dec-94	11.271	23515	1.924	6983	19.143	47850	62.570	155945	5.047	6305	68.112	115473	4.764	14481	1.650	6779
Jan-95	11.506	23529	1.773	6993	18.020	48294	62.470	156682	5.278	6344	66.690	115540	4.341	14539	1.567	6739
Feb-95	12.296	23542	1.868	7001	18.213	47789	65.480	157045	5.497	6385	69.840	115662	4.729	14605	1.633	6699
Mar-95	13.019	23545	2.031	7013	16.748	47976	69.940	157556	5.987	6439	76.510	115766	4.805	14641	1.660	6659
Apr-95	12.723	23558	2.494	7019	19.813	47976	77.370	158066	6.432	6461	83.940	116021	5.992	14695	1.667	6771
May-95	13.013	23562	3.222	7035	19.721	48908	91.370	159291	6.774	6485	92.860	116158	6.692	14772	1.663	6670
Jun-95	12.787	23561	2.633	7044	23.350	48752	80.460	159254	6.542	6503	86.090	116369	7.716	14807	1.591	6660
Jul-95	13.052	23571	2.494	7088	21.332	48798	84.480	159621	6.984	6523	86.240	116467	8.020	14883	1.705	6654
Aug-95	12.645	23563	2.232	7108	19.663	51850	81.030	160530	6.746	6567	80.930	116760	5.222	14951	1.652	6672
Sep-95	11.797	23574	2.330	7118	21.757	48947	75.020	160050	6.474	6626	80.150	116796	6.255	15010	1.628	6689

Appendix. (Continued) Amounts of water treated and number of metered connections at selected municipal water-treatment plants/service areas, 1992-2007.

(Mgal/d, million gallons per day; conn, number of active metered connections; ERC, equivalent metered connections; Daytona Beach, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (NE, NW service areas); STA, City of St. Augustine]

Month-year	Daytona Beach		Eustis		GRU		JEA		OCU (south)		OUC		SCU (NE, NW)		STA	
	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	ERC	Mgal/d	conn
Oct-95	11.745	23591	2.182	7128	19.753	48900	73.310	161061	6.260	6643	74.050	116961	5.727	15030	1.817	6676
Nov-95	11.800	23595	2.348	7141	19.362	48775	71.390	161108	5.891	6667	78.280	117222	5.942	15075	1.738	6689
Dec-95	11.439	23604	2.230	7150	17.703	49070	69.050	162745	6.061	6713	76.490	117259	6.203	15124	1.602	6678
Jan-96	11.348	23609	2.102	7171	18.005	49484	70.150	163508	5.603	6759	72.930	117404	5.473	15202	1.670	6705
Feb-96	12.521	23638	2.343	7185	17.969	49002	74.740	164170	6.001	6817	77.910	117646	5.741	15241	1.749	6703
Mar-96	13.019	23642	2.194	7195	18.012	49192	71.480	164557	6.129	6850	74.380	117857	5.912	15323	1.725	6701
Apr-96	12.673	23569	2.572	7212	18.864	49280	82.360	164941	7.281	6848	84.290	118083	5.443	15403	1.746	6712
May-96	13.045	23676	2.969	7220	21.949	50191	94.880	165763	7.433	6930	91.430	118283	8.350	15505	1.815	6729
Jun-96	12.717	23868	2.509	7234	24.708	49952	84.320	166484	6.760	7002	79.810	118448	7.688	15622	1.701	6742
Jul-96	14.145	23714	2.658	7251	19.954	50756	90.810	167467	7.643	7051	88.530	118663	5.043	15634	1.815	6754
Aug-96	12.897	23720	2.643	7264	21.181	53224	87.700	167920	7.904	7164	87.890	118841	7.244	15701	1.780	6777
Sep-96	12.090	23729	2.433	7270	21.825	50388	85.610	167898	6.870	7218	84.200	119037	7.586	15716	1.770	6793
Oct-96	11.742	23742	2.435	7284	20.420	50609	77.470	168736	6.864	7288	81.900	119215	6.130	15808	1.717	6792
Nov-96	11.523	23755	2.523	7293	20.358	50474	77.560	166989	7.076	7355	83.940	119433	7.042	15875	1.758	6805
Dec-96	11.255	23769	2.289	7301	19.457	51033	72.580	169379	6.564	8253	76.790	119610	6.447	16204	1.676	6812
Jan-97	11.510	23766	2.362	7318	19.172	51302	71.880	168757	7.578	9238	77.240	119686	5.884	16231	1.710	6832
Feb-97	12.404	23762	2.408	7324	18.745	50974	71.680	170084	7.349	9338	78.340	119909	6.566	16266	1.760	6858
Mar-97	13.345	23769	2.774	7336	18.279	51124	79.560	169809	7.734	9474	83.900	120117	6.216	16296	1.870	6876
Apr-97	12.847	23792	2.655	7353	19.327	51246	82.070	171309	7.996	9555	81.120	120497	6.687	16355	1.867	6879
May-97	12.619	23775	2.854	7359	19.592	51758	84.960	171311	8.071	9653	83.760	120620	6.368	16440	1.830	6915
Jun-97	12.507	23778	2.448	7366	21.356	51693	79.030	171926	7.782	9739	73.780	120980	7.685	16504	1.770	6914
Jul-97	13.300	23785	2.648	7385	19.988	52228	85.840	172375	8.014	9810	75.570	121179	7.097	16625	1.946	6931
Aug-97	12.861	23787	2.640	7403	19.185	54646	81.160	172773	7.626	9916	73.620	121261	6.385	16685	1.910	6973
Sep-97	12.517	23805	2.801	7413	23.922	51788	87.970	173388	7.712	10006	75.250	121324	7.357	16728	1.970	6999
Oct-97	12.345	23830	2.693	7463	25.163	51834	79.520	173903	8.720	10058	85.860	121560	8.134	16780	1.900	7023
Nov-97	11.783	23833	2.399	7477	20.717	51706	77.560	173586	8.200	10109	79.130	121796	6.973	16823	1.840	7021
Dec-97	11.442	23822	2.124	7490	18.944	52263	72.580	173397	7.053	10238	70.640	121860	6.638	16880	1.980	7350
Jan-98	11.661	23828	2.162	7496	18.429	52451	66.120	172002	7.584	10321	70.820	121846	5.233	16907	1.869	7341
Feb-98	12.196	23835	2.139	7501	18.613	52115	63.970	173673	7.427	10400	70.750	122068	5.601	17154	1.899	7338
Mar-98	12.719	24532	2.393	7508	16.290	52340	69.450	174558	8.128	10495	77.390	122107	4.874	17243	1.955	7329
Apr-98	13.717	23849	3.386	7521	21.462	52467	85.040	175793	10.187	10561	93.080	122551	6.744	17306	2.067	7353
May-98	13.958	23860	3.737	7529	24.328	53161	96.920	177049	10.654	10586	99.590	119184	8.736	17346	2.095	7378
Jun-98	15.053	23887	4.195	7538	30.901	53332	112.390	178764	12.498	10686	114.130	115816	13.196	17834	2.189	7081
Jul-98	13.455	23889	3.055	7550	27.085	53769	92.030	178727	11.257	10758	98.650	116071	11.778	17916	2.000	7104
Aug-98	12.913	23897	3.042	7555	20.055	56862	81.460	178817	10.689	10887	93.170	116244	8.649	17975	1.864	7133
Sep-98	12.623	23942	2.590	7563	23.020	53570	79.510	178922	9.064	11020	83.110	116095	8.880	18042	1.857	7155
Oct-98	13.026	23932	2.864	7574	20.491	53546	79.380	180507	9.705	11021	90.630	116835	7.734	18174	1.797	7168
Nov-98	12.537	23943	2.928	7581	23.791	53611	79.960	180417	9.759	11058	88.180	116955	9.571	18216	1.767	7177
Dec-98	11.758	23997	2.787	7594	22.957	54209	74.120	180924	9.249	11199	86.340	117223	9.888	18381	1.709	7176
Jan-99	11.823	24016	1.765	7601	20.783	54408	75.920	181299	8.473	11227	82.220	117373	8.128	18597	1.750	7192
Feb-99	12.929	24042	2.687	7615	20.015	54216	75.720	182335	8.858	11388	85.370	117648	8.253	18580	1.890	7220
Mar-99	13.648	24073	3.211	7639	19.610	54475	86.700	182271	11.002	11485	94.790	117806	8.278	18701	2.020	7222
Apr-99	14.040	24086	3.682	7646	25.463	54650	92.640	183326	13.095	11525	105.310	118147	10.863	18812	2.080	7234
May-99	13.032	24108	2.949	7658	25.100	55305	98.490	184093	10.418	11582	96.940	118342	10.528	18919	1.980	7262
Jun-99	13.290	24116	2.615	7668	25.737	55649	90.940	185855	10.160	11666	91.040	118352	10.315	19016	1.990	7250

Appendix. (Continued) Amounts of water treated and number of metered connections at selected municipal water-treatment plants/service areas, 1992-2007.

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Month-year	Daytona Beach		Eustis		GRU		JEA		OCU (south)		OUC		SCU (NE, NW)		STA	
	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	ERC	Mgal/d	conn
Jul-99	13.974	24140	2.776	7678	22.148	55765	94.350	186128	10.655	11809	96.240	118827	7.420	19116	2.200	7271
Aug-99	13.781	24149	3.001	7694	22.643	59449	94.060	189002	11.288	11942	101.340	118892	12.001	19214	2.260	7330
Sep-99	12.810	24178	2.644	7708	24.964	55568	87.800	189626	10.280	12035	91.880	118916	11.838	19299	2.150	7347
Oct-99	12.590	24178	2.408	7721	22.003	55553	85.440	188466	10.176	12086	85.540	118807	7.700	19421	2.100	7381
Nov-99	12.307	24191	2.612	7735	22.001	55750	84.910	189509	10.407	12138	89.070	119125	8.600	19543	2.010	7429
Dec-99	12.084	24191	2.520	7750	22.525	56710	82.380	190349	9.398	12352	85.870	119460	8.523	19664	1.920	7504
Jan-00	13.347	24191	2.539	7765	20.888	56504	77.920	190280	9.818	12374	86.142	119499	9.900	19786	1.980	7539
Feb-00	12.983	24191	2.656	7770	21.154	56328	81.370	190902	10.771	12495	90.332	119437	8.181	19935	2.020	7608
Mar-00	13.874	24245	3.146	7780	21.856	56487	88.140	191873	11.957	12571	99.558	120029	9.672	20223	2.170	7669
Apr-00	13.409	24245	3.250	7789	24.506	56615	96.470	192176	13.066	12652	104.111	120208	11.377	20648	2.120	7766
May-00	14.213	24245	3.978	7808	25.717	57600	115.610	193538	14.952	12743	119.263	120500	10.901	20706	2.160	7861
Jun-00	14.367	24275	3.270	7815	28.272	57648	109.530	194793	15.195	12904	116.269	120836	15.739	20814	2.120	7975
Jul-00	13.903	24171	2.775	7827	21.785	57998	103.520	194673	11.913	12870	100.735	120936	11.617	20857	2.190	8032
Aug-00	13.823	24171	2.968	7842	20.910	61552	103.970	195216	12.093	12987	97.707	121141	10.933	21027	2.160	8135
Sep-00	12.927	24148	2.557	7851	23.532	57998	88.410	196217	11.598	13063	95.200	121063	11.422	21012	2.150	8238
Oct-00	13.003	24148	2.836	7867	22.609	57564	91.340	197284	12.435	13097	100.471	121122	11.586	21107	2.400	8250
Nov-00	12.950	24168	2.895	7875	27.110	57489	91.980	197568	12.407	13186	99.645	121236	10.128	21384	2.390	8296
Dec-00	12.016	24168	2.578	7880	22.898	57720	85.620	198007	10.874	13308	91.458	121457	15.702	21618	2.320	8306
Jan-01	12.374	24623	2.544	7889	22.178	58226	77.840	198614	10.234	13328	83.216	121539	9.328	20435	2.370	8350
Feb-01	13.139	24648	2.472	7900	22.904	57910	78.440	198896	10.504	13472	81.579	121723	12.406	22254	2.460	8426
Mar-01	13.732	24664	2.472	7906	21.483	58065	77.720	199254	10.451	13548	80.955	121882	8.000	22266	2.530	8476
Apr-01	13.670	24679	3.009	7917	20.968	58156	100.210	200166	11.865	13559	89.040	121995	10.333	22278	2.660	8521
May-01	13.816	24693	3.183	7919	24.749	59020	112.120	201523	11.902	13679	92.100	122111	10.483	22059	2.630	8558
Jun-01	13.720	24403	2.625	7934	27.048	58963	95.810	202457	11.016	13813	83.576	122195	11.446	22462	2.560	8600
Jul-01	13.781	24403	2.116	7944	21.466	59622	95.540	203215	9.817	13921	83.027	122094	9.226	22567	2.490	8603
Aug-01	13.694	24432	2.358	7951	20.528	63609	96.200	203157	8.849	13979	84.346	122378	9.700	22916	2.490	8627
Sep-01	13.117	24432	2.154	7959	24.687	59153	77.850	203511	8.272	14152	79.775	122403	9.566	23265	2.000	8642
Oct-01	13.087	24646	1.767	7974	21.981	59418	84.757	203511	10.092	14136	85.409	122425	9.348	23180	2.030	8664
Nov-01	12.817	24693	2.358	7993	23.861	59200	92.427	203511	10.337	14353	81.889	122549	10.035	23189	2.240	8694
Dec-01	12.206	24703	2.370	7997	23.208	59383	80.810	204747	9.666	14436	82.844	122608	10.131	23298	2.280	8715
Jan-02	12.319	24701	2.397	8016	21.468	59654	77.140	204747	8.777	14367	78.683	122805	10.954	23375	2.210	8715
Feb-02	12.804	24745	2.335	8024	20.186	59415	77.030	236409	9.263	14441	78.436	122971	10.253	23451	2.240	8621
Mar-02	13.745	24757	2.675	8047	19.323	59487	85.040	236409	11.371	14495	88.622	123132	9.454	23500	2.050	8641
Apr-02	13.640	24809	2.806	8056	23.032	59720	96.850	237770	12.678	14549	94.067	123285	10.952	23613	2.130	8661
May-02	14.106	24827	3.407	8070	28.036	60747	117.830	239131	15.298	14603	99.673	123421	14.092	23685	2.450	8731
Jun-02	13.697	24827	2.316	8095	27.861	60404	104.350	241705	12.286	14657	84.226	123544	12.504	23779	2.420	8801
Jul-02	13.606	24827	2.102	8107	22.010	61462	107.040	242479	11.452	14707	81.489	123659	8.567	23622	2.630	8877
Aug-02	13.126	24833	2.180	8123	19.850	64289	104.090	242817	11.579	14717	80.578	123798	8.558	24031	2.390	8481
Sep-02	13.323	24825	2.271	8172	22.378	60345	101.150	243549	10.194	14919	79.301	123894	8.551	24161	2.330	8468
Oct-02	13.413	24863	2.774	8208	22.640	60300	102.660	239627	12.517	14873	86.886	123981	9.854	24177	2.500	8473
Nov-02	12.907	24879	2.640	8233	20.564	59910	98.560	239627	11.704	14982	80.515	124159	12.716	24333	2.460	8477
Dec-02	12.006	24904	2.328	8251	21.084	60164	91.010	245588	10.061	15078	76.166	124199	10.051	24325	2.290	8450
Jan-03	12.519	24914	2.548	8273	19.001	60423	95.030	245772	10.074	15074	77.625	124494	9.759	24449	2.510	8476
Feb-03	13.082	24909	2.328	8290	20.451	60093	81.560	246759	10.458	15179	78.741	124629	10.122	24508	2.520	8502
Mar-03	13.242	24924	2.413	8314	19.496	60278	84.350	247171	11.062	15323	77.734	124849	7.556	24544	2.500	8592

Appendix. (Continued) Amounts of water treated and number of metered connections at selected municipal water-treatment plants/service areas, 1992-2007.

(Mgal/d, million gallons per day; conn, number of active metered connections; ERC, equivalent metered connections; Daytona Beach, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (NE, NW service areas); STA, City of St. Augustine]

Month-year	Daytona Beach		Eustis		GRU		JEA		OCU (south)		OUC		SCU (NE, NW)		STA	
	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	ERC	Mgal/d	conn
Apr-03	13.477	24964	3.302	8323	20.619	60553	109.760	247893	13.118	15227	89.970	125054	9.844	24596	2.420	8598
May-03	13.890	24979	3.493	8349	23.373	61124	122.400	249511	14.290	15261	96.216	125266	12.000	24793	2.490	8610
Jun-03	13.443	24987	2.553	8368	25.088	61254	110.040	249485	13.129	15427	86.326	125497	11.491	24990	2.340	8619
Jul-03	13.797	24996	2.511	8386	21.749	62139	101.180	249485	13.725	15410	84.845	125817	10.588	25104	2.420	8620
Aug-03	12.881	25001	2.163	8424	21.351	64806	104.330	249485	11.943	15495	78.576	126095	9.101	25309	2.460	8724
Sep-03	12.583	25007	2.532	8453	21.454	61141	116.200	252613	11.794	15639	81.394	126325	9.673	25723	2.790	8755
Oct-03	12.145	25000	2.511	8474	23.300	61368	99.170	253803	13.261	15590	82.452	126902	9.338	25616	2.509	8771
Nov-03	12.353	25029	2.445	8487	22.985	61167	102.480	261048	12.690	15773	76.912	127049	10.058	25660	2.480	8808
Dec-03	11.958	25040	2.473	8503	21.626	61824	98.270	261542	12.346	15713	70.420	127246	10.494	25731	2.460	8822
Jan-04	12.281	25062	2.493	8516	21.059	62165	97.750	263029	12.686	15695	77.452	127940	9.976	25771	2.640	8822
Feb-04	12.600	25075	2.330	8528	20.423	62116	88.450	263932	12.604	15822	75.807	128441	8.592	25778	2.760	8895
Mar-04	13.529	25104	2.768	8535	18.652	62261	114.240	264054	14.264	15886	84.491	128722	8.852	26425	2.990	8936
Apr-04	13.640	25104	3.153	8554	24.853	62322	131.430	265093	15.903	15855	91.740	129203	12.408	26321	2.770	8884
May-04	13.861	25135	3.417	8569	24.217	62926	141.010	267293	15.706	15926	96.438	129523	11.059	23169	2.620	8923
Jun-04	13.663	25153	2.913	8590	28.624	63619	123.790	268392	16.590	15981	90.338	129859	13.752	26419	2.860	8962
Jul-04	14.135	25168	2.801	8609	23.856	63981	121.160	270079	16.184	16103	90.397	130285	11.421	26690	2.980	8980
Aug-04	12.887	25168	2.458	8652	22.859	67056	94.640	270965	13.938	16067	82.570	130092	9.485	26895	2.620	8967
Sep-04	11.757	25200	2.294	8668	23.079	63016	75.690	271852	11.904	15868	75.161	130461	8.390	26432	2.550	9045
Oct-04	12.735	25227	2.488	8705	19.571	63299	114.360	271852	14.483	15669	86.597	130644	8.658	26659	2.500	9010
Nov-04	12.884	25256	2.643	8729	21.519	63350	118.470	273431	14.943	15469	87.538	130795	10.056	26737	2.570	9046
Dec-04	12.158	25255	2.568	8778	21.260	63589	115.020	274504	14.098	15779	83.505	131230	11.561	27414	2.330	9149
Jan-05	12.271	25287	2.565	8804	20.253	63920	106.730	275695	13.848	15898	82.233	131688	9.725	27463	2.440	9257
Feb-05	12.696	25325	2.711	8831	21.712	63748	105.990	276540	14.699	15948	86.725	132165	9.750	26527	2.460	9284
Mar-05	13.026	25352	2.501	8867	19.405	64085	105.370	277704	14.201	16162	83.802	132555	10.331	27859	2.540	9310
Apr-05	12.880	25397	3.063	8886	20.043	63929	115.010	278739	15.455	16167	92.306	132981	10.877	27258	2.480	9290
May-05	12.932	25436	3.027	8924	20.105	64756	127.510	280161	16.151	16212	94.380	133347	9.612	26846	2.500	9369
Jun-05	12.873	25450	2.401	8958	23.623	65085	121.070	281608	14.068	16291	83.284	133611	12.279	28194	2.470	9366
Jul-05	13.703	25484	2.588	8989	20.959	65606	118.280	282740	16.018	16281	87.556	134118	8.910	27961	2.540	9411
Aug-05	13.200	25515	1.840	9015	20.677	69069	121.640	283286	15.258	16274	88.977	134429	10.274	27414	2.720	9459
Sep-05	12.747	25511	2.611	9043	24.130	65005	107.220	284629	14.912	16283	87.316	134706	12.484	28271	2.670	9542
Oct-05	12.394	25595	2.489	9083	23.228	64969	114.730	286422	14.968	16292	83.456	134800	8.877	28667	2.520	9607
Nov-05	12.700	25595	2.800	9098	21.944	65090	117.360	287133	14.826	16308	85.484	134999	10.945	28696	2.540	9619
Dec-05	11.574	25654	2.376	9133	23.367	65403	104.830	288509	13.982	16341	79.974	135066	10.758	28779	2.490	9635
Jan-06	12.258	25693	2.657	9158	19.974	65874	106.940	289470	14.743	16310	83.283	135169	10.904	28885	2.810	9662
Feb-06	12.586	25675	2.632	9197	20.085	63211	104.990	290470	14.604	16350	82.520	135388	11.428	29429	2.790	9763
Mar-06	13.445	25529	3.415	9216	19.471	68285	121.320	293031	16.986	16433	92.965	135711	14.156	29417	3.000	9806
Apr-06	13.967	25255	3.735	9345	22.776	65792	140.320	294449	18.645	16436	100.576	135979	14.809	29641	3.390	9825
May-06	13.968	25274	3.940	9384	22.816	66624	153.910	295539	18.770	16454	100.028	136127	13.939	29753	3.600	9843
Jun-06	13.853	25287	3.403	9414	25.905	66809	139.540	296567	17.775	16474	93.286	136306	17.056	29819	3.470	9868
Jul-06	13.877	25365	3.236	9455	25.242	67164	146.530	296567	16.871	16494	90.167	136398	13.003	29899	3.440	9900
Aug-06	13.368	25400	3.335	9476	23.948	70998	145.620	297584	17.150	16514	95.853	136452	14.000	29951	3.530	9946
Sep-06	12.587	25418	3.178	9559	24.491	66641	136.870	298271	14.660	16535	85.947	136698	12.448	30003	3.370	10012
Oct-06	12.917	25430	3.632	9654	23.251	66555	138.600	300340	17.370	16555	95.657	136941	11.799	29591	3.400	10070
Nov-06	12.376	25464	3.304	9697	24.293	66509	125.990	300393	16.026	16575	88.584	137027	14.240	30229	3.430	10085
Dec-06	12.051	25468	2.025	9705	20.943	66635	114.480	301927	14.760	16595	84.436	137361	12.049	30256	3.260	10138

Appendix. (Continued) Amounts of water treated and number of metered connections at selected municipal water-treatment plants/service areas, 1992-2007.

(Mgal/d, million gallons per day; conn, number of active metered connections; ERC, equivalent metered connections; Daytona Beach, City of Daytona Beach; Eustis, City of Eustis; GRU, Gainesville Regional Utilities; JEA, Jacksonville Electric Authority; OCU, Orange County Utilities (southern service area); OUC, Orlando Utilities Commission; SCU, Seminole County Utilities (NE, NW service areas); STA, City of St. Augustine]

Month-year	Daytona Beach		Eustis		GRU		JEA		OCU (south)		OUC		SCU (NE, NW)		STA	
	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	conn	Mgal/d	ERC	Mgal/d	conn
Jan-07	11.563	25488	3.008	9711	23.015	67141	107.427	302032	14.590	16605	82.278	137557	10.784	29478	3.275	10207
Feb-07	11.688	25513	2.950	9735	24.449	67081	111.288	302481	14.609	16615	81.132	137807	11.480	29721	3.323	10213
Mar-07	12.322	26930	3.469	9744	26.904	67265	127.523	303227	16.478	16625	90.209	138259	11.781	30467	3.439	10263
Apr-07	12.646	26988	3.744	9758	30.175	66951	147.234	303734	17.325	16635	93.976	140615	12.466	30462	3.642	10276
May-07	12.720	25608	4.147	9776	31.518	67935	156.137	304162	17.553	16645	99.503	140570	14.947	30484	3.979	10340
Jun-07	12.695	27088	3.628	9784	27.706	69863	137.429	304843	16.582	16655	93.022	140955	15.086	30523	4.085	10384
Jul-07	12.576	25648	3.187	9792	26.874	68847	130.050	305209	15.977	16665	87.386	140780	12.688	30668	3.896	10387
Aug-07	12.860	25662	3.557	9799	27.968	70753	152.903	305727	14.897	16675	96.059	141103		30792	3.679	10432
Sep-07	11.724		3.087	9811	28.009	66898	132.042	306062	14.872	16685	87.445	140899	13.521	30844	3.335	10427
Oct-07	11.569	25721	2.922	9822	25.726	70982	117.253	305492	14.822	16695	84.817	140508	10.369	30839	3.500	10420
Nov-07	11.617	25743	3.352	9832	25.961	67919	124.639	304575	15.691	16705	85.722	140694	12.174	30501	3.499	10477
Dec-07	10.817	25734	3.129	9835	23.312	69193	117.521	304245	15.451	16715	83.442	140773	12.064	30748	3.420	10477

L.C. Murray, Jr. — **Relations between Municipal Water Use and Selected Meteorological Parameters and Drought Indices, East-Central and Northeast Florida** —SIR 2009-5010

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