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ANALYSIS OF RESIDENTIAL DEMAND OF WATER IN THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

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ABSTRACT

Residential demand for publicly supplied water is estimated as a function of average price, family income, number of persons per household, season of the year, use of a private well, and the use of several water-using household appliances. The analysis is based on monthly cross-section data from 986 residential households in selected communities within the multi-county St. Johns River Water Management District in north-east Florida. Multiple regression analysis was applied to a model allowing the intercept and the coefficient for average price, respectively, to shift from one season to another. In this manner seasonal shifts in demand and in the price elasticity of demand attributable to lawn sprinkling were identified. The price elasticity of demand was found to be greater during the season in which lawn sprinkling accounts for a major portion of residential water use.

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CHAPTER I

INTRODUCTION

The Problem for Research

Studies on the structure of demand for water have been prompted nationwide by the realization that water supply systems will be increasingly pressured by depletion of readily available sources of water, by increases in the cost of water supply development, by growth in population, and by environmental objections to water projects not considered to be ecologically sound.

In Florida, water supply problems result from intense urbanization in the relatively water-scarce parts of the state. Of Florida's nine million residents, nearly 75% reside in coastal areas. Many of the state's annual influx of tourists are also attracted to shoreline areas where water supplies are less abundant than inland. The potential for excessive groundwater withdrawals and associated problems of salt water intrusion represent genuine cause for concern in many Florida communities.

The costs associated with further water supply development motivate interest in ways to effectively curb or otherwise manage the demand for water. The need to accurately forecast water demand also becomes increasingly important. These considerations point up the need for systematic analysis of the demand for water in each of several major water demand categories, especially residential demand for water.

Objectives

The objectives of this research are:

(1) to identify variables which explain variations in the rates of water use among residential customers of public water supply utilities in the St. Johns River Water Management District;

(2) to quantify the relationships between those causal variables and rates of use of publicly supplied water by the residential sector; and

(3) to interpret the implications of those interrelationships found to be statistically significant and to compare statistical results from different parts of the District.

Procedures

The St. Johns River Water Management District, in an earlier study, acquired observations from a questionnaire on residential water usage from over 2,000 households throughout the District. From this data a computerized water demand model will be constructed using multiple regression analysis, which will yield coefficients relating each of several major variables to rates of residential water use. The selection of variables for analysis is based upon the published findings of similar water demand studies conducted elsewhere by other researchers.

The model will be presented in several forms to permit exploration of certain variations in design. The general model, for convenience of reference, has been entitled the Water Use Demand Elasticity Model, hereinafter referred to as WUDEM.

Organization of this Report

This chapter identifies the problem setting and the objectives of this research and introduces the procedures. Chapter II expounds upon consumer demand theory and reviews the existing water demand literature. The presentation of the specific model, the estimation procedures, and the sampling design are included in Chapter III. Chapter IV analyzes the statistical results and Chapter V discusses the implications of those results for residential water management.

CHAPTER II

THEORY AND LITERATURE REVIEW

This chapter will provide a discussion of the theoretical basis of the procedures employed to measure the demand for residential water. It will also include an exposition of traditional water demand studies, water conservation studies, and studies on forecasting water demands of the residential sector. These analyses will be discussed from the view of how they contribute to an understanding of the structure of water demand, and how research could be improved to provide a more complete understanding of the residential demands of water.

Concepts of Demand

Within the expression "water use demand elasticity model" are embedded a number of economic concepts which require elucidation. In so doing, the following will provide the theoretical basis for the WUDEM model.

The term "model" refers in this case to a statistical relationship between the quantity of water demanded by households and the factors which account for variation in quantity demanded. Prior to gathering data for analysis, the model was "specified," that is, factors hypothesized to affect residential water use were identified and defined as explanatory variables. This process of model specification was facilitated by consultation with previous water demand studies. The empirical data required to test the hypothesis was then collected.

The general term "water demand" can be applied to two distinctly different approaches, the water requirements approach, and the economic demand for water approach. The former describes the traditional approach to the assessment of water demands. In this case "demands" are set by the historical patterns of use. These patterns or needs are accepted as given and are not viewed as being dependent on factors which may, in fact, determine their magnitude. All needs are considered to be of equal priority and thus worthy of fulfillment. The economic concept of demand, on the other hand, analyzes the factors which determine the amount of water demanded. These factors may exert a positive influence on demand, i.e., their presence may increase the quantity of water demanded; or they may exert a negative influence, thereby acting as a deterrent to water use. For example, water demand studies have shown that the quantity of residential water demanded is positively influenced by income, family size, and lawn watering practices. Also it is negatively influenced by price, an increase in which serves to discourage the consumption of residential water.

The water requirements approach does not yield this kind of useful information. Its models either exclude price as a variable (which implies an assumption that no relationship exists between water quantity and price) or it treats price as a constant. The recent history of rate structures nationwide and within the rapidly growing areas of the District should dispel this latter assumption. As for the former assumption, water demand studies have shown that the price elasticities for residential water are not zero.

The economic concept of demand begins with indifference curve analysis which represents the household's consumption choice process. Two assumptions about the consumer, or head of household, underlie this decision process: 1) his objective is to maximize his subjectively perceived satisfaction or "utility" by adjusting the level and mix of goods and services which he consumes, 2) his consumption patterns will be influenced, not only by his personal preferences for consumer goods and services, but also by the relative prices of goods and services, which, given his income, affect his purchasing power.

These assumptions are summarized in a utility function, $U = f(Q_1, Q_2)$, where U indicates a given utility level and Q_1 and Q_2 are commodities (this is a simple, two-good case). From this function is drawn the indifference curve, $U^{\circ} = f(Q_1, Q_2)$, which yields all Q_1, Q_2 quantity combinations from which the consumer receives the same level of utility. If asked to choose from among the quantity combinations along this curve, the consumer would express indifference.

The slope of the indifference curve, which is equal to $-\frac{dQ_2}{dQ_1} = -\frac{dU/dQ_1}{dU/dQ_2}$, represents an important assumption of demand theory. It is assumed that as more of a commodity is consumed, its utility (the satisfaction derived from successive increments) diminishes. This principle of diminishing marginal utility suggests that it is the valuation that a consumer places on the marginal unit of a commodity that determines the consumer's valuation of a good. The basic notion of diminishing marginal utility appears to be common sense: the consumer tires of a commodity or becomes satiated as he acquires more and more of it. Thus the marginal utility of it, in this case represented by $\frac{dU}{dQ_1}$ and $\frac{dU}{dQ_2}$, diminishes and accounts for the negative slope of the indifference curve. This slope is uniformly referred to as the marginal rate of substitution between two commodities.

The indifference map, a series of indifference curves, records sets of Q_1, Q_2 combinations which represent varying levels of utility. On the indifference map successive indifference curves to the northeast represent successively higher levels of utility, achieved by generally higher rates of consumption of Q_1 and/or Q_2. For example, in Figure 2-1, A, point (a) may represent $3Q_1$ and $2Q_2$ while point (b) may represent $7Q_1$ and $40Q_2$.

In theory, each consumer has an indifference map for any combination of commodities he wishes to purchase. He also has an income constraint which limits where on that map he can consume (this precludes deficit spending). Mathematically, the income constraint in our two-good example is represented by $Y° = (P_1Q_1 + P_2Q_2)$ where $Y°$ is given income level and P_1 and P_2 are the prices of Q_1 and Q_2 respectively. It is assumed that all income is spent on those two commodities. The consumer maximizes his utility function subject to his income constraint:

$$V = f(Q_1, Q_2) + g(Y° - P_1Q_1 - P_2Q_2).$$

His equilibrium, or maximization, point is reached when the marginal utilities for the goods, Q_1 and Q_2, are equal (at a in Figure 2-1, A). The solutions for Q_1 and Q_2 require fulfilling the following first-order conditions:

$$\frac{dV}{dQ_1} = f_1 - gP_1 = 0$$

$$\frac{dV}{dQ_2} = f_2 - gP_2 = 0$$

$$\frac{dV}{dg} = Y° - P_1Q_1 - P_2Q_2 = 0, \text{ where } f_1 = \frac{dU}{dQ_1} \text{ and } f_2 = \frac{dU}{dQ_2}.$$

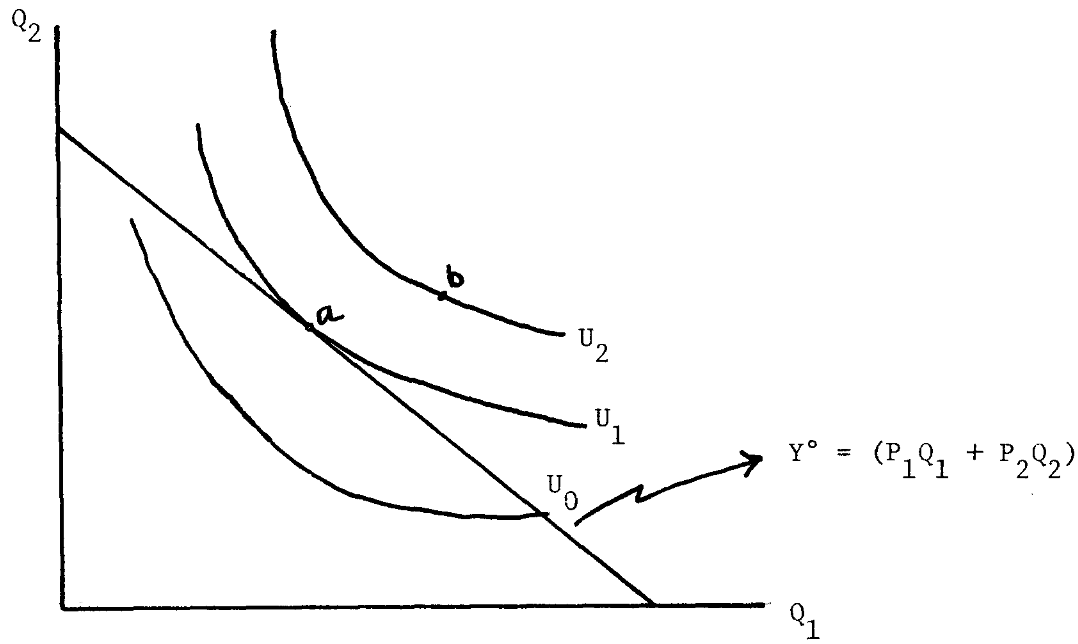

Figure 2-1 (A): Indifference curve map.

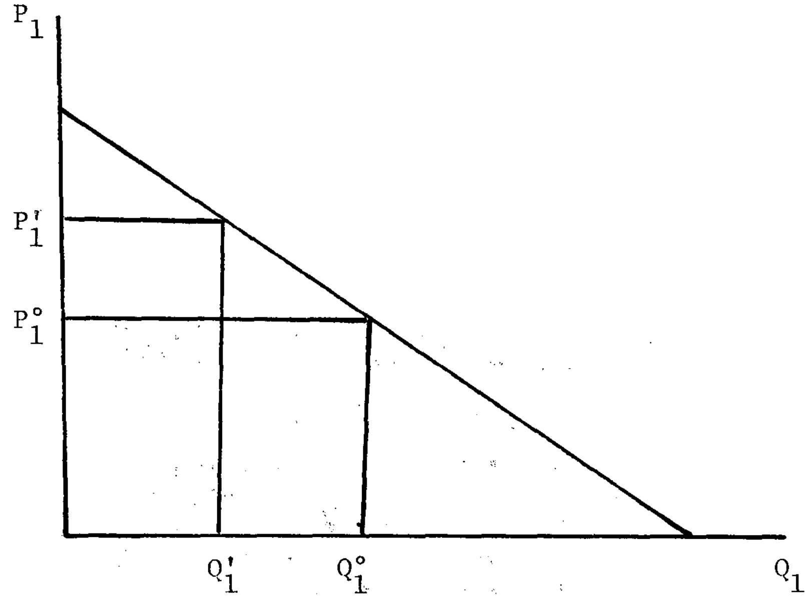

Figure 2-1 (B): Demand curve.

Second order conditions require that $[\frac{d^2V}{dq_1^2}]$ be positive at the equilibrium point; this ensures the convexity of the indifference curves. At equilibrium the ratio of marginal utilities to the prices of the commodities will be equal: $\frac{f_1}{P_1} = \frac{f_2}{P_2}$.

Demand analysis is most interested in the information supplied by the demand function which is derived from the utility maximizing process just described. Solving the previous system for Q_1 and Q_2 yields their demand functions:

$Q_1 = \frac{Y°}{2P_1}$ and $Q_2 = \frac{Y°}{2P_2}$. Other things being equal, when a consumer's income and the prices of the commodities are known, quantities of the goods which the consumer will consume can be determined from the demand function.

Demand functions (Figure 2-1, B) for any commodity are single valued functions of the independent variables. In this simple exposition the independent variables are price and income. When specifying a model for an empirical problem, the number of independent or explanatory variables is usually more numerous because demands for real world goods or resources normally have a more complex set of determining factors. In the initial WUDEM model, price and income are accompanied by 24 other variables.

The concept of price elasticities of demand is used extensively in water demand analysis. The price elasticity of demand is defined as the proportionate rate of change in the quantity demanded of a good (Q_1) divided by the proportionate rate of change in the price of the good (P_1) holding P_2 and Y° constant. Mathematically we have:

$e_{Q_1} = \frac{d(\log Q_1)}{d(\log P_1)} = \frac{P_1}{Q_1}\frac{(dQ_1)}{(dP_1)}$. Along a normal (downward sloping) demand curve, the elasticity will be negative. The demand curve is considered elastic in that region where $e_{Q_1} < -1$, inelastic in that region where $e_{Q_1} > -1$, and of unitary elasticity where $e_{Q_1} = -1$. At unitary elasticity the price, and subsequent quantity, change are of identical proportional magnitudes. Within the inelastic region price increases proportionally more than quantity decreases, and within the elastic region, price increases proportionally less than quantity decreases. Price elasticities of demand are not necessarily constant when treating empirical data.

The income elasticity of demand is defined as the proportionate change in quantity demanded of a good divided by the proportionate change in income holding prices constant. Mathematically we have:

$N_{Q_1} = \frac{d(\log Q_1)}{d(\log Y)} = \frac{Y}{Q_1} [\frac{dh(P_1,P_2,Y)}{dY}]$. If the good Q_1 is "normal" the N_{Q_1} will be positive indicating that an increase in income precipitates increased purchases of Q_1. If the good Q_1 is "inferior" the N_{Q_1} will be negative indicating that an increase in income precipitates a decreased demand for Q_1.

Price and income elasticities of demand for water have always been of interest because they are usually easily calculated and expected to be useful for forecasting. This is due, as we shall see, to income being historically one of the two major statistical determinants of domestic water demand use.

Price elasticities reported in cross-sectional nationwide and regional residential water studies have not been uniform. Although the price effect differs among studies, the evidence strongly suggests that price acts as an incentive to conserve water.

In cross-sectional studies price elasticities are normally evaluated at their means. At this point it usually denotes an inelastic response, e.g., an elasticity computed to be -0.63 indicates that for a 10% increase in price there is approximately a 6% decrease in water quantity demanded. It is often interesting to note at what price the response becomes elastic. Because residential water is usually priced very low it is common for this to occur at over a 50% increase in the current price.

Traditional Studies in Water Demand Analysis

The traditional approach to calculating water demand is the requirements approach. This approach assumes that all water needs of the residential sector, established through time, must be anticipated and satisfied by the water supplier. This method of calculating water demand directs that projected demands be based on the current water use patterns of the residential sector with no consideration given to use of potential disincentives such as the water price. Current use patterns are determined from population forecasts with average gallon per capita daily (GPCD) figures obtained from meter records. The total average use figure which results is applied to peak-to-average ratios to account for the additional demand caused by daily peak hours and by seasonal peaks, which usually occur during the summer months.

This approach assumes that over a projected period the GPCD would remain constant, i.e., that the technical and economic behavioral characteristics of the population which determine water use patterns would remain constant. As evidenced in the 1960's for most U. S. urban areas the GPCD had increased substantially over time and concern for adequate water reserves became a prodigious problem.

In 1964, the U.S. Federal Housing Administration commissioned the Johns Hopkins University Report on residential water demand to ascertain the major parameters influencing the level of demand. The study by F. Linaweaver, J. Geyer and J. Wolff, was a cross-sectional analysis using three years of data which covered both metered and flat rate pricing systems, and varying climatic conditions.[1] Through the isolation of socioeconomic factors, it was hoped that correlations between residential water demand and these hypothesized influences would assist in forecasting future water demands.[2]

The Linaweaver, Geyer, and Wolff study concluded that at the household level the market value of the home had the most significant correlation with water use level, i.e., this variable explained most of the statistical variation in the quantity of water demanded. This is presumably due to the high correlation between property value and the

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[1]Linaweaver, F.P., Geyer, J.C., and Wolff, J.B., Final Summary Report on the Residential Water Use Research Project, Department of Environmental Engineering Science, Johns Hopkins University, July, 1966.

[2]Total residential demand for water is comprised of domestic and sprinkling demand. Domestic, or in-house, use is comprised of kitchen, bathroom, laundry, etc. Sprinkling consists of lawn and shrubbery watering. Car washing is usually in the latter category. Some authors use the term "winter or summer" use. This refers to domestic use which comprises total use during the winter months. During the summer, total residential use is comprised of both domestic and sprinkling demands. Average per period use during the previous winter season is subtracted, on a year by year basis, from each peak summer observation. Appropriate adjustments are made to equalize the number of days in different periods where this is required. See Linaweaver, F., Geyer, J., and Wolff, J., op. cit., and Danielson, L., Estimation of Residential Water Demand, Economics Research Report No. 39, North Carolina State University, October, 1977.

presence of water using appliances and outdoor land area, each of which, in turn, would probably account for higher rates of water use. The study further concluded that apartment dwellings account for a lower mean annual domestic use, due to their usual lower density per household. It concluded that the sprinkling demand for water is primarily a function of climate: negatively correlated with precipitation and positively correlated with temperature, and a function of the types of pricing systems. Given similar climatic conditions, sprinkling demand for water was reduced in areas where the pricing system was metered as compared to sprinkling demand in areas where a flat rate was charged for water. This would imply that the price of water for residential irrigation does affect its use level.

On the other hand, the price of water for domestic, i.e., in-house, uses was reported to have little, if any, effect on use levels because no difference between metered and flat rate consumption during the winter season was discerned.

Actual price elasticities were not calculated until 1967 when C. Howe and F. Linaweaver pursued this effort with a cross-sectional analysis of U. S. households, again with varying pricing schemes and climates.[3] The variables which they found to be the major determinants of residential water use were the market value of the home, the age of the home, household size, average water pressure (psi), climate, and the price of water.

The variables included in this study and not previously discussed are the age of the home, household size, and the average water pressure. The

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[3]Howe, C. W. and Linaweaver, F. P., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, Vol. 3, No. 1, First Quarter, 1967.

age of the home is expected to be indicative of the condition of the plumbing network. The older a home the more leaky pipes it may have and consequently, the more water it will consume. A high water pressure level is expected to lead to more water used assuming that household members do not counter the propensity to use more by decreasing the time allotted to a water using activity. Household size is expected to influence water use because more persons obviously will require more water.

The performance of the price variable was of prime importance because there had been much controversy concerning its potential as a deterrent to water use. The study concluded that the national average domestic demands were inelastic, with elasticities ranging from -.23 for regular use periods to -.68 for peak use periods. Average irrigation demands were more elastic, ranging from -.7 in dry western states to -1.6 in eastern states. This difference in elasticity between the western states and the eastern states was not unexpected since sprinkling water should be regarded as more valuable in arid areas than in humid areas. It was concluded that, while the price elasticity of demand for water is not zero, the negative relationship between water use and price is not strong. It appears that water used inside the home is far less expendable than irrigation water, but that in either case, at least small amounts of water can be foregone when the price is increased.

Steve Hanke explored the demand response to price changes represented by a pricing system change from flat rates to metered water charges.[4] With the metered water charge the water bill received by residential customers

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[4] Hanke, S. H., "Demand for Water Under Dynamic Conditions," Water Resources Research, Vol. 6, No. 5, October 1970.

is based on the quantity of water that they use.

Hanke tested the hypothesis that price has a negative effect on the water use level in a continuous time-series study of consumption data in Boulder, Colorado between the years 1955-1968. Flat rate pricing took place in the years 1955-1961; in 1962 meters were installed and a rate of $.35/1,000 gallons was initiated.

The variables expected to affect outdoor water consumption, besides price, were the size of outdoor land area, temperature, precipitation, and percentage of daylight hours. Hanke was interested in determining if there was a decrease after 1962 in the sprinkling levels of residents. He was able to verify that, in this case, the institution of metered water charges influenced demand since sprinkling decreased substantially from 1962-1968 when compared with the previous period. Average domestic demand decreased 36 percent after 1962 and, as with sprinkling demands, did not begin to increase after the initial period.

Calculated price elasticities were considerably higher than those previously calculated on the basis of cross-sectional studies. Hanke attributes this to the fact that cross-sectional analysis uses price-quantity relations for many price ranges while this study analyzed a one-time change involving a positive incremental charge. Once meters were installed consumers fixed their leaky pipes and perhaps made other one-time alterations.

Hanke concluded that the price elasticity of demand for water is not zero, and that a price increase can be viewed as a potential deterrent to residential water use.

The influence of income on water consumed also received attention in the early analyses of residential water demand. In the Johns Hopkins

Report (1966) and in the study by Howe and Linaweaver (1967) income was proxied by property value and income elasticities were calculated from these figures. In the Howe and Linaweaver study income elasticities for domestic water demands yielded a national average of .35. For irrigation demands the income elasticites ranged from .45 for the western states to 1.45 for the eastern states.

J. Headley in 1963 calculated income elasticites directly using income and other data from 14 San Francisco Bay area cities.[5] This was a cross-sectional and time-series analysis of the years 1950-1959.

Variables tested were household income, number of bathrooms per residence, land area, and climate. There was a statistically significant relationship only between household income and water use levels with income elasticities averaging from 1.49 in 1950 to 1.24 in 1959 for all cities. The relationship between income and water use is curvilinear because some maximum use must obviously be reached.

Headley provided a forecasting model based on expected population and income increases, average consumption rates, and variables such as price, climate, level of household water-using technology and income distribution. Headley's relatively comprehensive model produced residential water use forecasts which were well below the official estimates. This comparison was an early example of the potential of the economic demand for water to bring more information into the preparation of water demand forecasts.

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[5] Headley, J. C., "The Relation of Family Income and Use of Water for Residential and Commercial Purposes in the San Francisco-Oakland Metropolitan Area," Land Economics, Vol. 39, No. 4, November, 1963.

Demand studies of the type presented above provided a useful insight into the structure of water demand in the residential sector. The water use determinants of income, property value, household size, and price have been identified. Even though the extent of their influences are not conclusive, the research supplies information required for the more accurate forecasting of residential water demand.

Conservation Water Demand Studies

The forecasting of demand is only the first stage of modern water management. Increasingly concern over the diminishing supplies of fresh potable water has necessitated new information needs. Now research is required to guide policy not only in the forecasting of demands but in the modification of those demands. "Demand management" is the term given to the policy which fosters the conservation of a resource through the development of use incentives and incentives to guide water demand. Demand management of residential water can only be successful if consumer behavior with respect to the resource is understood and subsequently applied in the formulation of policy.

In an analysis of the results of the conservation efforts during the California drought of 1976-77, M. Hoffman et al. reported that reduction of water use throughout the state averaged 49 percent.[6] They attribute this, first, to an immediate water use attitude shift, facilitated by the media, which led to voluntary cutbacks, and, second, to regulations prohibiting extensive outdoor water use. In either case something about consumer behavior was known or suspected: 1) that

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[6] Hoffman, M., Glickstein, R., Liroff, S., "Urban Drought in the San Francisco Bay Area: A Study in Institutional and Social Resiliency," Journal of the American Water Works Association, Vol. 71, No. 7, July 1979.

persons would respond eagerly to a "crisis" situation, and 2) that opposition to reducing outdoor water use would not surface because lawn sprinkling, car washing, etc. were low priority water activities (i.e., not essential to human health or hygiene).

There are many more information needs required for demand management. More research needs to be done concerning the accepted potential of rate structure changes and the degree to which income predicts water consumption. Also, the propensity for the reformulation of consumers' beliefs and attitudes through public education needs to be understood.

Two of these points were pursued by R. Clouser and W. Miller in their 1979 water conservation study based on a cross-sectional analysis of water use in two Indiana communities.[7] The objectives of this study were 1) to test whether income was an acceptable proxy for water using appliances, and to test the already proven variables of household size and seasonal variation, 2) to ascertain the extent of consumer knowledge about water conservation methods, and 3) to discuss water conservation strategies based on this information.

This study differed from the previously reviewed analyses in that it required the collection of primary data on the ownership and use of water intensive facilities such as bathrooms and water-using appliances such as dishwashers, washing machines, and swimming pools. Results of interest are the following: first, it was suspected that a correlation between appliance data and income would be noted. However, the study concluded that income was not a highly accurate proxy for water-using appliances as a variable to explain water use. As suspected the presence of water-using

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[7] Clouser, R. and Miller, W., Household Demand for Water and Policies to Encourage Conservation, Water Resources Research Center, Technical Report 124, Purdue University, August 1979.

appliances and facilities in the household were significant explanatory variables, but families of low income were just as likely to own dishwashers, washing machines, etc., as were high income families. This suggests that another proxy for water-using appliances must be used in water demand studies, or that future demand studies should rely on primary data. Second, the study concluded that the potential for water conservation was high because the majority of the consumers did not practice water conservation and were not familiar with water saving devices.

The research of William Buvold did not attempt to estimate a demand function; rather it was designed to reveal consumer attitudes towards their own conservation efforts and those of their respective utilities.[8] Buvold's research was initiated in the spring of 1977 in response to the worsening California drought. The study was confined to the San Francisco Bay area with consumers being selected for sampling from water utilities with a varying range of policy emphases on conservation efforts.

The specific objectives were 1) to obtain a consumer evaluation of conservation programs, 2) to obtain an evaluation of the effectiveness of conservation programs, 3) to test the preliminary hypotheses which related belief and behavior, and 4) to discuss the effectiveness of the San Francisco Bay area water conservation programs. The third hypothesis is of interest here.

Buvold proposed that some consumers would view the drought as a temporary aberration of nature and others would view it as a permanent condition brought on by the growing water demands of the Bay Area's

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[8] Buvold, W., "Residential Response to Urban Drought in Central California," Water Resources Research, Vol. 15, No. 6, December 1979.

increasing population. The consumers of the former group were expected to be willing to make fewer changes in their water use habits than those in the latter group, who were also expected to have lower GPCD rates. Buvold tested his hypothesis with variables representing a "belief in drought severity and a need for continued conservation" which he anticipated would explain water consumption levels during that time period more accurately than would income and education.

Two results were reported: a) a belief index of drought severity predicted a total conservation effort better than did income, education, or a belief in the need to continue conservation practices, and b) the index for the need to continue conservation practices proved a better predictor of daily per capita use than the other three variables. It had been hypothesized that consumers who believed that the drought was serious would have adopted more rigorous conservation practices and would have a lower GPCD figure than those who believed it was temporary. Results indicated that the degree of belief in drought severity was not correlated with GPCD but was correlated with conservation behavior or practices. The variable measuring the belief in the need to continue conservation was correlated with GPCD but was not correlated with conservation behavior. This seemingly odd result may indicate that those believing in the long term need to conserve had already previously adopted such measures. Those consumers who believed in a serious drought did indicate more new efforts at conservation than those who did not believe it was serious, but they used as much water on a per capita basis.

Buvold states: "These results suggest that the hypothesis relating belief to behavior needs to be reformulated to indicate that belief about the long term need to conserve is a significant determinant of actual daily use of water. This hypothesis may now be tested in research properly designed to account for the joint effects of economic incentives...and belief about the necessity of conserving over the long run."

Studies in Forecasting Residential Demands

Forecasting has traditionally been approached as the formulation of a projection, defined to be an arithmetic extrapolation of the past values of a variable for the purpose of predicting its value in the future. Water requirements forecasting has been employing the past values of GPCD figures and population growth figures to predict the amount of residential water that will be needed in some future period. The reasons for this type of analysis are 1) water demand forecasting is the responsibility of the water utilities, few of which have the research budgets to develop sophisticated forecasting methods, and 2) alternatives to simple projection forecasting, which were otherwise developed, existed only in theory and were not directly applicable.

The use of regression water demand models for forecasting is advocated in studies by Peter Whitford and Robert Saunders.[9] In both of these analyses they elaborate on the shortcomings of traditional forecasting. By so doing they provide guidelines for more advanced models. This effort is summarized in the following: traditional forecasting focused on water requirements rather than water demand in the economic sense. Methods were designed for urban uses, all of which were considered to be equally essential. This is tantamount to suggesting that water be made available in unlimited quantities at zero marginal cost. These assumptions are embodied

[9] Whitford, P. W., Forecasting Demand for Urban Water Supply, Report EEP-36, Stanford University, September, 1970; and Saunders, R. J., Forecasting Water Demand: An Inter- and Intra-Community Study, Bureau of Business Research, West Virginia University, 1969.

in the following characteristics of traditional forecasting: 1) the effects of potential water use deterrents, in particular price, were not considered to be substantial; 2) other influential variables on water use, such as income and household technologies, are assumed to be constant over the projected period; and 3) urban water use is usually aggregated so that little is known about the separate contributions of the residential, commercial, municipal, and industrial demand components of total water use. Each of these criticisms will be briefly discussed.

First, the traditional projection methods assume that past trends are valid predictors of future events. There is evidence [e.g., Howe or Hanke] that the experience of water pricing contradicts this assumption. Neither water supply costs nor water utility rates have remained constant over time for most cities.

Neglect of price effects on quantity demanded can also reflect the assumption that the demand for water is perfectly inelastic with respect to price changes. While all research on water price elasticities indicate that elasticities are small over the current price ranges, there are indications that a price region exists within which the demand for water may be relatively more elastic. Thus as water costs and rates increase, the price will become increasingly more significant as a deterrent to the unlimited use of water. As this occurs specific water uses will be tacitly arranged by consumers in order of priority and the relatively "unessential" needs will not be fulfilled.

Second, traditional forecasting assumes that household water-using technology is constant over the forecast period. This is usually the rule simply because changes in these variables, and changes in the relationship between these variables and water use levels, are very difficult to predict. Accurate information about the presence and the amount of use of household appliances cannot be obtained without incurring the prodigious costs of primary data collection. In water demand studies, income is usually employed as a predictor of the presence of water using appliances. A rise in income is expected to lead to an increase in the use of water-using appliances and a subsequent increase in per capita water consumption. This assumption may not be valid even in a water-plentiful time. Moreover, in the midst of pending scarcity, a different trend may begin to take place. An income increase may be increasingly correlated with an access to water conservation information and result in a shift toward more conservative water use habits. Innovations in appliance design can decrease the amount of water required for efficient operation. As more of the older "water guzzling" appliances are replaced with the latest models, a trend toward decreasing consumption levels will take place. Most certainly, price increases, official rationing schemes, and water saving building regulations will have negative effects on household water use. Unfortunately the magnitude of these parameters are merely conjecture. Consequently, although it is widely recognized that these effects are present, they have not been incorporated into the forecasting procedures.

Third, traditional water demand forecasting does not consistently separate total demand into its residential, commercial, municipal, and industrial components. Aggregate water use provides little information relevant to forecasting since the factors which determine the level of demand for one component of aggregate water demand may not be the same as the factors which determine the level of demand for another component.

One justification for the failure of most water demand studies to disaggregate the components of demand must surely be the high cost of obtaining the data specific to each demand sector.

In summary, information about the structure of residential water demand can provide useful information for public policies designed to encourage reduced water demand. It may also permit more realistic and more reliable forecasts of future water demand. A consistent finding is that the price paid for water is one factor which influences residential water demand, especially for such outdoor uses as lawn irrigation. Household income, number of residents per household, age of residence, climatic conditions, and average water pressure have also been identified as determinants of residential water demand by some studies. More information is needed as to the effect on water demand of attitudes and beliefs about water use and attitudes toward water conservation.

CHAPTER III

DEVELOPING THE WATER DEMAND MODEL

Introduction

This chapter is comprised, first, of a discussion of the variables which are included in the WUDEM model. This will expound on the anticipated influence that a variable has on residential water use in the District and on how it was defined and measured. This will also include the model specifications for the effects of seasonality. Second, this chapter will provide an explanation of the estimation procedures. And third, the data collection components of the survey questionnaire and the sampling procedures will be presented.

Components of the WUDEM Model

The WUDEM model contains eight explanatory variables which were hypothesized to influence monthly water consumption. The following provides an exposition on each variable, its hypothesized sign, the hypothesized magnitude of its influence, and how it was calculated.

The model is specified as follows:

AVG = f(WASHMACH, SWIMPOOL, HAVEWELL, SEWSEPT, WATERLG, NUMRESPH, INCOME, AVGPRICE, S1, S2, S1AVGPR, S1AVGPR).

The variables, DISHWASH and BATHROOM are also included in the analysis but will be treated in separate equations because of correlations between the variables INCOME, DISHWASH and BATHROOM.

The preceding variables are identified and categorized into the following variable groups:[1]

Domestic Technology

DISHWASH - the presence of a dishwasher,

BATHROOM - the number of bathrooms in the home,

WASHMACH - the presence of a washing machine,

SWIMPOOL - the presence of a swimming pool,

HAVEWELL - the presence of a private well,

SEWSEPT - use of a public sewer or septic tank,

WATERLG - indication of whether or not a lawn or garden is irrigated.

Socioeconomic Status

NUMRESPH - number of persons in a household,

INCOME - annual household salary or wages in current dollars.

Economic

AVGPRICE - average monthly price of water computed from respective water rate schedules. This does not include charges for wastewater or local taxes.

Seasonality

S1 - intercept shifter for the season representing the months, December to March,

[1]The variables which were originally expected to influence monthly water consumption numbered 26. Initial statistical manipulation eliminated most of these variables due either to consistent insignificant statistical results or to the presence of high correlations between explanatory variables. These variables will be presented in Appendix B because of their potential importance in future water demand research.

S2 - intercept shifter for the season representing the months, April to July,

S1AVGPR - slope shifter for the variable, AVGPRICE, for the season, S2, April to July,

S2AVGPR - slope shifter for the variable, AVGPRICE, for the season, August to November.

The preceding variables are explanatory or independent. The dependent variable, AVG, is the average monthly quantity of water, in thousands of gallons, consumed by the household. AVG is the variable upon which water demand analysts center their attention. If statistical relationships between the explanatory variables and the dependent variable can be identified and quanitfied, the observed changes in the explanatory variables will assist in predicting AVG, the quantity of water demanded by residences.

The manner in which the variables were measured and their anticipated effects on monthly water use are as follows:

(1) Number of persons in a household (NUMRESPH): this variable is expected to have a positive effect on the water use level, other things being equal. That is, as the number of persons in a household increases there is a corresponding increase in the amount of water a household will use. In the aforementioned and other demand studies from each national geographic area, this variable has been the chief determinant of water use levels, i.e., it has explained most of the statistical variation in water use models. In the sample the mean household size was 2.66 and the mode was 2. The respondents which represented the mode were 43 percent of the District sample. The percentages representing the modal household size in each Region were very close to the District mode of 2 persons. The mean household size ranged from 2.38 for Lake to 2.90 for Duval.

(2) Annual income of the household (INCOME): The variable income is expected to have a positive effect upon the water use levels of the household. There are two reasons for this. First, as income increases the household expenditure constraint expands and subsequently permits an increase of all household purchases. Second, income is expected to be highly correlated with the presence of water intensive facilities and appliances. For example, higher income families are more apt to have dishwashers, garbage disposals, etc. They are also more likely to have additional bathrooms and outdoor landscapes. Consequently income has often been used as a proxy variable for the home market value and for water intensive appliances in water demand studies which did not collect primary data.[2] Because the WUDEM study provides information on the household's appliance and facility use this correlation could be verified. In the final equations correlations between INCOME, BATHROOM and DISHWASH were high enough to allocate these variables to separate equations to avoid estimation bias.[3]

For the District the mean income group was $15,000 - 19,999 (see Table 3-1). The regional samples had similar mean incomes, the highest mean was Duval which approached $20,000.00 and the lowest was Lake which approached $15,000.00. Since income data was collected by Census Bureau classifications, the variable entered the equations in category form and was treated as an intercept shifter.

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[2]See Chapter II review of past water demand studies.

[3]The correlation coefficients between INCOME and BATHROOM averaged .432 for the Regions; between INCOME and DISHWASH the average was .404 and between BATHROOM and DISHWASH the average was .495.

Table 3-1: Income categories and mean values, by region

Region	Mean Values	Mode Values
District	4.03	4
Brevard	4.05	4
Duval	4.61	4
Lake	3.84	4
Orange	4.08	4
Volusia	3.66	4

Income Group Classification

1	less than $4,999
2	$5,000 - 9,999
3	$10,000 - 14,999
4	$15,000 - 19,999
5	$20,000 - 29,999
6	$30,000 - 49,999
7	over $50,000

(3) Number of bathrooms (BATHROOM): The number of bathrooms in the home is expected to be positively related to the amount of water a household uses. This is because the variable BATHROOM represents water using fixtures such as showers, bathtubs, toilets and sinks. Toilet flushing alone accounts for 45 percent of the household's indoor water consumption.[4]

(4) Presence of a washing machine (WASHMACH): The use of a washing machine is hypothesized to be positively correlated with household water use. The washing machine uses between 20 - 60 gallons per cycle, depending on the model.[5] In the District sample 90 percent of the respondents owned a washing machine. In the regional samples ownership percentages ranged from a high of 95 percent for Brevard and Orange to a low of 81 percent for Volusia. WASHMACH enters the equations as a zero - one variable where one indicates the presence of a washing machine, and zero indicates that there is no washing machine in the home.

(5) Presence of a septic tank or use of public sewer (SEWSEPT): the use of the public sewer was expected to have a positive effect on water use relative to use of a septic tank. This is because septic tank households may use less water to delay the expense of having their tanks pumped out and cleaned. The difference between the use of either method was not expected to be significant because septic tanks in the study area require cleaning every 5 - 7 years and it seemed unlikely that consumers would alter their water use

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[4]Milne, M. Residential Water Conservation, p. 18.

[5]Gehm, H., and Bregman, J., Handbook of Water Resources and Pollution Control, p. 57.

habits for this reason unless they had serious drainage problems.[6] However, the variable SEWSEPT was statistically significant in initial testing and its sign was unexpectedly negative.

In the District sample 75 percent of the respondents used the public sewer system. In the regional samples the percentages of public sewer households ranged from a high of 82 percent for Duval to a low of 54 percent for Lake. SEWSEPT was entered into the equations as a zero - one variable where one represented public sewer use and zero represented septic tank ownership.

(6) Presence of a swimming pool (SWIMPOOL): the presence of a swimming pool is hypothesized to have a positive effect upon household water use. Initially its influence was not expected to be highly significant because a swimming pool normally is filled only once in two or three years. The average size pool (16' x 32') requires about 25,000 gallons.[7] Its inclusion in the final equations, however, was due to its consistent significance during early testing procedures.

In the District sample 11 percent of the respondents indicated that they owned a swimming pool. The percentages of swimming pool ownership ranged from a high of 19 percent in Brevard to a low of 6 percent in Lake. SWIMPOOL entered the equations as a zero - one variable where one indicates the ownership of a pool and zero indicates no ownership.

(7) Presence of a private well (HAVEWELL): the effect of the presence of a well on water use depends on how the well is utilized. Respondents indicated that their wells were applied to the following

[7]Telephone conversation with Allied Pools, Gainesville, Florida, May, 1978.

uses: lawn and garden, household, both of the preceding uses, air condition/heat, or other. In the District sample 38 percent owned wells, predominantly for lawn irrigation. In the regional samples the percentages of well ownership ranged from a high of 65 percent in Volusia and 64 percent in Brevard to a low of 9 percent in Lake. Irrigation and other uses of a well would be expected to have a negative effect on use of publicly supplied water. That is, the well would substitute for publicly supplied water. The degree to which this is valid is probably a function of the degree to which the area in question is urbanized. Suburban neighborhoods may reflect a greater concern for lawn appearances. If the use of a well for some household purposes actually increases the use of public water for other purposes, then that negative effect may be mitigated. For example, using a well for lawn irrigation, which can account for 50 percent of all water used, may encourage increased use of public water. Lawn irrigation in Florida for 8000 square feet should require approximately 12,000 gallons for each month that the lawn or garden is irrigated.[8]

Heat pumps used for air conditioning and heating require on an average 43,200 gallons per month (based on use of four hours per day for 30 days).[9] In the District sample 9 percent of the respondents indicated that they used their wells for air conditioning/heat. Whether or not a private well was present was entered into the equation as a zero - one variable where one indicates

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[8]This amount is based on 500 gallons an hour, one hour a day, for 24 days a month.

[9]Information on heat pumps was obtained from a telephone conversation with the Harrell's Co. in Gainesville, Florida in March, 1981.

the ownership of a private well and zero indicates no ownership.

(8) Indication of whether or not a lawn or garden is irrigated (WATERLG): unless irrigation is accomplished with the use of a well, it will have a positive influence on the average monthly use of publicly supplied water. This will normally be reflected in the observed levels of water use during the months which experience the least amount of precipitation. In the District sample 78 percent of the respondents indicated that they watered some portion of their property. The irrigation of a lawn or garden was entered as a zero - one variable where one indicates the irrigation of a lawn and zero indicates no irrigation.

In the District sample 78 percent indicated that they irrigated a lawn or garden. In the regional samples the percentages ranged from a high of 87 percent in Lake to a low of 73 percent for Duval.

(9) Average price (AVGPRICE): this variable is expected to be negatively correlated with the use level because a standard demand relationship, where quantity demanded decreases as price increases, is expected. It is also expected that the correlation will not be strong. This would indicate that price changes over the current range of prices charged by utilities in the District, do not have <u>much</u> effect on the demand for water, i.e., demand is inelastic.

Each consumer within the service area of a given water utility will be purchasing water at the same price. Prices among utilities of course, will vary. The rate structure for each surveyed water supplier is listed in Appendix A.

For the purpose of estimating a demand relationship, a per-unit price was required. To determine the average per-unit price:

(a) The water bills for each consumer for 48 months were summed and divided by the number of available readings. This resulted in the average bill;

(b) total quantity figures were summed and divided by the number of readings. This resulted in the average monthly consumption figure (AVG); and,

(c) the average bill was divided by AVG to obtain AVGPRICE. The District mean value for average price is $1.08 per 1,000 gallons. Mean values for AVGPRICE in the Regions range from a high of $1.65 per 1,000 gallons in Volusia to a low of $0.75 per 1,000 gallons in Duval.

(10) Average monthly consumption in 1,000 gallons (AVG): For each household, monthly water consumption data was collected from the water utilities for the period, February 1976 to January 1980. A complete data set of all 48 months was available for none of the surveyed consumers, however, data for the years 1978 and 1979 were available for most of them.

Monthly consumption figures ranged from a high of 24,143 gallons in May, 1976 to a low of 6,310 in December, 1979 for the District sample. In the Regions the monthly averages for water consumption range from a high of 11.7 thousand gallons for Lake to a low of 5.1 thousand gallons for Volusia. The District monthly average is 8.92 thousand gallons.

The AVG variable was separated into three seasons based on the consumption patterns of the respondents. Season S1 represents the average monthly consumption data of the months December to March of the years 1976 - 1979. Season S2 represents the average monthly consumption data for the months April to July for those same years. Season S3 represents the same consumption data for the months August to November (as will be noted, "S3" will take on the variable names INTERCEPT and AVGPRICE).

Specifications for Seasonality

Climatic changes associated with the seasons are a recognized influence on the residential demand for water. This affects primarily the outdoor use of water but changes in domestic demand have also been noted.[10] Outdoor use pertains to the demand for water used for lawn and garden irrigation. Domestic demand which may be influenced by seasonal changes consists of bath and shower use, and laundry. When temperatures are high and precipitation is low the demand for water for these activities increases. Thus monthly consumption levels normally increase during the spring and summer months.

Outdoor demand for water is inversely related to precipitation and directly related to temperatures. Throughout the District, high precipitation rates and high temperatures will normally occur simultaneously throughout the spring and summer months. The major portion of the District's annual rainfall occurs during the months of June through September.[11] As will be seen, the demand for residential water begins to increase during the drier, warm months of April and May and is usually

[10] See Chapter Two on previous water demand studies.

[11] St. John's River Water Management District, Resource Management Plan, Phase I, p. 15. See also Appendix A.

sustained into the month of August. The month of September which is normally very wet evidences a relative demand reduction, although temperatures remain high into October.

Seasonal correlations with residential water use cannot be precisely identified with any specified measure because water meters provide only the aggregated monthly quantity and do not distinguish outdoor use from domestic use.

Two attempts at discerning a correlation between seasonal factors and water use will be made in this study. First, the temperature and precipitation data for selected counties is compared with the pumpage rates from respective utilities (Table 3-2). It appears that the usual months during which maximum pumpage is experienced occurs in the months when precipitation is relatively low and temperatures are increasing; the maximum rates of pumpage are usually observed during April and May. During these months temperatures for the District range in the mid to high 70's and precipitation ranges from 3 to 4 inches.[12] This information does not, however, reveal anything conclusive about residential water demand since pumpage rates also include commercial and industrial users of publicly supplied water.

Second, average monthly consumption data for the 986 sampled respondents is examined for evidence of a correlation between the household use level and the time of year. Within the sample for the time period 1976-1980, April to July are months of distinctively

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[12] Pumpage rates in 1979 were compared for all District cities having populations of more than 10,000. The maximum month for most is April or May, the minimum month is usually February or November.

Table 3-2: Climatic conditions and water pumpage rates for selected District counties

COUNTY WEATHER STATIONS	DECEMBER-MARCH	APRIL-JULY	AUGUST-NOVEMBER
ALACHUA, Gainesville			
TEMPERATURE	59.7	77.8	75.2
PRECIPITATION	3.6	5.5	4.3
PUMPAGE		MAX	MIN
*BREVARD, Titusville			
TEMPERATURE	63.4	77.4	76.2
PRECIPITATION	2.5	5.5	6
PUMPAGE	MIN	MAX	
DUVAL, Jacksonville			
TEMPERATURE	57.9	77	73.6
PRECIPITATION	3.4	4.8	4.8
PUMPAGE	MIN	MAX	
LAKE, Clermont			
TEMPERATURE	63.4	78.2	76.3
PRECIPITATION	2.8	5.9	4
PUMPAGE			
NASSAU, Fernanino Bch.			
TEMPERATURE	58.5	76.6	74.3
PRECIPITATION	2.9	4.6	4.6
PUMPAGE		MAX	MIN
ORANGE, Orlando			
TEMPERATURE	62.8	77	76.4
PRECIPITATION	3.1	4.9	4.8
PUMPAGE	MIN	MAX	
PUTNAM, Palatka			
TEMPERATURE	61.2	77.8	75.2
PRECIPITATION	3.5	5.1	4.9
PUMPAGE	MIN	MAX	
St. Johns, St. Augustine			
TEMPERATURE	59.7	76.2	74.4
PRECIPITATION	4.3	4.9	5.9
PUMPAGE	MIN	MAX	
VOLUSIA, Daytona Beach			
TEMPERATURE	61.9	75.4	74.7
PRECIPITATION	2.8	4.6	5
PUMPAGE	MIN	MAX	

Source: Temperature and precipitation data: Florida Almanac, 1980-1981 and NOAA , 1981. Figures entered are averages for period 1930-1978. Pumpage data: USGS, Public Water Supplies of Selected Municipalities in Florida 1970,1975. Figures are averages for the period 1956-1975.

Table 3-3: Public water annual pumpage rates for district cities of population over 10,000 (in millions of gallons)

City	1956	1965	1970	1975
Altamonte Springs	NA	NA	NA	1314.0
Casselberry	62.2	146.0	358.0	475.0
Cocoa/Cocoa Beach	370.8	5146.5	5595.0	5262.7
Daytona Beach/South Daytona	1464.0	1963.7	3498.0	4062.0
Deland	585.6	912.5	895.8	1164.0
Gainesville	1306.6	2833.5	3975.0	5048.3
Jacksonville	12,532.5	13,415.9	15,521.0	21,333.2
Jacksonville Beach	475.8	686.2	NA	642.4
Kissimee	311.1	NA	498.5	830.5
Leesburg	629.5	1204.5	1693.0	1415.2
Melbourne	256.2	1314.0	2818.0	3248.5
New Smyrna Beach	457.5	638.8	625.6	907.7
Orlando	5500.7	9275.1	11,825.0	14,881.1
Ormond Beach	329.4	554.8	732.0	1204.5
Palm Bay	(Served by Melbourne)			
Port Orange	75.2	NA		637.1
Rockledge	(Served by Cocoa)			
St. Augustine	549.0	NA	684.0	932.0
Sanford	457.5	866.6	975.0	1595.1
Titusville	117.1	NA	1273.4	1274.6
Vero Beach	512.4	547.5	971.7	1427.5

Source: Healy, H. G., Public Water Supplies of Selected Municipalities in Florida, 1975, U. S. Geological Survey, Tallahassee, Florida, 1977.

Table 3-4: Population served and per capita water use figures for district cities over 10,000 persons (1979)(first entry is population, second entry is gallons per capita daily)

City	1956	1965	1970	1975
Altamonte Springs	NA	NA	NA	16,710 (215)
Casselberry	1250 (136)	3500 (125)	9400 (104)	14,429 (90)
Cocoa/Cocoa Beach	9500 (210)	58,000 (97)	100,000 (153)	100,000 (144)
Daytona Beach/South Daytona	61,000 (66)	51,000 (106)	56,606 (170)	62,300 (179)
Deland	13,500 (118)	16,000 (149)	16,691 (147)	18,000 (177)
Gainesville	29,000 (123)	65,000 (120)	70,000 (155)	80,000 (173)
Jacksonville	247,000 (139)	262,215 (137)	190,000 (132)	250,000 (152)
Jacksonville Beach	10,500 (123)	12,500 (150)	12,600 (150)	15,800 (111)
Kissimee	6000 (141)	NA	8000 (100)	11,848 (192)
Leesburg	13,000 (132)	12,700 (260)	11,869 (390)	14,200 (273)
Melbourne	8500 (82)	40,000 (90)	63,464 (121)	90,000 (99)

-- Continued --

Table 3-4: Population served and per capita water use figures for district cities over 10,000 persons (1979)(first entry is population, second entry is gallons per capita daily)--Continued.

City	1956	1965	1970	1975
New Smyrna Beach	8420 (148)	14,000 (122)	10,580 (161)	13,500 (179)
Orlando	90,000 (167)	144,216 (176)	175,000 (185)	196,000 (208)
Ormond Beach	6000 (150)	22,000 (70)	25,565 (79)	25,668 (129)
Palm Bay		(Served by Melbourne)		
Port Orange	3000 (70)	NA	NA	10,562 (166)
Rockledge		(Served by Cocoa)		
St. Augustine	19,500 (77)	NA	12,352 (152)	20,000 (173)
Sanford	20,000 (60)	20,500 (136)	22,400 (121)	22,636 (193)
Titusville	3500 (91)	20,000 (200)	30,515 (114)	33,094 (106)
Vero Beach	11,000 (127)	12,500 (120)	16,000 (166)	15,500 (252)

Source: Healy, H. G., op. cit.

increased consumption. The gallons per capita daily (GPCD) figure for April-July is 20 percent higher than the period December-March, and 30 percent higher than for the period August-November. It is not possible to categorically attribute this increase to lawn irrigation. However, in the sample a high percentage of all District respondents indicated that they use publicly supplied water for irrigation.

Seasonal specifications were introduced into the model in two ways. First, seasonal distinctions were used to test whether or not more residential water was demanded during season S2, April to July, relative to season S1, December to March, and to season S3, August to November. This is accomplished with use of the intercept shifters, S1, S2, and the intercept which represents S3. These shifts isolate seasonal responses because all other variables remain constant. It is hypothesized specifically that S2 will be positive thereby implying a substantial increase in demand, i.e., an outward shift of the demand curve, during the months April to July, relative to the other seasons. It is further hypothesized that S1 will be positive but less than S2 in magnitude thereby implying a lesser increase in demand during December to March relative to the S3 months of August to November.

Second, seasonal distinctions were applied as price slope shifters through the variables S1AVGPR, S2AVGPR, and AVGPRICE, which represents season S3. It is hypothesized that when the values of S1AVGPR and S2AVGPR are added to the variable AVGPRICE, with all other variables held constant, that price elasticities for the seasons will differ. Specifically, the water quantity response to price will be more elastic during season S2 because of the increase of outdoor uses of water. As noted in Chapter Two, outdoor uses are assumed to be less essential than indoor uses and should, therefore, respond more substantially to price changes. The price responsiveness to season S3 is expected to be the least elastic because it is assumed to be mainly comprised of indoor uses. Season S1 price responsiveness is expected to lie within the range of seasons S2 and S3.

Estimation Procedures

In the previous section a causal relationship was postulated between a dependent variable and its explanatory or independent variables. Quantification of these relationships was accomplished through the construction and application of a multiple regression model, the parameters of which were estimated using the statistical method of ordinary least squares. The hypothesized true regression equation relating y to the X_i is represented by the following equation:

$$y_i = \alpha + \beta_1 X_1 + \ldots + \beta_n X_n + E_i$$

The estimated relationship is summarized in the following equation:

$$\hat{y}_i = \hat{\alpha} + \hat{\beta}_1 X_1 + \ldots + \hat{\beta}_n X_n + \hat{e}_i$$

where $\hat{y}$ is the estimated value of the dependent variable and X_i through X_n are the observed values of independent variables. The intercept term is $\hat{\alpha}$ and the slope coefficients are symbolized by $\hat{\beta}_i$. The observed variation in y will be explained by variation in the X_i variables and represented by $\hat{\beta}_i$, the parameter coefficient. In a linear equation, $\hat{\beta}_i$'s are the partial derivatives of y with respect to X_i when all other variables are constant: $\frac{\partial y}{\partial X_i} = \beta_i$, where i = 1 ... n. The intercept value, $\hat{\alpha}$, gives the value of $\hat{y}$ when the X_i are zero. The error term, or residual e, indicates the variation in y which is left unexplained by the independent variables in the equation.

The least squares estimator is designed to minimize the sum of the squared residuals ($\sum e^2$) thereby insuring the best possible fit of the y values generated by the regression equation to the observed values of y.[13] The assumptions of the least squares estimator are:

(1) $E(e_i) =$ zero for all i;

(2) $E(e_i^2) = \sigma^2$,

(3) $E(e_i e_j) = 0$ for $i \neq j$,

(4) $E(e_i X_i) = 0$.

When these assumptions hold the least squares estimators are known to yield the best linear unbiased estimates. This reflects the desirable estimation properties of 1) minimum variance, and 2) unbiasness, i.e., the expected value of its estimated parameters will equal the value of the true parameters.

When estimates of parameters have been obtained, the results are evaluated by applying statistical methods of testing the "significance" of the coefficient. When a coefficient is significant a difference between the slope coefficient and zero is statistically discernible, indicating that some relationship exists between the dependent variable y and the independent variable X_i.[14]

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[13] See Wonnacott, R. J. and Wonnacott, J. H., Econometrics, Chapter 1 and 2.

[14] Insignificant terms are not necessarily unimportant to the analysis, however, they do indicate that the data at hand do not support the hypothesis that a y, X_i relationship exists.

(1) The F-test: the statistic used to test the overall explanatory power of the independent variables taken as a whole. Mathematically the F-test is:

$$\hat{F} = \frac{\sum (\hat{y}-\bar{y})^2/k}{\sum (y-\hat{y})^2/n-k-1},$$

where $\bar{y}$ is the mean value of y, k is the number of parameters and n is the sample size. The probability that the null hypothesis is correct, i.e., H_o: $\beta_1 = \beta_2 = \ldots = \beta_k = 0$, is determined by comparing the computed F value with a tabulated critical F value. If the computed F exceeds the critical value of F then at least one parameter in the estimated regression equation is significant.

(2) The t-test: the statistic used to compute the probability level at which the individual coefficient is significantly different from zero. The t-test is derived by dividing the coefficient by the standard error of the estimate.[15] The test level of significance is determined by comparing the computed t value with a tabulated critical t value. The amount of confidence one can attribute to the statistical significance of coefficients increases at different test levels. The resulting coefficients for this analysis (see Chapter IV) will be tested at the .10, .05 and .01 test level. Of these three test levels, the .01 test level represents the highest level of confidence.

(3) The R^2: the statistic, known as the coefficient of multiple determination, used to determine the amount of variation explained by the estimated equation. Mathematically R^2 is:

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[15]The standard error of the estimate is the standard deviation of the coefficients. It yields the average magnitude by which the estimated y will deviate from its actual value.

$$R^2 = \frac{\sum(\hat{y}-\bar{y})^2 - \sum e^2}{\sum(y-\bar{y})^2}$$

where $\sum(y-\bar{y})^2$ is the total variation and Ee^2 is the unexplained variation. The remainder of $[\sum(y-\bar{y})^2 - \sum e^2]$ is the amount of explained variation, $\sum(\hat{y}-\bar{y})^2$. Since the R^2 statistic is a ratio its range is between 0 and 1.0.

The Sample Design

The technique employed to draw the sample was a combination of cluster, stratified and systematic sampling.[16] This was chosen to fulfill the objectives of obtaining the most information about the statistical population for the least possible cost while insuring the randomness of the sample.

The first step was to stratify the sample which means separating sample areas into nonoverlapping groups, called strata, based on homogeneous characteristics. The advantage of this procedure is the reduced variability within each stratum which results in minimum variance estimators. The District was divided into separate strata based on county groups. Each group was selected on the basis of major geographical and socioeconomic characteristics which best represented the District in terms of influential factors on household water use. For example, the amount of rainfall, temperature, and degree of urbanization are all known determinants of public water use levels. Therefore, areas demonstrating homogeneity in these characteristics were placed together in a stratum.

Following this strategy, the following regions were delineated: Region I) southern, urban, and coastal; Region II) northern, urban, and

[16] Details on sampling procedures can be found in Scheaffer, R., Mendenhall, W., and Ott, L., Elementary Survey Sampling, Chapters 5, 7 and 8. The sampling design and, therefore, the data upon which this analysis is based was developed by the Water Resources Planning Staff of SJRWMD before the authors were commissioned to conduct the analysis.

coastal; Region III) central, rural and inland; Region IV) central, urban, and inland; Region V) central, urban and coastal. These categories were selected according to population growth trends, i.e., no county is exclusively urban, however, if it possesses a growing urban center it would be classified as "urban."

From each region one representative county was chosen as the primary cluster unit. Cluster sampling is used to reduce the geographical area of a sample, i.e., distances within one county are less than throughout the Region, a group of counties. This second step was to choose one county from each region, yielding the following results:

Region I:	Brevard
Region II:	Duval
Region III:	Lake
Region IV:	Orange
Region V:	Volusia

For the third step the secondary cluster units were chosen from among the local water companies, a complete list of which was available from the Florida Department of Environmental Regulation. Each utility in the region was included provided that their management was cooperative and their records were reasonably accessible. The variability of water prices was achieved by the inclusion of both large public and small private companies whose rates tend to vary.

Within each Region the total sample size was based on the number of households of the total service area of the water utilities which were to be surveyed.[17] The total number of households which is the statis-

[17]The household number was determined by dividing the population of the service area by the average household size for that county as determined by the 1970 U.S. Census.

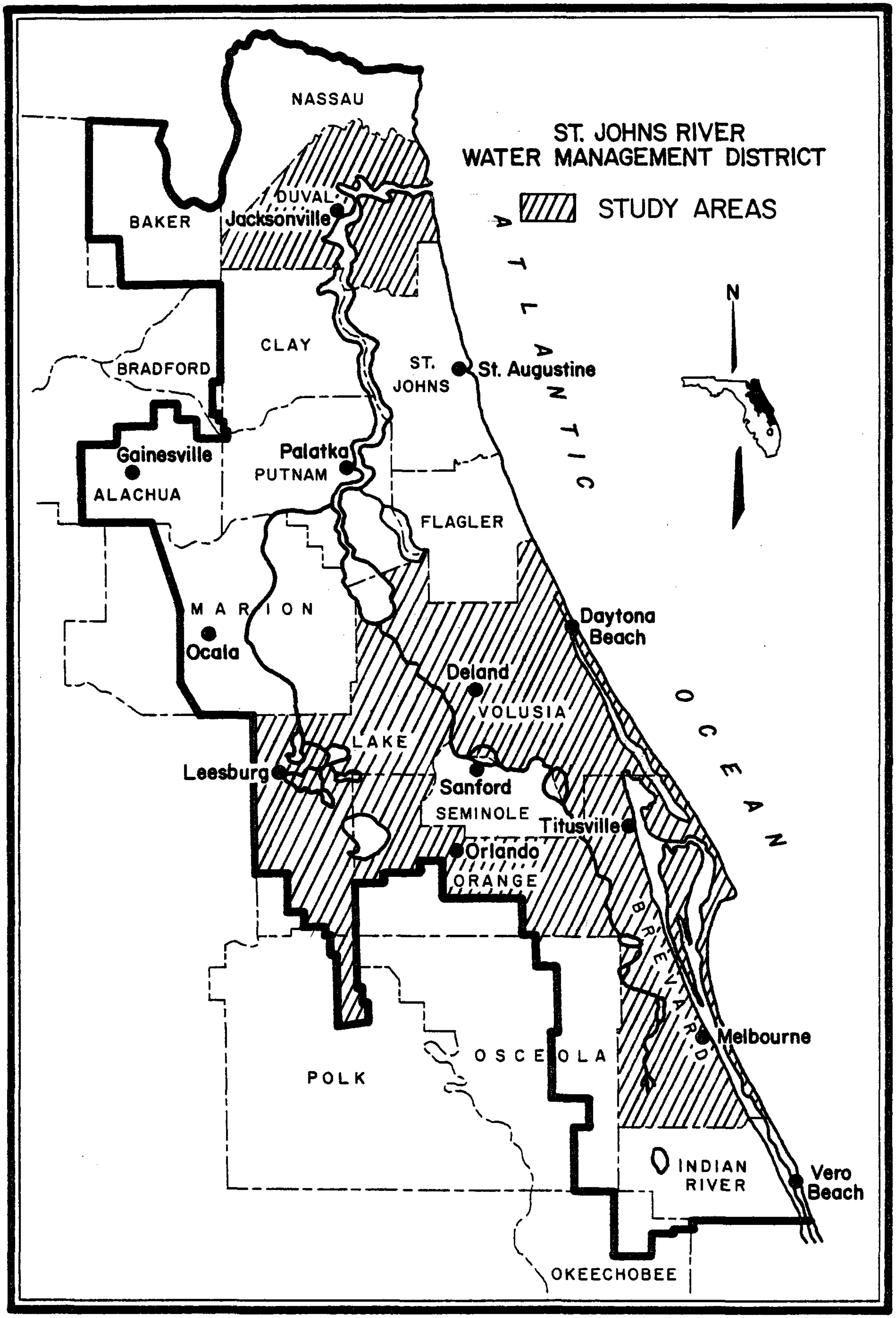

Figure 3-2. --Study Area Map

tical population represented by N, were as follows:

Along with the population, the determination of the appropriate sample size uses the population variance (σ^2) and the bounds on the error of estimation (D). The formula for the sample size (n), is:

$$n = \frac{N\sigma^2}{(N-1)D+\sigma^2}$$

The population variance was obtained from the estimated range of household water consumption using this formula:

$$\sigma^2 = (\frac{range}{4})^2$$

This is an estimate based on the fact that the range is usually equal to 4 standard deviations (4σ), one standard deviation is the square root of the variance. The estimate of the range was obtained from the water suppliers surveyed. The lower bound was estimated to be zero and the upper bound was estimated to be 100,000 gallons. The estimated population variance was calculated to be 625,000,000.

The bounds on the error of estimation were obtained using the following formula:

$$D = \frac{B^2}{4} \quad \text{where } B = 2\sqrt{\frac{\sigma}{n}\left(\frac{N-n}{N-1}\right)}.$$

The results from these equations were used in the sample size formula for each Region. The resulting sample sizes were:

Region I: 240

Region II: 252

Region III: 338

Region IV: 268

Region V: 367

The preceding sample sizes were allocated to each company according to its proportion of residential customers in the service area. For example, of the five companies surveyed in Brevard county, the City of Cocoa Water Department serviced 84 percent of all customers and was therefore allotted 84 percent of the sample size which needed to be taken.

Large companies were able to take a simple random sample by computer and furnish the amount of consumer names quickly. At the smaller utilities, where the work was done by hand, systematic samples were taken. The number of customers was divided by the needed sample size to obtain the value "X." There was a random selection of the first X elements in the population and every Xth element thereafter until the sample size was obtained.

Once the names and addresses were collected the actual data gathering involved two steps: 1) water consumption data was obtained from the utility records for the period February 1976 to January 1980 for each customer. Few customers had a complete set (48 months) of water use data so consumption levels were averaged over varying periods between 1976-1980. Also rate schedules were furnished so that average water bills could be computed; and 2) each consumer was mailed a survey on the water using behavior of his household (see Appendix E).

The response rate was relatively good; of the 2167 surveys mailed 47 percent were returned. Of these surveys 30 were considered unusable and, therefore, discarded. The remaining 986 constituted the total sample which represented the residential customers of the St. Johns River Water Management District. The total sample was divided among the Regions of the District as follows:

Region I:	123
Region II:	246
Region III:	186
Region IV:	130
Region V:	301

CHAPTER IV

ANALYSIS OF STATISTICAL RESULTS

Introduction

The estimation procedures for the District water consumption data were separated into analyses for the total District sample and for each of the five regional samples. The results of these procedures will be presented in the following manner: first, the hypothesis that was tested and its outcome will be presented; second, the value of the coefficients and their implications will be discussed; and, third, the significance level of each parameter will be presented. Regional differences and similarities for each variable will be discussed along with the results for the total sample.

Summary of Results

For each region and for the combined District sample there are three equations (see Table 4-1). All variables are alike in each except income, number of bathrooms, and dishwasher. Each equation will contain one of each of these variables. They are separated because the high degree of correlation (.45 - .60) among them can invalidate hypothesis testing procedures. The variables INCOME and BATHROOM will be discussed with reference to the equations in which they appear. DISHWASH and the remaining variables will be discussed with reference to the equation containing the DISHWASH variable. The coefficients for the remaining variables are very similar for all three equations in each Region.

Table 4-1: Regression Results for Residential Water Consumption Data for St. Johns WMD (In semilogarithmic form)

Region		INTERCEPT	NUMRESPH	AVGPRICE	WASHMACH	SEWSEPT	SWIMPOOL	WATERLG	HAVEWELL	BATHROOM	INCOME	DISHWASH	S1	S2	S1AVGPR	S2AVGPR	R^2	F-VALUE
District	I	1.55 (0.047)	0.148 (0.007)	-0.310 (0.016)	0.152 (0.031)	-0.105 (0.021)	0.218 (0.029)	0.144 (0.022)	-0.168 (0.120)			0.207 (0.190)	-0.050* (0.022)	0.147 (0.022)	-0.245 (0.036)	-0.440 (0.036)	.57	319.9
	II	1.37 (0.049)	0.143 (0.007)	-0.320 (0.016)	0.155 (0.031)	-0.100 (0.021)	0.225 (0.028)	0.148 (0.022)	-0.166 (0.020)	0.160 (0.014)			-0.050* (0.022)	0.148 (0.022)	-0.231 (0.036)	-0.426 (0.036)	.57	322.8
	III	1.43 (0.051)	0.150 (0.008)	-0.319 (0.016)	0.185 (0.031)	-0.102 (0.021)	0.229 (0.030)	0.149 (0.022)	-0.155 (0.020)		0.043 (0.007)		-0.050* (0.022)	0.147 (0.022)	-0.244 (0.037)	-0.439 (0.037)	.56	305.7
Brevard	I	1.13 (0.128)	0.145 (0.016)	-0.157 (0.030)	0.390 (0.106)	-0.102* (0.052)	0.231 (0.057)	0.151 (0.056)	-0.179 (0.046)			0.255 (0.046)	0.072*** (0.059)	0.286 (0.060)	-0.291* (0.137)	-0.468 (0.137)	.57	39.3
	II	0.911 (0.146)	0.139 (0.017)	-0.167 (0.030)	0.458 (0.108)	-0.119* (0.053)	0.255 (0.058)	0.140 (0.058)	-0.181 (0.047)	0.180 (0.044)			0.071*** (0.061)	0.285 (0.061)	-0.287* (0.139)	-0.464 (0.139)	.55	36.7
	III	1.04 (0.138)	0.136 (0.018)	-0.169 (0.031)	0.414 (0.109)	-0.108* (0.054)	0.241 (0.061)	0.157 (0.058)	-0.176 (0.047)		0.060 (0.018)		0.065*** (0.061)	0.279 (0.061)	-0.255* (0.141)	-0.432 (0.141)	.55	35.6
Duval	I	2.32 (0.103)	0.132 (0.012)	-1.090 (0.081)	0.022*** (0.062)	-0.073* (0.038)	0.250 (0.042)	0.098 (0.034)	-0.091 (0.035)			0.163 (0.035)	-0.074** (0.046)	0.073** (0.046)	-0.139 (0.080)	-0.038)*** (0.080)	.58	80.7
	II	2.13 (0.106)	0.124 (0.012)	-1.100 (0.081)	0.051*** (0.060)	-0.083* (0.037)	0.239 (0.042)	0.116 (0.033)	-0.116 (0.035)	0.145 (0.022)			-0.063** (0.045)	0.085* (0.045)	-0.169 (0.079)	-0.008*** (0.079)	.59	84.2
	III	2.18 (0.111)	0.134 (0.012)	-1.130 (0.081)	0.042*** (0.062)	-0.058** (0.038)	0.256 (0.043)	0.101 (0.034)	-0.098 (0.035)		0.049 (0.012)		-0.070** (0.046)	0.077* (0.046)	-0.149 (0.081)	-0.028*** (0.081)	.57	78.9
Lake	I	2.01 (0.122)	0.139 (0.020)	-0.534 (0.074)	0.020*** (0.071)	-0.036*** (0.042)	0.159 (0.073)	0.162 (0.062)	-0.159 (0.072)			0.179 (0.044)	-0.275 (0.062)	0.089** (0.062)	-0.442 (0.103)	-0.562 (0.103)	.56	57.5
	II	1.80 (0.123)	0.135 (0.019)	-0.558 (0.073)	-0.097** (0.074)	-0.012*** (0.042)	0.136* (0.072)	0.190 (0.061)	-0.184* (0.069)	0.217 (0.036)			-0.258 (0.061)	0.106* (0.061)	-0.395 (0.101)	-0.516 (0.101)	.58	61.2
	III	1.83 (0.131)	0.130 (0.021)	-0.532 (0.074)	0.037* (0.071)	-0.016* (0.043)	0.147* (0.074)	0.213 (0.062)	0.138 (0.070)		0.055 (0.016)		-0.274 (0.063)	0.089** (0.063)	-0.441 (0.103)	-0.561 (0.103)	.57	56.5
Orange	I	2.76 (0.216)	0.113 (0.021)	-1.480 (0.160)	0.165* (0.131)	-0.181 (0.064)	0.009* (0.082)	0.048* (0.070)	-0.017* (0.071)			0.235 (0.060)	-0.020* (0.076)	0.215 (0.076)	-0.209* (0.208)	-0.221 (0.208)	.57	42.0
	II	2.62 (0.220)	0.112 (0.021)	-1.540 (0.159)	0.167* (0.131)	-0.174 (0.064)	0.050 (0.079)	0.027* (0.071)	0.024* (0.071)	0.172 (0.045)			-0.015* (0.076)	0.220 (0.076)	-0.183* (0.208)	-0.194 (0.208)	.57	41.8
	III	2.65 (0.232)	0.124 (0.021)	-1.500 (0.163)	0.209** (0.132)	-0.187 (0.065)	0.066 (0.082)	0.055* (0.072)	0.010* (0.072)		0.040** (0.021)		-0.020* (0.077)	0.215 (0.077)	-0.210* (0.211)	-0.221 (0.211)	.56	39.7
Volusia	I	1.33 (0.084)	0.159 (0.013)	-0.283 (0.025)	0.192 (0.041)	-0.116 (0.040)	0.159 (0.063)	0.085 (0.036)	-0.131 (0.035)			0.188 (0.032)	0.089* (0.050)	0.202 (0.050)	-0.166* (0.086)	-0.273 (0.086)	.56	92.9
	II	1.15 (0.087)	0.154 (0.013)	-0.290 (0.025)	0.196 (0.040)	-0.109 (0.040)	0.161 (0.062)	0.070 (0.036)	-0.114 (0.034)	0.160 (0.021)			0.083* (0.050)	0.196 (0.050)	-0.150* (0.085)	-0.258 (0.085)	.57	97.0
	III	1.27 (0.088)	0.158 (0.013)	-0.300 (0.025)	0.221 (0.041)	-0.127 (0.041)	0.137* (0.065)	0.057 (0.037)	-0.118 (0.035)		0.044 (0.011)		0.091* (0.051)	0.205 (0.051)	-0.171* (0.087)	-0.279 (0.087)	.55	89.7

(no asterisk) Significant at .01
* Significant at .05
** Significant at .10
*** Insignificant

The functional form of the equations chosen was semi-logarithmic where the dependent variable for each model was transformed to natural logarithms and the independent variables remain in non-logarithmatic form. This form accomodates the curvilinearity of the estimated functions and permits the evaluation of price elasticities at varying points along the demand curve. This does not inhibit the use of ordinary least squares because the equations are intrinsically linear in logarithmic form.

Seasonality (intercept, S1, S2)

The effects of seasonality on consumption was introduced into the analysis first by the use of the intercept shifters, S1 and S2. The coefficients of S1 and S2, respectively will indicate whether the demand-for-water curve shifts, or changes, for the months December to March or for the months April to July. These changes are referenced from the intercept value which represents the months August to November. It was hypothesized that for S2 the demand curve would shift outward to show an increase in demand for the spring and summer months. It was further hypothesized that for S1 the demand curve would shift outward but that the increase would not be as substantial as the shift for S2.

For the District sample and all Regional samples the demand curve shifted the farthest outward or right in S2, i.e., the demand for residential water increased for the months April to July, all other variables held constant, from the S3 season, August to November. In four of the samples (District, Duval, Lake and Orange) the greatest shift to the left of the demand curve, or the least amount of water demanded due to seasonality is experienced during S1, the months December to March. For

Brevard and Volusia the corresponding season of least use is S3, the months August to November.

The magnitude of the difference for the District sample is a range of 1.50 for S1 to 1.70 for S2. This translates into an average monthly difference of 992 gallons between the highest use and lowest use seasons.[1] For the regional samples the difference in monthly consumption between the S1 and S2 seasons was 1426 gallons for Duval, 2469 gallons for Lake, and 2062 gallons for Orange. The differences in monthly average consumption between S3 and S2 seasons are 1042 gallons for Brevard and 837 gallons for Volusia. These quantities represent the range between the minimum and maximum.

Confidence in these results depends upon the significance levels attained by the coefficients. For the District sample the intercept (S3), S1, and S2 coefficients are significant at .01. For Brevard and Orange, the intercept and S2 coefficients are significant at .01 while S1 is insignificant. For Duval, both S1 and S2 are significant at .10, while the intercept is significant at .01. For Lake, the intercept and S1 is significant at .01, while S2 is significant at .10. For Volusia, the intercept and S2 are significant at .01 while S1 is significant at .05. In summary, the most confidence can be placed in the S3 and S2 seasonal shifts because all but one value are consistently significant at the high test level of .01. It is with less confidence that the value of S1 can be presented as statistically different from zero.

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[1] Figures are rounded to the nearest whole number.

Seasonality (AVGPRICE, S1AVGPRICE, S2AVGPRICE)

The seasonal effects were also introduced into the analysis through the average price variable shifters. It was hypothesized that the quantity response to price would be more elastic during the S2 season than during S1 or S3, because April to July were months of lawn watering and other relatively more dispensable water using activities. It was expected that the S1 and AVGPRICE (S3) price coefficients would be less elastic than S2, and specifically that AVGPRICE (S3) would be less elastic than S1AVGPR since less water by the household is used during this period (and therefore more water is allocated to the less dispensable in-house water users).

The results indicate that for all samples the price coefficients are most elastic for S2 season, April to July. The least elastic season is S3, August to November for the District and all Regions except Duval for which S1 was the season of the highest price elasticity. The range of the most price elastic season to the least price elastic season was approximately -.60 to -.34 for the District. In the S2 season a price elasticity of -.60 indicates that if the price changed by 10 percent there would be a 6 percent change in the quantity of residential water demanded in the opposite direction. The price elasticities for all three seasons for each region are listed in Table 4-2.

The value of the price coefficients for the District indicates that if the average price increased by 10 percent the decrease in monthly average water consumption for season S1 would be 1057 gallons; for season S2, the decrease would be 1078 gallons; and the decrease for season S3 would be 1032 gallons.

The monthly average decrease in water use precipitated by a 10 percent price increase for season S1 for Brevard was 1046 gallons, for Duval was

Table 4-2: Price Elasticities at Mean Average Price, by Season

Region	December-March S1	April-July S2	August-November S3	Average Price* Means
District	-0.599	-0.810	-0.335	1.08
Brevard	-0.605	0.844	-0.212	1.35
Duval	-0.713	-0.843	-0.818	0.75
Lake	-0.752	-0.847	-0.411	0.77
Orange	-0.829	-0.929	-0.532	0.86
Volusia	-0.741	-0.917	-0.467	1.65

*This is the price per 1,000 gallons as calculated from the respondents' water bills. It is not the respective water rate structures. Since virtually all District utilities operate on the declining block system the price per 1,000 gallons depends on which thousand, e.g., first, fourth, etc., is being addressed. This distorts the normal demand relationship because the price per unit changes at different quantity intervals. The declining block billing system can actually encourage increased consumption because the price falls as more gallons are used. By computing the AVGPRICE from consumers' bills the declining block intervals were "smoothed" or averaged into one price per 1,000 gallons.

1100 gallons, for Lake was 1102 gallons, for Orange 1101 gallons, and for Volusia it was 1046 gallons.

The corresponding decrease for season S2 was 1065 gallons for Brevard, 1120 gallons for Duval, 1116 gallons for Lake, 1114 gallons for Orange, and 1057 gallons for Volusia.

The corresponding decrease for season S3 was 1016 for Brevard, 1115 for Duval, 1055 gallons for Lake, 1055 for Orange, and 1028 for Volusia.

For the District the decrease in consumption associated with a 10 percent price increase in season S2, April to July, was 2 percent greater than in season S1, December to March, and 4.5 percent greater than in season S3, August to November. For the Regions the average consumption decrease in season S2 was 1.1 percent greater than in season S1, and 3.1 percent greater than in season S3.

For the District sample and the Lake Sample the AVGPRICE (S3), S1AVGPR, and S2AVGPR were significant at .01 and S1AVGPR was significant at .05. For Duval AVGPRICE and S1AVGPR were significant at .01 and S2AVGPR was insignificant.

Number of Persons per Household (NUMRESPH)

The number of persons per household was hypothesized to have a positive influence on residential water consumption since additional persons would increase the household's water using activities. The regression results indicate that the hypothesis is correct for the District and all regional samples. For the District an increase of one individual to the household size would increase the monthly average consumption by 1160 gallons, other things being equal. The corresponding increases for the regional samples are 1156 gallons for Brevard, 1141 gallons for Duval, 1149 gallons for Lake, 1112 gallons for Orange, and 1172 gallons for Volusia. For the District and for all Regions, the NUMRESPH variable was significant at .01.

Annual Household Income (INCOME)

It was hypothesized that household income would be a positive influence on the amount of water which a household consumed. This is because income creates an expenditure constraint and also because it tends to be correlated with water using facilities and appliances within the home. With the WUDEM data this correlation proved to be relatively high between income and the variables representing the number of bathrooms and the presence of a dishwasher.

Results indicate that income does have a positive effect upon residential water consumption. For the District the effect of its mean income on the average seasonal consumption is an increase of 1188 gallons. The corresponding additional quantities of water which can be attributed to the effect of the mean income are 1193 gallons for Brevard, 1252 gallons for Duval, 1232 gallons for Lake, 1178 gallons for Orange, and 1177 gallons for Volusia. As income increases by one, i.e., going from one income category to the next, these quantities will be added to the average seasonal quantity. The INCOME variable was significant at .01 for all samples except Orange where it was significant at .10.

Number of Bathrooms per Household (BATHROOM)

It was hypothesized that the number of bathrooms per household would have a positive influence on the amount of water the household used. The results indicate that this hypothesis was correct for the District and for all the Regional samples. For the District an increase in the home of one bathroom would increase monthly average consumption by 1174 gallons. The corresponding figures for the Regions show an increase of 1197 gallons for Brevard, an increase of 1156 gallons for Duval, an increase of 1240 gallons for Lake, an increase of 1188 gallons for Orange, and an increase of 1174 gallons for Volusia. The variable BATHROOM was significant at .01 for the District and all regional samples.

Presence of a Dishwasher (DISHWASH)

The presence of a dishwasher in the home was hypothesized to have a positive effect upon the amount of water a household used. The results indicated that that is correct for the District and for each of the Regions. In the District sample the dishwasher increased monthly average consumption by 1230 gallons. The corresponding increases for the Regions were 1290 gallons for Brevard, 1177 gallons for Duval, 1196 gallons for Lake, 1265 gallons for Orange, and 1207 for Volusia. The variable DISHWASH was significant at .01 for the District and for all regional samples.

Presence of a Washing Machine (WASHMACH)

The presence of a washing machine was hypothesized to have a positive influence on household water use. The results indicate that a home with a washing machine does indeed require additional amounts of water. For the District sample, the increase in monthly average consumption of water due to the use of a washing machine is 1164 gallons. For the regional samples these respective increases were 1477 gallons for Brevard, 1022 gallons for Duval, 1037 for Lake, 1179 for Orange, and 1212 for Volusia. Statistical significance of these results vary among the Regions. For the District, Brevard, and Volusia, the variable WASHMACH was significant at the .01 test level. For Duval, Lake and Orange WASHMACH was not statistically significant.

Presence of a Swimming Pool (SWIMPOOL)

The presence of a swimming pool was hypothesized to have a positive effect upon the household water use level. This hypothesis was confirmed by the results which indicated that the use of a swimming pool for the District increased the monthly average consumption of water by 1244 gallons. For Brevard the increase due to a swimming pool is 1260 gallons, for Duval the increase is 1284 gallons, for Lake 1172 gallons, for Orange 1009 gallons, and for Volusia the increase in monthly water use due to a swimming pool is 1172 gallons. The variable SWIMPOOL was significant at the .01 test level for each sample except Orange where it was insignificant.

Use of a Septic Tank or Public Sewer (SEWSEPT)

The presence of a septic tank versus use of the public sewer was initially hypothesizdd to have little effect on household water consumption. Because it was significant, however inconsistently, in the initial equations it was included in the final regressions. Its effect was expected to be positive, i.e., the use of a public sewer system would be associated with an increase of water use. In each Region and in the District sample, however, the SEWSEPT coefficient had a negative sign, indicating that the use of the public sewer contributed to a decrease or a greater decrease in water use relative to the septic tank method of wastewater disposal.

For the District this decrease in monthly average water consumption was 1111 gallons. The corresponding decreases for Brevard is 1107 gallons, for Duval is 1076 gallons, for Lake is 1037 gallons, for Orange is 1198 gallons, for Volusia is 1123 gallons. Statistical confidence in these results varies among the Regions. The variable SEWSEPT is significant at the .01 test level for the District, Brevard, Orange, and Volusia. For Duval it is significant at the .05 test level, and for Lake SEWSEPT is statistically insignificant.

Presence of a Private Well (HAVEWELL)

It was hypothesized that the presence of a private well would most likely decrease the monthly average consumption of household water from public supply. The results indicate that this is the case for the district and all regional samples. The decrease in the average water consumption for each season is 1183 gallons for the District due to the use of a private well. The corresponding decreases for the Regions are 1196 for Brevard, 1095 for Duval, 1172 for Lake, 1017 for Orange, and 1140 for Volusia. The variable HAVEWELL is significant at .01 for the District and all Regions except Orange where HAVEWELL was statistically significant.

Indication of Whether or Not a Lawn or Garden is Irrigated (WATERLG)

The irrigation of a lawn or garden was hypothesized to have a positive effect upon the households' water use. The results confirm this hypothesis for each of the samples. For the District the irrigation of outdoor landscapes increase the seasonal average consumption of water by 1015 gallons. The corresponding increases for the Regions are 1163 gallons for Brevard, 1103 for Duval, 1176 gallons for Lake, 1049 gallons for Orange, and 1089 gallons for Volusia. The variable HAVEWELL is significant at test level .01 for all samples except Orange where it was statistically insignificant.

CHAPTER V

SUMMARY AND CONCLUSIONS

This research commenced with the following objectives:

(1) to identify variables which explain variations in the rates of water use among residential customers of public water supply utilities in the St. Johns River Water Management District;

(2) to quantify the relationships between those causal variables and rates of use of publicly supplied water by the residential sector; and,

(3) to interpret the implications of those interrelationships found to be statistically significant and to compare statistical results from different parts of the District.

This chapter reviews the results of the analysis in terms of the determinants of residential water demand. Implications of these results are discussed in terms of price elasticities of demand, implications for water conservation, implications for demand forecasting and opportunities for further research.

Determinants of Residential Water Demand

The first two objectives were the identification and quantification of the determinants of residential water demand in the District. Initially 26 variables were tested in a multiple regression format. The final equations contained the ten variables, NUMRESPH, INCOME, AVGPRICE, SEWSEPT, HAVEWELL, WATERLG, SWIMPOOL, DISHWASH, BATHROOM, WASHMACH, plus four seasonal slope and intercept shifter variables.

The analysis indicated that the number of persons in a household (NUMRESPH) has a positive effect on water consumption, implying that an increase in the number of residents per household would, in the average residence, result in an increase in water consumption, if all other factors were held constant. The trend in the United States and in Florida is toward smaller household units. (The mean household size for the District counties was less than three persons). The implications are that water consumption per household would decrease over time if other factors affecting water demand were to remain constant.

The analysis indicated that the variable SEWSEPT was significant, implying that the use of the public sewer (as opposed to a septic tank) was associated with a net reduction, averaging 1,126 gallons per month, in water use as compared to the rate of use observed for households using septic tanks. (An exception to this finding was demonstrated in the Lake County sample where the SEWSEPT variable was not statistically significant.) The inverse relationship between use of public sewer and rates of water use is probably explained by the fact that public sewer charges are usually tacked onto water bills on the basis of metered water use. In effect, the water bill for water customers on public sewer lines reflects a higher charge per thousand gallons of water delivered than for customers who use septic tanks. The sewer charge has the same inhibiting effect on water consumption as a higher price would have. Sewer charges throughout Florida tend to be high relative to the price charged for water because sewage treatment costs are high relative to water supply treatment costs in this state where high quality groundwater is a principle source of water supply.[1] Because sewer charges are usually proportional to water quantities registered on the meter, it is not unlikely that consumers willfully reduce their water use to avoid sewer charges.[2] The SEWSEPT results suggest a direction for further study redefining the price variable to include sewer charges.

Analysis indicated that the presence of a private well, denoted by the HAVEWELL variable, was consistently associated with a reduction in monthly consumption of publicly supplied water, other factors being held constant. This effect was relatively uniform throughout the District. In the District where 38 percent of the respondents own a well, it contributed to a reduction of 1183 gallons a month. This suggests that, indeed, the private well is a substitute for publicly supplied water. It should be noted that this reduction applies only to public water and to water in general

The analysis indicated that households which water their lawn or garden, denoted by the variable WATERLG, use an average of 1,015 gallons more publicly supplied water each month than households which do not water lawns or gardens, other factors being equal. Lawn and garden irrigation is extensive throughout the District (78 percent of the respondents practice residential irrigation). There appears to be a substantial number of households which irrigate but which do not have a well. This implies

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[1]Water Utility Rate Survey for Florida, ACT Systems, Winter Park, Florida, 1979; and conversation with R. Boyd of the Orlando Utilities Commission, August, 1980.

[2]Of sampled respondents in the District, 91 percent indicated that they were conscious of the cost of water while using it, and 51 percent indicated that they were familiar with the local water rate schedule.

a large potential for replacing publicly supplied water with private well water in lawn and garden irrigation.[3]

In the category of household technology three other variables were tested and found to be influential in the determination of domestic water use: BATHROOM, DISHWASH, and WASHMACH. Households with two or more bathrooms used more water than households with one bathroom, other things being equal. The addition of one bathroom to a District home would increase monthly water use by 1174 gallons. This, of course, implies an increase in the amount of water demanded for use of additional bathtubs, showers, toilets and sinks. The correlation between BATHROOM and INCOME suggests that higher income families, most likely via more expensive homes, have more bathrooms. For example, in Brevard, where 80 percent of the sample had at least two bathrooms, 68 percent of the respondents had incomes over $15,000. The correlation in Duval is also very similar.

The presence of an automatic dishwasher or a clothes washing machine increases monthly average water use in the District home by 1,230 and 1,164 gallons respectively, other things being equal. The correlation between DISHWASH and INCOME suggests that, like an increasing number of bathrooms, the homes which have dishwashers (48 percent of the District sampled households) are likely to have higher incomes. Washing machines, on the other hand, are owned by 90 percent of the District households.

The variable DISHWASH had high statistical significance for all regions. WASHMACH was highly significant for the District, Brevard,

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[1]Only in the Orange County sample were both HAVEWELL and WATERLG not statistically significant. In this region, only 8 percent of the respondents had a well, and 87 percent reported watering their lawns. Lack of significance for these variables is not readily explainable, although it may reflect a tendency for households in this county to use only small amounts of water for irrigation.

and Volusia samples. It was not a statistically significant variable in the Duval, Lake, and Orange samples.

The analysis revealed that household income was a statistically significant factor in explaining residential use of publicly supplied water in every sample. Although the effect attributable to income is relatively small compared to the effects of other variables, income revealed a consistent positive relationship with quantity of water used.

The detection of correlations between income and water using appliances and facilities was of interest for its research implications. The analysis suggests that income cannot be substituted for WASHMACH as a variable in demand estimation, but can perhaps be used as a proxy for DISHWASH or BATHROOM because of strong correlations among these variables. It must be noted that the inclusion of the INCOME variable serves another important purpose in water demand models (and in economic demand models for most goods or services): income is an important constraint on spending patterns of households, a fact which operates in varying degrees as a factor which determines the quantity of water (or other commodity) which a household will consume in a given period of time.

Seasonality proved to have a significant impact on the average monthly consumption of residential water for all of the regions. First, the intercept shifter S2, indicated that in season S2, the months April to July, the demand for water increased, given no change in the other variables. The intercept shifter S1, likewise, indicated that the demand for water increased during season S1, December to March, but less substantially. Season S3, August to November, was shown to be the season of lowest consumption rates. Seasonal changes in the price elasticity of residential water demand were reflected in the coefficient of the price variable, AVGPRICE, as demonstrated by the performance of its seasonal slope shifters, S1AVGPR and S2AVGPR. The consistent significance (with one exception) of these variables confirms the hypothesis that price elasticities change with the seasons. More specifically, it verified that during the spring and summer months of April to July, the price elasticity increases, i.e., the potential deterrent capability of the price of water is greater in magnitude. Likewise, the winter and spring months, December to March, also experience an increased price elasticity for most of the regions. The exception is Duval where the season S3, August to November had, a greater price elasticity than season S1, December to March. The difference between the S1 and S3 price elasticity is 0.105. It is interesting to note that the difference between S3 and S2 price elasticities is only 0.025 (see Table 4-2).

Evaluation of Price Elasticities

Price elasticities were evaluated at prices other than the mean for purposes of comparison. For the District sample the price at which the elasticity is unitary for season S1 is $1.80 per 1,000 gallons. This means that if the average price for water were $1.80 per 1,000 gallons, a given percentage increase in price would induce the same percentage decrease in the quantity of water demanded by the household. Furthermore, because the price, at $1.80 per 1,000 gallons, would be entering the "elastic region" of the demand curve, prices beyond $1.80 per 1,000 gallons, would induce a percentage decrease in water quantity which is greater than the percentage increase in price. During season S2 the demand for water becomes relatively elastic at $1.33 per 1,000 gallons. The impact of price as a disincentive for water consumption is greatest during the months of

April to July. This, as already noted, implies that non-crucial, e.g., outdoor, uses of residential water will be foregone first if water users attempt to reduce consumption. The demand for water during season S3 is so inelastic that it would require a price of $3.23 per 1,000 gallons before a given percentage increase in water price would induce the same percentage decrease in consumption.

Table 5-1 contains information on price elasticities for the Regions. As expected, the quantity response to a price increase would be greatest during season S2 for all samples. The quantity response to a price increase is smallest during season S3 for all Regions except Duval.

A caveat needs to be issued at this point in the discussion of the potential of water prices as a deterrent to consumption. The calculation of these price thresholds uses the coefficients of the regressed equation. The price coefficient yields the change in water demanded as price increases, <u>with all other variables held constant</u>. If this assumption is known to be the case then the use of price ranges established from the coefficients can be applied with confidence.[3] However, if the constancy of the other variables is unlikely or unknown then the use of price ranges typified by Table 5-1 should be utilized only as a guideline for water rate structure policy.

Implications for Water Conservation

An objective of this chapter is to apply the results of the regression equations to a discussion of the potential for residential water conservation for the St. Johns River WMD.

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[3]For example, a variable like household size is unlikely to change very quickly over time.

Table 5-1. Prices at which demand for water becomes elastic* (points of unitary elasticity)

Region	S1 December - March	S2 April - July	S3 August - November
District	1.80	1.33	3.23
Brevard	2.23	1.60	6.37
Duval	1.05	.89	.92
Lake	1.03	.91	1.87
Orange	1.04	.93	1.88
Volusia	2.23	1.80	3.53

*Prices are average prices as previously defined.

The need for conservation in the District has been expressed by the District Board and by several coastal water utilities for some time. Recent endeavors to institute conservation by District wide authorities include:

(a) The city of Jacksonville in 1977 passed an ordinance against use of the Floridan Aquifer for once-through cooling of heat pumps. The restriction was in response to the significant deterioration of the quality of the Aquifer which is Jacksonville's primary source of potable water.[4]

(b) The city of Titusville in 1980 was issued by the SJRWMD an extension of its present well capacity only after agreeing to submit, within 18 months of the issuance, a water conservation plan designed to reduce the GPCD figures for residential consumers. This was the first time a water conservation program was stipulated in the issuance of a well permit.[5]

(c) The city council of Vero Beach in 1981 voted to alter the residential water rate structure from the declining block system to one which penalizes heavy residential users.[6]

(d) The county of Brevard has recently instituted a water conservation program in the public schools. Students are becoming acquainted with the causes of water shortages and ways in which they may practice

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[4]Communication from Gary V. Weise, Water Conservation Manager, City of Jacksonville, dated 27 March 1981.

[5]St. Johns River Water Management District, Permit No. 2-009-0008, date issued 12 August 1980.

[6]Gardner, G., "Council Votes to Penalize Residential Water Waste," Beach Press-Journal, 5 February 1981.

conservation in their homes. The pollution of water supplies by salt water intrusion is the crucial problem which has resulted from increases in public water demand.[7]

The conclusions which were drawn concerning seasonality effects on residential water use suggest several prospective success areas for conservation. It was established that the outdoor uses of water, e.g., lawn and garden irrigation, which took place primarily during the late spring and early summer months were more expendable to the residential consumer. Thus official discouragement of such uses through rationing or seasonal peak rate adjustments may be very effective. It should be noted that the role of public education could be very successful as well. The lag time between the institution of public education programs and the desired results is likely to be greater than with the other two programs (more on this subject will be provided below).

Disincentives for use of lawn and garden irrigation water should not be limited to public supply users. Whether or not water is treated and publicly distributed or drawn from private wells, its aquifer or surface source may be the same. Likewise, the initial landscaping of outdoor land areas whose maintenance will require prodigious amounts of water can be influenced by city ordinances or price policies, and they are appropriate targets for public education programs.

The use of the public sewer instead of the septic tank tended to decrease water consumption. As previously noted, the existence of high wastewater charges in the District may account for this. As the District increases its urbanization rate from its present 80+ percent of the

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[7] Communication from Robert Massarelli, Director, Water Resources Dept., Brevard County, 16 April, 1981.

population, the use of public sewer mains may increasingly replace septic tanks. The "conservation effect" of this replacement will occur naturally as present municipal water systems spatially extend their services or new systems are created in growing communities.

The discussion thus far has centered on the water conservation possibilities for outdoor uses. The regression results have also indicated areas of conservation within the home. The percentage of homes in the District which own clothes washing machines is 90 percent. Because we have established that the washing machine has a notable effect on monthly water use, conservation practices applicable to that 90 percent of presently installed machines may produce desirable results. This may include such practices as insuring that loads are maximum, and that washing and rinsing cycles are shortened where possible. On the other hand, if the remaining 10 percent of non-owners are viewed as potential owners of washing machines, then the purchase of the newer water saving models should be encouraged.

The solution for the conservation of water in dishwasher use is similar. The present owners of machines should be encouraged to fill them completely before use. And again, the 52 percent of potential owners, i.e., those households who do not presently own a dishwasher, should be encouraged to purchase water saving models.

Additional bathrooms in homes have a significant impact on the amount of water used. This is of course due to the presence of showers, bathtubs, toilets, and sinks. Conservation practices which alter the amount of water consumed per use period for each of these are available. Habits of use such as toilet flushing after each use, maximum filling of bathtubs, and 30 minute showers can be reduced. Also the installation of water saving devices such as pressurized showerheads, mechanical adjustments for toilets, etc., would, no doubt, lower household water use.[8] Given that a positive correlation between bathrooms and income was notable, households with more than one bathroom can, at least theoretically, afford to purchase water saving devices.

It should be noted here that the purpose of water conservation in American residential communities is to lower the quantity of water demanded for uses which are relatively inessential. Conservation programs are not designed to endanger human health or hygiene. Implicit here is the serious consideration of the priorities of water demand in light of the vagaries of the water supply.

Water conservation can be implemented in a number of ways, all of which have been previously mentioned. The methods are rationing, public education, the dissemination of water saving devices, and pricing policies. Rationing can be effected in different ways; some water uses can be prohibited altogether, such as irrigation or car washing, or quantity maximums can be established with the imposition of a fine or greatly increased price for gallons used over the ceiling quantity. This method is essentially a supply reduction scheme. However, it does reflect demand information: a) it rates certain uses of residential water as less important to consumers and therefore, at least temporarily, expendable, and b) it recognizes that, at least at some high range, price will be an ultimate deterrent to use. Rationing is most effective only as a short term program because enforcement costs of use prohibitions are expensive, and fine impositions could be more efficiently handled in the long run with rate structure changes.

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[8]See Milne, M., Residential Water Conservation, for more information about conservation type models of household water using appliances and water saving devices for bathroom fixtures.

Public education programs are very effective means for effecting water conservations. Programs geared toward school children can help inculcate conservation values. Use of the media is also very crucial. In California in 1977 the statewide response to drought conditions was assisted by the success of the media in alerting citizens to the drought problems and instructing them in water reduction practices.[9] The offices of information are necessary to facilitate any water conservation plan. Consumers must first, understand and appreciate the dimensions of water availability problems in their areas, and second, be advised of how they can help to forestall dangerous shortages.

The dissemination of water saving devices by an official distributor, e.g., water utility, would be effective if they were, in fact, installed by the receiving consumers. Just how effective such devices are has already been demonstrated. Dissemination of water saving devices, however, implies a costly public program. In the District the installation of these conservation devices might be considered with a public education program which suggests that individuals purchase and install them on their own.

An incentive for these purchases beyond "moral suasion" can most certainly be provided by an adjustment of the water rate schedules. The potential effectiveness of higher prices for residential water has been discussed. As a conservation plan, it should be noted that rate increases are the most efficient means of insuring conservation because it entails no additional programs, or enforcement, although the rationale for the adjustments should of course be made known to the public.

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[9] See Hoffman, M., et al., "Urban Drought in the San Francisco Bay Area: A Study is Institutional and Social Resiliency," Journal of American Waterworks Association, Vol. 71, No. 7, July 1979.

Conservation and Forecasting

Another objective of this chapter was to use the preceding objectives in a discussion of the role of the WUDEM model in forecasting demand. As noted earlier, WUDEM was not designed to be a forecasting model. However, the information it yields can be helpful as a general guide to effecting the changes in forecasting methods which were presented in Chapter Two.

Forecasting relies on two tools, the GPCD figure and population estimates. The residential portion of the former is affected by the variables that were regressed in the demand equations (and also by other variables which were included and remain unknown). It is known that if prices of water increase it will have a negative effect on that residential GPCD figure.[10] Likewise, if income and household sizes were to increase, more water using appliances were to be purchased, and more bathrooms added to homes, these circumstances would tend to increase the GPCD figures.

The promotion of water conservation programs, if it is successful, will make forecasting difficult. The effect of the variables above will have to be modified. For example, the contribution of income to an increase in demand may be mitigated by more access to information concerning conservation. If so, the higher income household may purchase water saving devices and otherwise limit their use of water. Other examples may be found in the domestic technology variables. Effective water conservation programs may be persuasive enough to reduce the effect of

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[10]It should be noted again that the WUDEM model represents single-family dwellings. The structure of demand for water may be different for multiunit households. This possibility deserves further research, especially in light of the decline in the family sizes.

appliances if water saving models are purchased. What this discussion implies is that during the period of time in which the water psychology and policies are in transition from "abundance to scarcity," forecasting methods must also change.[11] The WUDEM model represents a point in time which is on the threshold of this transition. Forecasting in a dynamic sense now is a requirement for the prediction of water demands; the use of the past to predict the future will not be acceptable.

For Further Research

Throughout the analysis section of this report suggestions for further research of certain variables were proposed. As a final note, two very comprehensive areas in water demand analysis which require further research will be presented:

(1) The possibility of time of day rate structure changes needs to be explored. "Time of day" pricing refers to the changing of higher rates per 1,000 gallons during periods of the day in which the most water is used simultaneously by the majority of the community's households, e.g., around 6-7 p.m. Previous studies suggest that such pricing would be effective, however, the rising trends of women working may neutralize the disincentive to change the execution of household chores from peak periods to nonpeak periods. This question of time of day pricing and the flexibility of household scheduling would be a valuable area for future research endeavors.

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[11]This kind of transition is not new. In the late fifties and early sixties, due to increasing incomes and changes in household technology, the GPCD figure rose substantially. At the time forecasting with "old" models resulted in water supply shortages.

(2) The use of time series analysis would be an effective method for the evaluation of the impact of price elasticities. Because of the incomplete data sets of the respondents time series could not be applied in this study. It is for this very reason that such analysis has been used infrequently in water demand research. The use of "dynamic" information, however, would most certainly enhance water demand analyses which is presently based primarily on cross-sectional data.

APPENDIX A

RESIDENTIAL WATER RATE SCHEDULES FOR SAMPLED SJRWMD WATER UTILITIES

APPENDIX A
RESIDENTIAL WATER RATE SCHEDULES
FOR SAMPLED SJRWMD WATER UTILITIES

(Rates are for 3/4, 5/8" meter and do not include wastewater charges or taxes unless otherwise noted)

Utility	Minimum bill and quantity covered in minimum bill	Charge per 1,000 (M) gallons beyond minimum bill	Billing period
Brevard			
City of Palm Bay	$6.00[a]	$2.50/M gallons for all gallons	monthly
City of Cocoa[b]	$4.80 for 0 - 4M gallons	$ .70/M gallons for 5M - up gallons	monthly
G.A.C. Utilities	$12.50 for 0 - 4M gallons	$ .85/M gallons for 5 - 10M gallons	monthly
		$ .50/M gallons for 11 - 100M gallons	monthly
		$ .35/M gallons for 101M - up gallons	monthly
General development utilities	$4.68	$1.45/M gallons for all gallons	monthly
West Melbourne	$8.79 for 0 - 3M gallons	$1.30/M gallons for 4M - up gallons	monthly
Duval			
Artesian utilities	NOT AVAILABLE		
Beauclerc utilities	$6.39 for 0 - 9M gallons	$ .35/M gallons for 10M - up gallons	quarterly
Canal utilities	$7.80	$ .32/M gallons for all gallons	
City of Atlantic Beach	$6.00 for 1 - 15M gallons	$ .15/M gallons for 16M - up gallons	quarterly

RESIDENTIAL WATER RATE SCHEDULES
FOR SAMPLED SJRWMD WATER UTILITIES
(Continued)

Utility	Minimum bill and quantity covered in minimum bill	Charge per 1,000 (M) gallons beyond minimum bill	Billing period
El Aqua utilities[b]	$6.22 for 0 - 8M gallons	$ .41/M gallons for 9 - 12 M gallons	monthly
		$ .36/M gallons for 13M - up gallons	
City of Jacksonville	$5.54 for 0 - 500 cubic feet	$4.40 + (each 100 c.f. x .38)	monthly
City of Jacksonville Beach	$4.84	$ .31/M gallons for all gallons	monthly
City of Neptune Beach	$6.00 for 0 - 15M gallons	$ .40/M gallons for 15 - 30M gallons	quarterly
		$ .35/M gallons for 31 - 45M gallons	
		$ .30/M gallons for 45 - 60M gallons[c]	
Jacksonville suburban utility corporation[d]	$9.87 for 0 - 1200 cubic feet	$ .69/100 cubic feet for all cu. feet	quarterly
Mandarin utility	$15.33 for 0 - 9M gallons	$ .87/M gallons for 10M - up gallons	quarterly
Normandy Village utility corporation	$3.50 for 0 - 500 cubic feet	$ .40/100 cubic feet for 500 - up cubic feet	monthly
City of Baldwin	$3.50 for 0 - 4M gallons	$ .75/M gallons for 5 - 7M gallons	monthly
		$ .60/M gallons for 8 - 10M gallons	
		$ .50/M gallons for 11M - up gallons	
Southern utilities	$10.68 for 0 - 1200 cubic feet	$ .57/100 cubic feet for 1200 - up cubic feet	quarterly

RESIDENTIAL WATER RATE SCHEDULES
FOR SAMPLED SJRWMD WATER UTILITIES
(Continued)

Utility	Minimum bill and quantity covered in minimum bill	Charge per 1,000 (M) gallons beyond minimum bill	Billing period
Lake			
Astor-Astor Park Water Association	$9.00 for 0 - 5M gallons	$2.00/M gallons for 6M - up gallons	monthly
City of Clermont	$3.00 for 0 - 3M gallons	$ .50/M gallons for 4 - 10M gallons	monthly
		$ .40/M gallons for 11M - up gallons	
City of Eustis[b]	$4.00 for 0 - 4M gallons	$ .54/M gallons for 5 - 50M gallons	monthly
		$ .44/M gallons for 51M - up gallons	
City of Fruitland	$3.00 for 0 - 3.7M gallons	$ .53/M gallons for 4.7 - 7.5M gallons	monthly
		$ .47/M gallons for 8.5 - 15M gallons	
		$ .40/M gallons for 16 - 22M gallons	
		$ .33/M gallons for 23M - up gallons	
City of Groveland	$4.50 for 0 - 5M gallons	$ .25/M gallons for 6M - up gallons	monthly
City of Howey in the Hills	$2.40 for 0 - 4M gallons	$ .45M gallons for 5 - 10M gallons	monthly
		$ .35M gallons for 11 - 50M gallons	
		$ .25/M gallons for 51M - up gallons	
City of Leesburg	$4.00 for 0 - 4,488 gallons	$ .47/M gallons for 5,488 - up gallons	monthly

RESIDENTIAL WATER RATE SCHEDULES
FOR SAMPLED SJRWMD WATER UTILITIES
(Continued)

Utility	Minimum bill and quantity covered in minimum bill	Charge per 1,000 (M) gallons beyond minimum bill	Billing period
City of Monteverde	$4.50 for 0 - 3M gallons	$ .35/M gallons for 4 - 13M gallons	monthly
		$ .30/M gallons for 14M - up gallons	
City of Minneola	$3.50 for 0 - 2M gallons	$ .50/M gallons for 3M - up	monthly
City of Mt. Dora	$2.64 for 0 - 300 cubic feet	$ .34/100 cubic feet for 400 - 100 cubic feet	monthly
		$ .28/100 cubic feet for 1000 - 4000 cubic feet	
		$ .20/100 cubic feet for 4000 - up cubic feet	
City of Traveres	$3.00 for 3M gallons	$ .50/M gallons for 4 - 50M gallons	monthly
		$ .40/M gallons for 51M - up gallons	
City of Umatilla[b]	$4.00 for 0 - 5M gallons	$ .35/M gallons for 6 - 10M gallons	monthly
		$ .30/M gallons for 11 - 20M gallons	
		$ .25/M gallons for 21M - up gallons	
<u>Orange</u>			
Central V Utilities	$3.35 for 0 - 3M gallons	$ .48/M gallons for 4M - up gallons	monthly
Orange County	$5.00 for 0 - 4M gallons	$ .70/M gallons for 5 - 10M gallons	monthly
		$ .60/M gallons for 11M - up gallons	

RESIDENTIAL WATER RATE SCHEDULES
FOR SAMPLED SJRWMD WATER UTILITIES
(Continued)

Utility	Minimum bill and quantity covered in minimum bill	Charge per 1,000 (M) gallons beyond minimum bill	Billing period
Orlando Utility Commission (OUC)[b]	$1.85 for 0 - 1M gallons	$ .44/M gallons for 2 - 100M gallons	monthly
		$ .37/M gallons for 101M - up gallons	
<u>Volusia</u>			
City of Daytona Beach	$4.14 for 0 - 2M gallons	$1.12/M gallons for 3 - 8M gallons	monthly
		$1.04/M gallons for 9 - 50M gallons	
		$ .94/M gallons for 51M - up gallons	
Green Acres Estates	$3.00 for 0 - 2M gallons	$1.00/M gallons for 3M - up gallons	monthly
Holly Hill[b]	$3.50 for 0 - 2M gallons	$ .75/M gallons for 3M - up gallons	monthly
New Smyrna Beach Utility Commission	$4.12	$ .75/M gallons for all gallons	monthly
City of Ormond Beach[b]	$12.60 for 0 - 2M gallons	$ .85/M gallons for 3M - up gallons	monthly
City of Ponce Inlet	$5.00 for 0 - 2M gallon	$2.20/M gallons for 3 - 9M gallons	monthly
		$2.70/M gallons for 10 - 22M gallons	
		$3.20/M gallons for 23M - up gallons	

RESIDENTIAL WATER RATE SCHEDULES
FOR SAMPLED SJRWMD WATER UTILITIES
(Continued)

Utility	Minimum bill and quantity covered in minimum bill	Charge per 1,000 (M) gallons beyond minimum bill	Billing period
City of Port Orange[b]	$4.00 for 0 - 2M gallons	$1.02/M gallons for 2M - up gallons	monthly
City of South Daytona	$3.75 for 0 - 2M gallons	$1.25/M gallons for 2M - up gallons	monthly

Notes:

[a]Rate includes wastewater charge.

[b]Inside-city limits rate quoted only.

[c]Complete rate structure continues on this pattern.

[d]1 cubic foot = 7.48 gallons

APPENDIX B

OTHER VARIABLES FOR WHICH DATA WAS COLLECTED

APPENDIX B

OTHER VARIABLES FOR WHICH DATA WAS COLLECTED

The following provides a discussion on the variables which were not used in the final equations, due either to their high correlation with variables presently in the final equations or to their consistent demonstration of statistical insignificance in the initial analyses. They are presented in appendix form because of their potential importance in further estimation procedures.

The variables are identified and categorized into the following variable groups:

<u>Domestic Technology</u>

GARBAGED - the presence of a garbage disposal,

WASHCAR - the frequency of car washing,

SIZEAREA - dimensions of area irrigated,

TIMEDAY - time of day which the irrigation of a lawn or garden takes place.

<u>Socioeconomic</u>

AGE0T10 - persons in a household who are 10 years of age or younger,

AGE11T20 - persons in a household who are between 11-20 years of age,

AGE21T40 - persons in a household who are between 21-40 years of age,

AGE41T60 - persons in a household who are between 41-60 years of age,

AGE61UP - persons in a household who are over 60 years of age,

OCCUPAT - occupation of the head of the household,

SCYRSCOM - highest level of education attained by the head of the household.

Knowledge

COSTCONS - awareness of cost when using water,

RATESCHE - familiarity with the local water rate schedule.

Miscellaneous

GUESTS - number of guests per year,

STAYPD - average length of stay for guests.

The following provides an explanation of each variables effect on household water use:

(1) Presence of a garbage disposal (GARBAGED): the presence of a garbage disposal is expected to be positively correlated with water use. The garbage disposal is estimated to use between 3 - 15 gallons per 3 minute period.[1] In the District sample 31 percent of the respondents owned garbage disposals. GARBAGED did not, however, appear to be consistently significant in the critical equations.

(2) Washing a car at home (WASHCAR): this variable is expected to be positively correlated with water use levels. WASHCAR was not statistically significant in initial testing. In the District sample 66 percent of the respondents indicated that they seldom washed their automobiles at home.

(3) Time of day during which watering is usually done (TIMEDAY): it is hypothesized that more water may be required if irrigation takes place during the times of the day when evapotranspiration is the highest. While rates of evapotranspiration vary throughout the

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[1] Gehm, H. and Bregman, J. Handbook of Water Resources and Pollution Control, p. 57.

District, generally the highest rates are from 6 AM to 6 PM and the lowest are from 6 PM to 6 AM. These two periods were divided into four periods and consumers indicated during which period they usually irrigated. The TIMEDAY variable was not statistically significant in initial testing. In the District sample 35% of the respondents indicated that they watered their lawns and gardens from 6 PM - 12 AM.

(4) Size of the area watered (SIZEAREA): this variable will be positively correlated to water use levels if the consumer does not possess a well for irrigation. This variable did not appear to be statistically significant in initial testing. In the District sample 86 percent of the respondents indicated that they watered a lawn or garden which was equal to or less than a one-fourth acre in size.

(5) Ages of residents in a household (AGE0T10, AGE11T20, AGE21T40, AGE41T60, AGE61UP): the preceding variable NUMRESPH, was divided into respective age groups. It was hypothesized that changes in certain age groups will have effects on the overall water use in the household. It is expected that the age groups AGE11T20, and AGE21T40 will require more water (for personal hygiene and laundry) than the youngest or the oldest groups, thus these variables will have a higher positive influence on monthly average water consumption. Age distributions are correlated with NUMRESPH and thus would have to be separately tested in the statistical equations. In the District sample, 19 percent of the households had persons from 0 - 10 years, 25 percent had persons from age 11 to 20, 36 percent had persons from age 21 - 40, 46 percent had persons from age 41 - 60, and 39 percent had persons over age 60.

(6) Occupation (OCCUPAT): this variable is expected to have a positive effect on water use because of its anticipated high correlation with income. Occupations were grouped into U.S. Census Bureau categories with professional, technical and managerial categories in the highest numerical categories. In the District sample, 21 percent of the respondents were listed as professional or technical, and 31 percent were retired. The next two largest categories were managers and sales workers, each at approximately 10 percent of the total sample.

(7) Highest level of education completed by the head of the household (SCYRSCOM): this variable is hypothesized to have a positive effect on water use because of its anticipated high correlation with occupation and income. For the same reason it was not utilized in the final equations. In the District sample 39 percent of the respondents indicated that they had completed high school, and 19 percent indicated that they had completed 4 years of college.

(8) Consumer consciousness of water costs (COSTCONS): consumers were asked if they were usually conscious of the cost of water when using it. This variable is expected to be negatively correlated with the amount of water used since water's "cost" would most likely be interpreted as "price" which is expected to be a deterrent to water use. While 91 percent of the sample reported that they were cost conscious, the variable was not statistically significant in initial testing.

(9) Knowledge of the residential water rate schedule (RATESCHE): consumers were asked if they were familiar with the rate schedule which the local utility uses to determine their water bill. This is expected to be negatively correlated with water use for the same

reasons as COSTCONS. The variable RATESCHE was not statistically significant. In the sample 60 percent of the respondents indicated that they were familiar with the local rate schedules for residential water.

(10) Number of guests per year (GUESTS) and the average length of their stay (STAYPD): both of these variables are expected to be positively correlated with water use levels. Neither of these variables appeared to be statistically significant in the initial testing. In the sample 77 percent of the respondents reported that they received less than 10 overnight guests a year, and 63 percent indicated that the average length of stay for guests was 2 - 7 days.

APPENDIX C

DESCRIPTIVE STATISTICS OF THE SAMPLE AND POPULATION

APPENDIX C

DESCRIPTIVE STATISTICS OF THE SAMPLE AND POPULATION

The following section provides the descriptive socioeconomic data of both the sample respondents and the District population. It is important to compare these characteristics to ascertain the extent to which the sample is representative of its population. The characteristics which will be presented are number of persons per household and their age groups, income, and education levels.

Household Size

For NUMRESPH the modal household size was two and this category alone accounted for 43% of the sample. The percentage of the sample under 5 persons per household was 90.5 percent. The mean household size was 2.66 persons. In 1970 the average household size in Florida for single family dwellings was 3.11 persons. It is anticipated that that figure would decrease by 11.5 percent (the national average) due to changing lifestyles. This would place the mean single family household size in Florida at 2.75 persons. Assuming that the District follows similar trends, the comparison between the household size for the sample and the population are quite good.

In the disaggregated regional data the mode again is 2 and the means measure between 2.38 persons in Region III (Lake County) and 2.9 persons in Region II (Duval County).

Age Groups

In 1978 the District percentage of the population under 15 years of age was 24.4 percent. In the total sample 18.6 percent of the households

Occupational Group Percentages, by Region

Region	Professional, technical, managerial	Retired
I	38.5 %	30.8 %
II	45.1	16.2
III	21.6	39.4
IV	32.3	22.6
V	22.6	39.9
Total sample	21.6	30.5

Income Group Percentages, By Region

	% in average income group					
Region	5-9.9	10-14.9	15-19.9	20-29.9	30-49.9	over 50
I	15.0	18.7	20.6	22.4	15.9	3.7
II	8.8	10.2	20.0	28.8	25.1	6.0
III	24.0	14.4	13.0	26.7	11.6	2.7
IV	16.5	21.1	18.3	19.3	19.3	3.7
V	28.0	20.4	17.6	15.6	9.2	4.8

had members under the age of 11 years. Of this group, 11 percent had one person in this category and 6.6 percent had 2 or 3 members under 11 years.

In the total sample 62 percent of the households had members between the ages of 11 and 40. District wide in 1978, the percentage of the population between 15 and 44 years was 40.2 percent. Within the sample 21 percent of the household had 2 persons between the ages of 21 - 40. The age group 45 - 64 accounted for 21.2 percent in the district counties while in the sample the corresponding age category 41 - 60 accounted for 28 percent with 37 percent of the households having one or two persons in this age group.

The oldest age group, over 64 years of age, accounted for 14.3 percent of the District population while the corresponding sample age group, over 60, accounted for 41.1 percent of the households having members in that category. It is relatively safe to say that in age groupings the sample is a fair representation of the population in the District. The discrepancies can perhaps be explained by the wider spread of ages in the sample categories which, in all probability, account for the comparatively higher categories in the sample than in the population statistics.

Income

The model group for annual household income was $20,000 - $29,000 with 22.4 percent of the sample falling into this castgory. Over 57 percent of the sample fell below $20,000. When the groupings were averaged the mean income was approximately $14,600. The Florida state average household income in 1977 was $10,032. The District average in 1977 was $9,112.00.

Within the Regions differences appear between sampled incomes and average incomes for the counties. In Region I (Brevard) the average income in 1977 was $11,063. In the Region I sample the percentage falling in this category was 18.6 percent while the modal income group was $20 - 29,999. In Region II (Duval) average income in 1977 was $10,489. In the corresponding sample only 10.2 percent fell in this category and the modal group was $20 - 29,999 which comprised nearly 30 percent of that Region's respondents. In Region III (Lake) the average income in 1977 was $8,517. In the corresponding sample the respective modal income group, $5 - 9,999, accounted for 24 percent of the respondents. The modal group, $20 - 29,999, was still higher at 26.7 percent. In Region IV (Orange) the average income in 1977 was $10,006. In the sample, the percentage falling into this income category, $10 - 14,999, was the mode at 21.1 percent. In Region V (Volusia) the average income in 1977 was $8,367. In the sample this modal income category, $5 - 9,999, received nearly 30 percent of the Region's sample.

Thus in two regions, Volusia and Orange counties, the income characteristics between the sample and the population converge better than in the other three regions. One minor statistical explanation for the divergence could be that real income figures are only available in 1977 and that some growth in average income by 1979 would be expected. Probably a more likely reason for the difference is the tendency for higher income persons to respond to mailed surveys. In light of the high income reported it is interesting to note the occupational categories of the respondents (see Table C-1).

Education

An average of the median years of education completed for all

District counties is 12.1 in 1970 and the median of the total sample was 12.4. The average percentage of persons graduating from college was 27.7 percent. In each region the percentage of college graduates was approximately the same as in the total sample except for Region II (Duval) where the percentage of college graduates in the sample was 46 percent. Again the reasons for the differences are probably first, that education statistics of the population are 9 years old and that most likely the true figures for 1979 are higher, and second, that comparatively educated persons are more likely to respond to mailed surveys.

In summary, the sample represents the population of the SJRWMD most accurately in terms of household size and age groupings but probably less so in terms of income and education. Considering the qualifications given for the discrepancies, however, the sample drawn can be used with confidence to represent that portion of the District population served by public water utilities.

APPENDIX D

DESCRIPTIVE STATISTICS OF ALL WUDEM VARIABLES FOR DISTRICT SAMPLE

APPENDIX D

Descriptive Statistics of All Wudem Variables for District Sample

Variable	Mode	Sample % at mode	Mean	Range		% of respondents answering
NUMRESPH	2	.43	2.66	1	10	.99
AGE0T10	0	.81	.27	1	3	.97
AGE11T20	0	.74	.42	1	5	.97
AGE21T40	0	.63	.59	1	3	.97
AGE41T60	0	.53	.76	1	4	.97
AGE61UP	0	.60	.63	1	6(one case)	.97
INCOME	$20-29,999	.22				.84
OCCUPAT	Retired	.31				.96
SCYRCOM	12	.39	13.36	1	22	.95
BATHROOM	2	.50	1.81	0(three cases)	6(one case)	100
DISHWASH	yes	.53				100
WASHMACH	yes	.90				100
GARBAGED	no	.69				100
SWIMPOOL	no	.89				100
SEWSEPT	public sewer	.75				.99
HAVEWE11	no	.62				.98
WE11USE	lawn/garden	.86				.37
WATERLG	yes	.78				.99
TIMEDAY	6 PM-12AM	.35				.70
SIZEAREA	1/4 ac or less	.86				.76
WASHCAR	seldom	.66				.99
COSTCONS	yes	.91				.99
RATESCHE	yes	.60				.99
GUESTS	0-10	.77				.98
STAYPD	2-7 days	.63				.89
AVG*			7.1	1.33	130.5	100.00
AVGPRICE			$ 1.08	.19	11.50	100.00

*in thousands of gallons

APPENDIX E

RESIDENTIAL WATER USE SURVEY
TO CONSUMERS AND SUPPLIERS

APPENDIX E

RESIDENTIAL WATER USE QUESTIONNAIRE

W__________

1. How many people presently live in this household? _______________
Ages of residents (number in each category)

_______0-10 _______11-20 _______21-40 _______41-60 _______61+

2. What was the last grade completed in school by the head of this household?

3. Number of overnight guests per year (check one)

_______0-10 _______11-20 _______21-40 _______over 30

Average length of stay (check one)

____ 1 day ____2-7 days ____1-2 weeks ____2-4 weeks ____Over 1 month

4. Which of the following appliances or facilities do you have in your household?

__Garbage Disposal __Dishwasher __Washing Machine __Swimming Pool

5. How many bathrooms does your household have? _____

6. Do you water your lawn or garden? ___Yes ___No, If Yes, Approximate time of day ________
Approximate size of area which you water (check one)

___1/4 acre or less ___1/2 acre ___3/4 acre ___1 or more acres

7. Do you have a well? ____Yes ____No, If Yes, What is it used for__________

8. Do you have ____public sewer or ____septic tank?

9. Do you wash your car at home? (check one) ___Often ___Seldom ___Never

10. Please list the occupations of the head of the household and other working members of the household____________________________________

11. Are you at all conscious of cost when you are using water? ___Yes ___No

12. Are you familiar with the rate schedule which the utility uses to determine your water bill? ____Yes ____No

13. What is the combined yearly income of the working members of this household?

_____5,000-9,999 _____10,000-14,999 _____15,000-19,999 _____20,000-29,999

_____30,000-49,999 _____Above 50,000

14. COMMENTS:____
____

ST. JOHNS RIVER
WATER MANAGEMENT DISTRICT

FREDERICK O. ROUSE
Executive Director

ROUTE 2 BOX 695
PALATKA, FLORIDA 32077
TELEPHONE (904) 325-5383

To Head of Household:

The St. Johns River Water Management District is undertaking a survey of water use in various municipalities throughout the District and your household has been chosen at random to be a part of our sample.

The purpose of this study is to better understand the factors which affect water use by individual households. This is of utmost importance in assessing and planning for the overall water needs of your area.

As the validity of this study depends upon only a small number of households, your responses are highly significant. Therefore, we would greatly appreciate your cooperation in filling out and returning this questionnaire.

We would like to assure you that the information in the questionnaire will be used for statistical purposes only and that your name and individual responses will not be identified in the published report. Should you have any questions about the survey, you may contact us at the District headquarters by calling 904/325-5383 or by writing to the address listed above.

Sincerely yours,

Arlene Malick
Resource Economist
Department of Resource Planning

AM:djm
Enclosure

ST. JOHNS RIVER

WATER MANAGEMENT DISTRICT

ROUTE 2 BOX 695
PALATKA, FLORIDA 32077
TELEPHONE (904) 325-5383

May 30, 1979

Dear Water Supplier,

The St. Johns River Water Management District is initiating a study of residential water demand patterns to better understand the factors which affect individual household water use. The study will provide useful information for both residential water supply companies and the District for use in allocation decisions, efficiency planning, water shortage problems and water use projections.

There are a large number of cities included in the District boundaries and surveying all of them would be too expensive and time consuming. Your responses to the attached questionnaire are very important in helping us choose sample areas that will be most representative of the District as a whole.

It is important that you answer the questions fully as quantity and price data will be gathered from the water companies chosen for the sample, and record keeping methods and rate structures must be comparable. All information gathered will be used for statistical purposes only and will remain anonymous.

Should you have any questions or comments, feel free to contact me at the District headquarters by calling 904/325-5383.

Sincerely yours,

Arlene Malick

Arlene Malick
Resource Economist
Division of Resource Planning

AM/lb

Residential Water Supply Questionnaire

1. Name, address and phone number of your company:

____

____

____

____

2. Please attach a copy of your rate structure for residential water use and sewage service.

3. Are your water use and disposal rates related to each other?____________________
If so, how?____

____

____

____

____

4. Does your rate structure include an initial flat fee?____________. If so, for how many gallons?_______________.

5. Is there a separate rate structure for water used in lawn irrigation?
________________________.

6. Describe your record keeping system (what is recorded; how is it recorded).

____

____

____

____

____

7. How far back in time are your records kept?___________________________________

8. Are commercial and residential accounts kept separate?_________________________

9. Has there been any rate changes in the last five years and, if so, was the quantity of water used by each customer recorded during the changes?______________________

____

____

____

____

____

10. How many residential customers do you serve (number of connections)?_______________

Please feel free to attach any additional comments or information.

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