5-1964

Demand for Household Water in Northern Utah, 1962

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DEMAND FOR HOUSEHOLD WATER IN NORTHERN UTAH, 1962

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Agricultural Economics

UTAH STATE UNIVERSITY
Logan, Utah

1964

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ACKNOWLEDGMENTS

I wish to express appreciation to the Department of Agricultural Economics' staff for their professional guidance. Special appreciation is expressed to Dr. B. Delworth Gardner for his superior interest and guidance through the difficulties encountered in this study.

Extraordinary appreciation is expressed to my wife, Karren, for her efforts in typing and editing the preliminary copies.

Seth H. Schick

INTRODUCTION AND STATEMENT OF THE PROBLEM

Water is not a single use resource. It can be used for completely unrelated purposes. There are four general uses for water: household, industrial, agricultural, and recreational. Since water is an economic good it must be properly allocated among the four uses to maximize the returns to society. Also, There must be proper allocation among competing units within each major use.

Household water is defined in this study to mean all water supplied by the municipal water system used in the house for human consumption and water-using conveniences plus all water used outside the house for irrigation. The term "household" is preferable to the term "culinary", which is often used to refer to one of the four major uses of water because the term "culinary" implies kitchen uses only.

Metropolitan areas must be supplied with household water that is both palatable and non-infectious because it is used for human consumption. This means water used for household purposes cannot be highly discolored due to a high saline content or contaminated with disease. Only water meeting certain quality standards can be used. Thus, water can be shifted from other uses to household use only if it is of acceptable quality.

Industrial water can be of lower quality in some cases than water used for household purposes. However, the closer water is to being pure the more easily it can be applied to industrial use. Boilers using water high in mineral content become lined with mineral deposits that must be periodically removed. For reasons such as this, manufacturers like to use the highest quality water available. This means that industry often competes with households for water supplies.

In 1958, Utah manufacturers used 4,518,518,000 gallons of water; (9) of this quantity, 76.2 percent was recirculated. The remaining 23.8 percent of the water used by manufacturers came from fresh supplies and not from recirculation. Also, 80 percent of fresh water used by Utah manufacturers was supplied by the companies themselves.

Agriculture, especially in Western United States, is dependent on water for survival. Large canals have been constructed to bring water to soil that would otherwise have very little production potential. Quality of this water can vary, within limits, according to the crops that are being produced.

In many cases water is of such quality and in the proper location to be used for any one of the four major uses. Sometimes these uses can be complementary, such as recreational uses and agricultural uses, where water can be used for both purposes. It is even conceivable that the same water could be used for all four purposes. For example, water can be used first for recreational purposes where it is stored for later use when the supply is not as great as the demand. The water could next be used for household purposes where it would later be reclaimed. Next, the water could be used by industry and again reclaimed and then used by agriculture where it would be consumed by plants and animals.

Unfortunately, not all water is of high enough quality and in the proper location to be used for all four purposes. Proper development of household and industrial reclaiming units are not used by all municipalities and industries. They may also all need or desire the given water supply at the same time. Therefore, the four uses of water must compete for the water supply.

Presently, Utah's water laws and regulations prohibit free movement of water resource to the use where it has highest marginal utility (8). Economic theory postulates that in order to maximize utility from a given resource it is necessary that marginal value of utility divided by price of water in each use be equal. Maximum utility from all uses would be where

$$\frac{MVU_{y1}}{P_{Xy1}} = \frac{MVU_{y2}}{P_{Xy2}} = \ldots = \frac{MVU_{yn}}{P_{Xyn}} =$$

Where MU_{yi} = marginal utility of water used for various purposes

P_{Xyi} = price of water used for various purposes.

As applied to industrial, agricultural, and recreational uses of water this becomes

$$\frac{MVU_{household}}{P_{household}} = \frac{MVU_{ind.}}{P_{ind.}} = \frac{MVU_{agric.}}{P_{agric.}} = \frac{MVU_{rec.}}{P_{rec.}}$$

This same theory might be used to allocate water between uses within each of the four major uses of water. The marginal utility per dollar spent for water should be equal for all users as well as uses.

REVIEW OF LITERATURE

Literature was reviewed which used analytical methods pertinent to the objectives of this study. Methods of determining significant variables and their elasticities were of particular interest. Studies pertaining to public resources, such as electricity and water, were reviewed to obtain clues to possible difficulties. Applications of least squares regression models, where water was involved, were also reviewed.

Dawson (1) was concerned with the manner in which one might obtain estimates of the demand for water on individual farms in a particular area. He states that if more information were available on the value of water for different uses, more could be said about needed directions in the reallocation of the source. Dawson discusses only water used for irrigation.

Three approaches were suggested that could be used to arrive at the demand for water. First, consider the market value for land, taking a cross-sectional sample of farms with water rights to various quantities of irrigation water. These must have similar soils and be located in a relatively homogeneous climatological area. These data were not available to him. Second, in certain areas one can look at the market value of water itself--either water rights or water. This would include water sold by those owning rights to storage water. Third, consider cost-quantity relationships on farms where irrigation is from wells and cost of pumping varies among farmers. This is the approach Dawson follows.

Dawson hypothesized that as cost of water increased quantity used decreased. Data were collected in Nebraska from farms using water from wells for irrigation. He assumed once a decision had been made to install a pump-irrigation system the farm would equate the short-run value of marginal product to the short-run marginal cost of water.

Cost of pumping water varied according to depth of the water table below the surface of the ground. He assumed pumping equipment could be varied in size to pump any quantity of water. Using least squares regression, elasticity of demand for irrigation water was found to be -0.5.

Hartment and Anderson (4) used the first method mentioned by Dawson where value of irrigation water is determined by value of land. They collected data from forty-four farms in one irrigation company in Colorado.

Data were taken from county and irrigation company records over a period of six years. Independent variables were assessed value of buildings, shares of irrigation company stock, 1960 sale of land (9 observations), 1959 sale of land (14 observations), 1957-1958 sale of land (11 observations), and 1954-1956 sale of land (10 observations). The dependent variable was value of the water stock in the irrigation company.

Data were fitted to a linear regression equation and the value of water stock was estimated. The coefficient of determination (R^2) for this model was 74 percent, which is the portion of the total sum of squares attributable to the set of independent variables. After several different models were tried, assessed value of farm buildings and total acres of farm land were found to be the most important independent variables.

Milliman (6) was concerned with techniques used for project planning and evaluation. The procedure most widely used by federal agencies is the "budget" method, which involves the estimation of primary benefits of water by making assumptions as to crops to be produced on the land and gross receipts arising from their sale.

Also, value of water can be determined from increased value of land. However, both the land value method and the budget method require bold assumptions, and the better method will depend upon circumstances which stem from individual project evaluation problems.

Milliman states that general pricing techniques for water leave a surplus of value. This means value received from the use of water is greater than cost incurred obtaining the water. The surplus value is then capitalized into value of the land. The land value method of measuring irrigation benefits would be the most applicable in this case.

Fisher and Kaysen (2) were concerned with demand for electricity in the United States. Their study was divided into four parts: demand by households, demand by industry, and short and long run determinants for each respectively. Basic techniques used were multiple regression and covariant analysis. This review will only be concerned with the part on households as this is pertinent to the present study.

The study was made using first differences of data taken over time. First differencing was done to partially remove interaction between variables used in the study made by Fisher and Kaysen. When summarizing the short run condition the states were in two major categories. Younger states have a higher price elasticity than the more mature states. Younger states have a price elasticity that is less than one and the more mature states have a price elasticity near zero. When summarizing the long run condition, elasticity of price had almost no effect on the consumption, and price of white goods (appliances) had only a small effect. First differencing was not used in the present study because comparisons were cross-sectional rather than over time. Fisher and Kaysen's study was reviewed here because it applied the multiple regression analysis technique to a public utility study.

Gottlieb (3) did extensive work with price as a factor affecting consumption of domestic water. He said price variation was partly attributable to economies of scale. Public water systems commonly frame rates to permit improvements or extension to be financed on the installment plan basis out of operating incomes, and this may have also caused variation in water prices. Also, pricing schemes may have been another cause of variation in prices between water systems if they were used as a means of excise taxation to supplement or replace the property levy.

Gottlieb makes reference to several studies where conclusions were made that price did not have a lasting effect on consumption of water. Many water works specialists were reported skeptical of cross-sectional regression studies where price is said to have prompt proportionate affect on consumption of water. One engineering firm expressed doubt that an 85 percent increase in water rates would have any permanent retarding influence on real per capita consumption.

After the review of price and consumption, Gottlieb turned to a multiple regression analysis using consumption of water as the dependent variable and price and income as independent variables. This study was done using 12 water systems in Illinois in 1947-49, 19 water systems in Kansas in 1952, two sets of 24 water systems in Kansas in 1957, 18 water systems in the United States in 1955, and another 34 water systems in the United States also in 1955. Each group of water systems was analyzed separately, and the results are in table 1 where the model assumed an equation that was linear in logarithms.

Headley (5) wrote on demand for residential and commercial water in the San Francisco-Oakland area. The objective of this study was to define the determinants of demand for water used for residential and commercial use and, where possible, to estimate parameters associated with these determinants as a basis for study and projection of demand for residential and commercial water.

Table 1. Results of multiple regression analysis (3)

	Million gallons per	No. of systems included	Year	Income elasticities	Price elasticity	Cor-relation (R)
Illinois	capita	12	1947-49	.89468	+ .27007	.949
Kansas	cust.	19	1952	.44946	-1.23820	.8286
Kansas	cust.	24	1957	.58283	- .67984	.8511
Kansas	capita	24	1957	.278442	- .65638	.8266
U.S.A.	[a]	18[b]	1955	.344	- .385	.45 (est.)
U.S.A.	[a]	34[c]	1955	.277	- .387	.45 (est.)

[a] Residential water use in 1,000 cubic feet per person per year

[b] Middle-sized standard metropolitan area

[c] All-sized standard metropolitan area.

Headley speculated that quantity of water demanded should be functionally related to price per unit, income of users, temperature, and precipitation. Cross-sectional comparisons were made in one model and demand relationships were described. Time series comparisons were made in another model for given cities.

Temperature and precipitation were not included as variables because the area studied was homogeneous with respect to weather conditions. Ten of the fourteen cities studied were supplied by the same company, and the four remaining cities obtained water from the same company. Also, because there were only two companies pricing the water, price could not be tested as an independent variable due to lack of variation.

This left only the family income variable to be tested. Headley felt that income could be used as a proxy for variables such as water-using appliances and fixtures and, therefore, the simple regression might be quite revealing.

A linear least squares regression equation was fitted to the data. The results were $X_0 = -30.24 + 2.16X_1$, where X_0 is consumption of water and X_1 is income. Standard error of the regression coefficient was .295 and a calculated t-ration of 7.33. Coefficient of determination was .81 and coefficient of simple correlation was .90. These calculations were for the cross-sectional analysis for 1950.

In the 1959 cross-sectional analysis, the result was $X_0 = -18.77 + 1.27X_1$. Standard error of the regression coefficient was .185 giving t-ration of 6.86. Elasticity of income was 1.47 in 1950 and 1.24 in 1959. From this he concluded that purchases of residential water were very responsive to changes in income and, therefore demand for residential water with respect to income was elastic.

Time series data were analyzed using the years 1950-1959 for each of the 14 cities. Each city was analyzed separately and regression coefficients and income elasticities were calculated.

There were marked decreases in elasticities of income. The simple average of the elasticities estimated was .25. Also, regression coefficients were not as significant as those for the cross-sectional model.

There were only two cities with a regression coefficient significant at the 10 percent level of significance. One reason they were not significant above α .10 might have been caused by the small number of degrees of freedom.

Headley concluded, in view of the historial information which he had showing the increase in gallons per capita per day of residential water purchases over time from 1950 through 1959, that elasticities estimated from the time series analysis seemed to be more reasonable and more useful in projecting demand for residential water even though they were not statistically significant. Also, Headley said the cross-sectional elasticities estimated would be useful to a city contemplating an additional subdivision or to estimate change in the demand due to a change in the method of billing.

OBJECTIVES OF THE STUDY

The supply of water for household purposes is not always sufficient to meet demand under present pricing and distribution conditions. Therefore, various methods have been used to ration supply to consumers. By determining the extent that certain factors affect demand, better methods of rationing can be made possible and also, better methods of predicting future consumption can be formulated. The objectives of the study were:

Objectives

1. To identify and quantitiatively estimate the importance of each variable affecting cross-sectional variation in consumption of household water during 1962.
2. To derive the demand curve (or schedule) for the consumption of household water.
3. To determine the elasticities of variables significantly affecting the consumption of household water.

The first objective, to find the significant variables, utilized three criteria that were generated by the regression analysis. The first was to compute regression coefficients, b's, for each of the variables and test them for statistical significance. Second, simple partial coefficients of determination (r^2) for each independent variable and per capita consumption were computed which will give a further indication of the explanatory variables.

Finally, standard partial regression coefficients ("the partial regression coefficients when each variable is in standard measure") (7, p.284) were computed for each independent variable. A priori, these variables seemed to be: price of household water, price of fuel used to heat water, real family income, weather conditions, lot size, value of homes, and whether or not homes have a complete plumbing unit.

A t test was used to test the hypothesis that $\beta = 0$ at the $\alpha_{.05}$ level. If the simple partial coefficients of determination (r^2) were less than 11 percent the independent variable was considered to have "low or little" affect on the dependent variable based on a lack of significance of the r^2 at the $\alpha_{.05}$ level with 35 degrees of freedom. If an r^2 was 11 percent but less than 17 percent the variable was considered to have "fair or medium" affect on the dependent variable based on a test of significance of r^2 at the $\alpha_{.05}$ using 35 degrees of freedom. If an r^2 was 17 percent or greater the independent variable was considered to have "high" affect on the dependent variable based on the r^2 being significant at the $\alpha_{.05}$ level using 35 degrees of freedom.

The standard partial regression coefficients were used as the third criterion. This criterion ranked the independent variables in relation to each other.

Each of the three criteria was used as an indicator of significance as no single criterion alone was considered sufficient. Also, it might be difficult to say each criterion was necessary since sometimes they give contradictory results. The criteria was used only as indicators, and if the indicators consistently showed strong significance the variable was considered significant. If only one indicator showed non-significance, a judgment had to be made on the level of significance indicated by the other two.

The second objective, to derive the demand curve for consumption of household water, made use of the hypothesis that as price increased quantity of water consumed per capita per day decreased as illustrated in figure 1.

The demand equation was simply the regression of price and consumption holding all other regression variables constant at

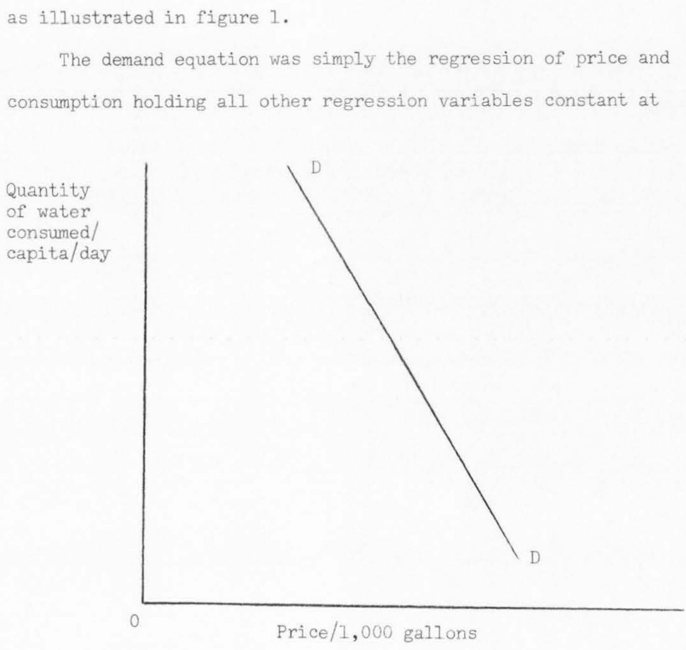

Figure 1. A hypothetical demand curve for water

their arithmetic means. Contrary to the convention of economics, note that price was measured along the horizontal axis consistent with statistical practice of placing independent variables there.

The third objective was to determine elasticity of the variables that were found to be significant. The general formula for price elasticity is $\frac{\Delta Q}{\Delta P} \cdot \frac{P}{Q}$. The regression coefficient for price (b_i) yields $\frac{\Delta Q}{\Delta P}$ and can be used directly to calculate elasticity. Therefore, elasticity = $b \cdot \frac{P}{Q}$.

Following convention, if elasticity $< |1|$ it is said to be inelastic; and if elasticity $> |1|$ it is said to be elastic.

DEVELOPMENT OF VARIABLES AND PROCEDURE

Empirical Procedure

It has already been stated that least squares regression will be used as a tool to produce information that will indicate which variables are important. The general model used was:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8$$

where Y = consumption of household water per capita per day

X_1 = price of water

X_2 = per capita median income

X_3 = value of home per capita

X_4 = lot area per capita

X_5 = percent of homes having a complete plumbing unit

X_6 = average precipitation

X_7 = average maximum temperature

X_8 = price of fuel used to heat water

Using cross-section analysis data for each variable were collected from cities with 1,000 or more population in Utah, Salt Lake, Davis, Weber, Box Elder, and Cache Counties. Cache County was included in the study because of its similarity with the other counties along the Wasatch Front and because research was conducted on the Utah State University campus, which allowed various parts of the research to be tested without greater time and travel expense.

Data on consumption of water and price of water were obtained from municipal water corporations on a questionnaire that was mailed to the cities studied. Administrators in cities not answering the questionnaire were contacted in person.

A priori selection of variables

The dependent variable, Y, could have been family consumption, consumption per connection, or per capita consumption. Family consumption was not used because the number of families served by each system observed was not available. Consumption per connection has the disadvantage of describing consumption where two or more apartments are served by one connection, and the cities were not homogeneous in number of apartment houses. Consumption per capita was selected because number of persons served by each system was available, and this could be used to calculate consumption per capita. This also took out any variation due to population so economically important variables could be determined. Consumption per capita was converted to the day basis to reduce the size of numbers used in the calculations.

Price of water was selected as an independent variable because people in the market economy are expected to be influenced in their consumption decisions by what they have to pay for a commodity. Usually they take more at a lower price than at a higher price, and water for household use would not seem to be an exception.

Level of family income is also a traditional explanatory variable which explains part of the consumption of most commodities since it reflects ability to pay for the commodity used. Water is an economic good that must be paid for. Therefore, some form of family income must be included. Income per capita was used because it represented income on the same basis as the dependent variable.

The mode or average income may have been used in place of the median income. However, data for the mode income were not available in the census, and data for the average income were not as complete for the cities observed as was the median income.

Value of the house might be important as a variable affecting consumption because as value of homes increases the number of water-using facilities usually increases. When water-using facilities increase, amount of water used will increase. An example of this would be the sanitary disposal which is built into the kitchen sink of homes. When the disposal is operating, water is used to flush trash down the sewer system. In less expensive homes this type of water-using facility may not be installed and quantity of water used would be reduced.

In Utah most lawns are irrigated during the summer months, and size of the lawn was assumed to be a function of the lot area. Lot area was selected as an independent variable on the basis of the assumption that water furnished by the water system was used to irrigate the area outside the house. As the area around the house increased, water used during the summer months was also expected to increase.

In 1961, Jerome B. Wolff (10) reported information which he found with respect to lot size and water consumption. As far as can be determined he used total lot area not just the area water could be applied to. However, he did find a strong correlation between lot size and water consumption. Wolff's results are presented in table 2.

Water consumed per capita would seem to be directly related to the plumbing facilities in the home. A complete plumbing unit was assumed to include a toilet, bath tub, wash basin, and a kitchen sink. Homes without these facilities, or only a portion of them, would not be expected to use as much water as those with the complete unit.

Table 2. Water used by lot size

Lot size square feet	Average day gallons per day
2,000 - 2,400	163
5,000 - 7,500	183
9,000 - 12,000	227
15,000 - 25,000	333
40,000 and more	524

The first of the weather variables considered to be important was average maximum temperature during the summer months. It was assumed that as temperature increases, the amount of water consumed for irrigation and possibly human consumption increases.

Precipitation was included as an independent variable because as precipitation increases, need for irrigation decreases. This would result in less frequent irrigation of the area around a house.

Relative price of fuel used to heat water probably affects consumption of household water because there is a considerable amount of water heated for use in a home. The amount of water a person is willing to heat would be a function of price of fuel used to heat water.

Development of Variables

Dependent variable

The dependent variable, consumption of water per day per capita, was calculated from data taken from the questionnaire obtained from each water system. Total water sold during 1962 was reported along with total population served over the same period. The quantity of water sold was divided by the number of people served, which gave the total gallons consumed annually per capita. This was then divided by the number of days in a year to arrive at consumption of water per day per capita.

Three cities could not report their actual water sold during 1962 because they had no method of measuring the quantity that went through their water system. Data for these three cities were calculated by taking a random sample of individual connections, and an average was taken from the sample. The average consumption per connection was then multiplied by the number of connections that were in each system. The result was an estimate of total water consumed by household connections only.

Total water consumed in these cities was not equivalent to the rest of the observations reporting, however, because it did not include water furnished churches, schools, and city parks. Therefore, a fourth city that was similar to the other three was sampled, and a correction factor was determined for the difference between the total water served individual connections and that served the total system. The correction factor was then applied to the three observations to make them comparable to the others. Table 3 contains data for the dependent variable and all independent variables for each observation (city) reporting.

Price variable

The most basic and probably the oldest method used by a water system to collect revenue for operation expenses is the "flat rate" method. The flat rate method is a fixed price which is charged all customers regardless of their location or quantity of water used.

Most of the systems using the flat rate method recognize some of the inadequacies that exist in the one-price system. These systems have changed from a single price for all customers to a separate price for each customer. This price for each customer is determined by a minimum rate plus an additional charge for each

Table 3. Data from 43 water systems observed

Observation no.	Consumption per day per capita	Average price per 1,000 gallons	Average marginal price per 1,000 gallons	First marginal price per 1,000 gallons	Median income per capita	Value of homes per capita	Lot area per capita	Percent of homes having complete plumbing unit	Average precipitation per month	Average monthly maximum temperature
	(gallons)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(sq. ft.)	(percent)	(inches)	(degrees)
1	268	.052	.009	.07	1,877	4,024	2,921	100	.97	82.8
2	149	.183	.167	.17	1,604	3,651	2,976	96	1.05	79.0
3	1,412	.013	.000	.00	1,074	2,941	13,557	92	.99	79.6
4	244	.107	.048	.10	1,475	3,513	4,892	96	.97	82.8
5	121	.147	.055	.10	1,222	5,000	1,436	90	.82	78.6
6	246	.115	.075	.20	1,409	3,105	2,918	98	.82	79.8
7	144	.153	.145	.11	1,084	3,735	1,535	97	.81	79.2
8	362	.074	.015	.20	1,488	3,024	11,251	87	1.05	79.0
9	162	.165	.000	.00	1,244	3,051	2,634	85	1.11	82.1
10	78	.194	.183	.23	1,492	3,757	1,911	93	1.10	81.6
11	88	.242	.544	.21	1,706	4,257	2,497	94	1.05	79.0
12	183	.157	.120	.30	1,241	2,529	3,348	94	.65	80.5
13	136	.221	.189	.23	1,445	3,023	3,621	98	1.05	79.0
14	299	.088	.018	.12	1,074	2,500	10,751	93	1,00	77.2
15	254	.148	.030	.18	1,592	3,543	4,188	98	1.11	82.1
16	372	.045	.023	.12	1,238	3,909	2,386	93	1.00	77.2
17	166	.183	.172	.21	1,534	4,323	1,096	93	1.10	81.6
18	835	.051	.000	.00	1,074	3,000	9,491	92	1.14	77.7
19	215	.163	.116	.20	1,486	3,171	2,634	92	1.05	79.0
20	78	.324	.041	.20	1,451	3,022	1,192	100	1.05	79.0
21	293	.060	.010	.15	1,344	3,182	8,715	98	.81	79.2
22	185	.145	.040	.20	1,429	2,895	5,356	95	1.10	81.6
23	399	.086	.054	.20	1,624	4,733	2,575	98	1.18	82.3
24	169	.121	.109	.15	1,479	4,567	2,810	94	1.10	81.6
25	124	.232	.292	.17	1,366	3,263	5,523	94	1.10	81.6

continued

Table 3. Continued

Observation no.	Consumption per day per capita	Average price per 1,000 gallons	Average marginal price per 1,000 gallons	First marginal price per 1,000 gallons	Median income per capita	Value of homes per capita	Lot area per capita	Percent of homes having complete plumbing unit	Average precipitation per month	Average monthly maximum temperture
	(gallons)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(sq. ft.)	(percent)	(inches)	(degrees)
26	132	.202	.202	.21	1,255	3,049	5,449	97	.90	79.6
27	110	.340	.112	.20	1,429	3,439	7,071	93	1.10	81.6
28	144	.257	.270	.10	1,488	3,024	2,972	99	1.10	81.6
29	337	.086	.020	.15	1,263	3,057	2,384	96	.78	82.7
30	181	.164	.040	.25	1,203	3,293	13,301	74	.82	79.8
31	320	.165	.116	.18	1,074	3,088	6,404	91	1.00	77.2
32	215	.126	.110	.10	1,259	2,486	6,669	97	.99	79.6
33	277	.104	.034	.20	1,259	2,771	4,077	94	.82	79.8
34	335	.076	.013	.10	1,367	3,000	4,168	97	.81	79.2
35	145	.195	.186	.20	1,536	3,781	1,761	94	1.11	82.1
36	121	.224	.222	.18	1,841	3,108	2,474	94	1.05	79.0
37	151	.200	.084	.23	1,488	4,079	4,059	97	1.10	81.6
38	92	.477	.266	.40	1,877	4,024	3,467	90	.97	82.8
39	214	.143	.075	.16	1,416	3,563	1,911	95	1.10	81.6
40	122	.200	.200	.20	1,488	3,875	3,467	96	.97	82.8
41	341	.120	.089	.12	1,438	3,694	2,420	96	1.10	81.6
42	166	.199	.152	.22	1,323	2,881	2,133	96	.97	82.8
43	151	.185	1.79	.15	1,488	3,378	5,292	98	.97	82.8

toilet, tap, and sink. Items included in the additional charge vary with the system. However, after this price is set for each customer the charge does not vary with the quantity of water used.

Another method, and currently the most frequently used, is the block or multiple price schedule. This is a more equitable method of pricing than the flat rate scheme; however, to facilitate the use of this multiple price schedule, the water system must be metered. Metering is an additional cost to the system, and if the system is comparatively small the additional cost may be prohibitive.

When the system is metering water to each customer an accurate record of gallons used during a specific period is taken. It is this quantity of water that the multiple price shcedule is applied to, and the customer remits according to his usage.

Generally, under a multiple price system, there is a minimum price that must be paid. The minimum price is to insure that the system is at least returning cost due to depreciation. For this minimum price the customer is allowed a given quantity of water.

When the quantity allowed under the minimum price is exceeded, according to meter records, a marginal price is charged which may be assessed by 1,000 gallon units, cubic feet units, or other fluid measuring units. This charge is then added to the minimum price.

The first marginal price above minimum price may or may not be allowed to cover all water consumed above the amount allowed under minimum price. Frequently, marginal price charged is only applicable within a bracket or block of water consumed. For example, marginal price may be $.10 a thousand gallons for all water used between the maximum quantity allowed under minimum price and 50,000 gallons.

After the quantity covered by first marginal price is exceeded, there may be another marginal price (which may be more or less than the previous marginal price) for a new bracket or block. Generally, the last bracket is left open to cover all water used after this point.

Each system studied used one of the pricing methods described above. Table 4 is a presentation of the number of systems that were observed using each method.

Data in table 4 show more systems are using the multiple pricing system with a decreasing price per thousand gallons as consumption increases. The three systems that used a flat rate method of pricing were among the smallest systems observed.

From the forty-three municipalities observed it was found that three different price variables could be used in the analysis. They were average price, average marginal price, and first marginal price. It was decided that each of the price variables would be tried in the model to see which gave the best fit.

Average price was derived from questionnaire data. Total revenue received from the sale of water was divided by total water sold (thousand gallons) which gave the average price per thousand gallons of water sold.

The average marginal price of water was found by dividing the marginal revenue by the marginal quantity of water. Marginal

Table 4. Pricing methods[a]

Method	Number
I. Systems using a flat rate price	3
II. Systems using a minimum price with one or more marginal price	40
A. Systems using a minimum price with <u>only one</u> marginal price	13
B. Systems using a minimum price with <u>more than one</u> marginal price	27
1. Systems with more than one marginal price whose price per M decreases as the quantity used increases	26

[a] Data taken from 43 systems observed in Utah, Salt Lake, Davis, Weber, Box Elder, and Cache Counties.

quantity of water was found by multiplying the amount of water allowed under the minimum price times the number of connections and subtracting this from total water sold. The marginal price was arrived at by taking the number of connections times the minimum price charged and subtracting this from the total revenue, leaving only revenue received from marginal price. This marginal revenue was then divided by marginal water sold. This gave an average marginal price for all water sold in each city observed.

The average marginal price variable was expected to account for more of the variation in consumption of water than average price or first marginal price. It was assumed people would think of the price of additional water before consuming additional quantities. They would consume additional water only if the price was below or equal to their marginal utility for more water.

However, problems were encountered in the calculation of average marginal price because some connections in each city did not use the amount covered by the fixed surcharge as assumed in computation of marginal price. In addition, free service connections such as schools, churches, and city property, which generally are not metered, did not consume the same percentage of total water in all cities. This would tend to decrease marginal price more in some cities than others. Also, water lost in the system due to leaks would increase quantity of water reported sold that would also bias marginal price.

The first marginal price was taken directly from the price schedule for each water system observed. First marginal price was defined as the price charged for the first 1,000 gallons of water used after the maximum amount had been used that was allowed under the minimum price.

In some systems observed a two price system was used. There was a price for connections served inside the city limits and another price for connections served outside the city limits. In these cases the first marginal price was weighted by the number of connections served in each area.

Price of fuel used to heat water variable

Price of fuel used to heat water was narrowed to the price of gas since the majority of homes in all cities observed used natural gas to heat water. All cities observed were supplied with natural gas by the Mountain Fuel Supply Company. All cities served in the state of Utah by this firm had the same price schedule except that additional charges were made in five cities.

The following cities have additional charges of two percent: Salt Lake City, Sandy City, Provo City, and Brigham City. South Salt Lake has an additional charge of one percent. All of these cities were observed in this study.

However, because there was so little variation in the price of fuel among cities it obviously could not produce variation in water consumption. The price of fuel used, therefore, will not be included in the study.

Income variable

Since water consumption was converted to a per capita basis, median income was expressed in the same term. Information for developing median income per capita was taken from the United States Census of Population, 1960 PC (1) 46C, Utah. The basic data used were total population, number of families, and median family income.

Total population was divided by number of families which gave the number of persons per family. Median family income was then divided by number of persons per family, giving the desired per capita median income.

Median family income was not given in the census for cities with less than 2,500 population. However, mean family income and median family income were given for all counties. The difference between mean family income and median family income was found for each county. The difference was divided by the mean family income of each county to find the percent the difference was of the mean. The average difference for the six counties was 16 percent. The mean incomes were then reduced by 16 percent which made them somewhat comparable to the median incomes.

For Davis County, where the population in the cities was homogeneous with respect to density, the county data were used to represent all cities under 2,500 population where median family income data were not available. This method was assumed to be more accurate than adjusting the mean family income for small cities in this particular county.

For counties with heterogeneous (with respect to density) populations among cities, the total family income for the large population concentration cities was subtracted out of the county total family income. The population for the same cities was removed from the county population and then divided into the corrected mean family income. This figure was adjusted by the 16 percent correction factor, and median family income was determined.

Value of homes per capita variable

Median value of homes owned was taken from the United States

Census of Housing, 1960, for Utah, HC (1) Number 46, Utah. The value of homes owned was used because data were not available for commercially rented apartments. Here the assumption was made that people living in other than owner occupied units (this would be all tenants) would have the same per capita value of homes as those owner occupied.

To arrive at the median value per capita of homes, median value of homes owned for each area was taken from the census report and divided by the median number of persons per owner occupied unit. This gave per capita owner occupied median value of homes.

Median values of homes owned were not available for cities of less than 2,500 population, but mean values were. A correction factor would have been employed to adjust mean to median values, but the cities over 2,500 population did not have mean values so differences could not be determined. This practice of using both mean and median values may not seriously bias the results, however, since values were not consistently higher or lower than median values.

Lot area variable

Lot area was placed on a per capita basis and additional refinement was made by subtracting out area covered by houses, porches, and garages. Driveways were not taken out because of inconsistencies in records. This variable then became the per capita square feet in lots not covered by houses, porches, and garages, and will be referred to as the lot area per capita variable.

Data for the lot area per capita variable were obtained from county plat books. Each of the six counties in the study were contacted by a personal interview. The specific lots were found in the plat books using a random numbers table. The dimensions of the lots were taken from the records to get the total lot area. Then, by using the serial number on the lot selected, the building identification card was pulled from the records of the county assessor. The houses, garages, and porches were then subtracted from the total lot area. After one city had been sampled, a Stein's two stage sample size test was applied to get a more accurate sample size for remaining observations and to verify the size of the first observation.

Homes having a complete plumbing unit variable

The number of homes having a complete plumbing unit in each city was divided by the number of homes and multiplied by 100 to give the percent. Data were taken from the United States Census of Housing, 1960, for Utah.

Weather condition variable

The most important period for weather conditions to affect consumption of water would be during the months of May, June, July, August, September, and October. It was assumed during the remaining part of the year there would be very little change in water consumption due to precipitation or temperature.

Data for both temperature and precipitation variables were taken from the United States Weather Bureau Climatological Data for 1962. The same time period, May through October, was used for both variables. Weather stations were selected as near to the area observed as possible.

Average precipitation was calculated by first finding the precipitation for each of the six months. The monthly totals were then added together and divided by number of months to get the average precipitation per month for the selected period.

Average monthly temperature was first adjusted to read the average maximum monthly temperature, assuming that daily maximum temperature would influence the consumption more than daily mean temperature. The average maximum temperature for all of the six months were added together and divided by six to arrive at the average maximum temperature.

ANALYSIS AND RESULTS

In the regression model let:

Y = consumption of water per day per capita (gallons)

X_1 = average price (dollars)
marginal price (dollars)
first marginal price (dollars)

X_2 = median income per capita (dollars)

X_3 = value of homes per capita (dollars)

X_4 = lot area per capita (square feet)

X_5 = percent of homes having complete plumbing (percent)

X_6 = average monthly precipitation (inches)

X_7 = average maximum monthly temperature (degrees)

Initially the analysis assumed a linear regression model. Scatter diagrams are presented in figures 2 through 10 for the independent variables plotted against the independent variable.

There were 43 water systems observed in this study. Using seven independent variables and one dependent variable, there are 35 degrees of freedom (n - 8). Using this information, the t value from the t table was 2.030 at the 5 percent level of significance. This value of t will be compared with calculated t later.

Because of three different prices that could be used in the X_1 variable, price, it was necessary to solve the multiple regression equation three times. Each time the regression equation was solved a different price variable was used in X_1.

The IBM 1620 computer was used to solve all multiple regression equations. The reason for using the computer was to avoid as many mathematical errors as possible when so many digits to the right of the decimal place must be carred (minimum of 8) when inverting the sums of squares matrix. This also expedited the study.

Analysis Using All 43 Observations

Results of regression equation one, using average price as the X_1 variable, were

(1) $$Y = -878.93 - 1042.65X_1 - .1852X_2 + .0330X_3$$

S_b	(348.98)	(.1766)	(.0489)
t	(2.99)	(1.0487)	(.6748)

$$+ .0357X_4 + 849.03X_5 + 301.58X_6 + 2.23X_7$$

(.0124)	(222.61)	(225.51)	(16.59)
(2.8790)	(3.81)	(1.34)	(.13)

Values under the regression coefficients that are in parentheses are standard error values (S_b) and calculated t values respectively. This procedure was used in all e uations of this type presented in the study.

The multiple coefficient of determination (R^2) for this model was 55 percent.

Results of regression equation two, using the calculated average marginal price as the X_1 variable, were

(2) $$Y = -901.12 - 507.88X_1 - .2590X_2 + .0682X_3$$

S_b (290.14) (.1841) (.0574)

t (1.75) (1.4068) (1.1882)

$$+ .0417X_4 + 1372.95X_5 + 255.73X_6 - 4.97X_7$$

(.0112) (714.88) (241.33) (5.68)

(3.7232) (1.92) (1.06) (.88)

The multiple coefficient of determination (R^2) for this model was 48 percent.

Results of regression equation three, using the first marginal price as the X_1 variable, were

(3) $$Y = -652.86 - 11038.36X_1 - .1317X_2 + .0515X_3$$

S_b (1305.84) (.1835) (.0520)

t (8.45) (.7177) (.9904)

$$+ .0414X_4 + 932.48X_5 + 38.94X_6 - .1445X_7$$

(.0100) (706.54) (239.89) (16.39)

(4.1400) (1.32) (.16) (.01)

The multiple coefficient of determination (R^2) for this model was 54 percent.

Simple partial coefficients of determination (r^2) were calculated from the correlation coefficients which were supplied by output data from the IBM 1620 computer, table 5. Partial coefficients of determination will only be given for the association between X_i (the independent variables) and Y (the dependent variable). The association of one independent variable with another will be

Table 5. Simple partial coefficients of determination (r^2) using 43 observations

Independent variable	Dependent variable	Coefficient of determination (r^2)
X_1 (average price)	Y	34.2%
X_1 (marginal price)	Y	19.2%
X_1 (first marginal price)	Y	28.9%
X_2 (median income/capita)	Y	16.4%
X_3 (value of homes/capita)	Y	04.0%
X_4 (lot area/capita)	Y	31.7%
X_5 (percent of homes having a complete plumbing unit)	Y	00.7%
X_6 (average precipitation)	Y	00.0%
X_7 (average maximum temperature)	Y	05.9%

discussed later.

Standard partial regression coefficients were also part of the output data from the IBM 1620 computer. The coefficients changed each time the price variable was changed. These coefficients were placed in the standard partial regression coefficient, table 6, under the respective price variable and their respective rank is in parentheses.

Analysis Using Only 40 Observations

The 43 observations had two types of pricing systems. The majority of the systems observed had their systems fully metered and

Table 6. Standard partial regression coefficients

Variable	Average price[a]	Marginal price[a]	First marginal price[a]
X_1 (price)	-.4011 (2)[b]	-.2405 (3)	-.3704 (2)
X_2 (income)	-.1684 (4)	-.2355 (4)	.1198 (5)
X_3 (value of homes)	.0874 (6)	.1807 (5)	.1364 (4)
X_4 (lot size)	.5052 (1)	.5902 (1)	.5861 (1)
X_5 (percent complete plumbing)	.1704 (3)	.2754 (2)	.1872 (3)
X_6 (average precipitation)	.1649 (5)	.1398 (6)	.0213 (6)
X_7 (average maximum temperature)	.0174 (7)	-.0388 (7)	.0011 (7)

[a] Average price, marginal price, and first marginal price represent equations one, two, and three respectively.

[b] The number in parentheses is a rank number.

water was sold according to amount used on what is called the block system where price decreased as quantity used increased from block to block.

The remaining systems observed used a flat rate system of pricing water to users. There was a fixed monthly charge made regardless of the amount of water used by the customer. This type of pricing gave users fewer reasons to conserve water. There was no additional charge if they used more water thus, there was a marginal price of zero.

Scatter diagrams presented in figures 2,3, and 4 show the dispersion of quantities consumed at various prices whether price was average price, marginal price, or first marginal price. There were only three flat rate water systems observed, and in all scatter diagrams the two large observations were flat rate water systems. The third flat rate water system was located at approximately the 360 gallon mark, which is also on the right of most systems observed.

These facts indicate that it may not have been wise to include the three flat rate systems in the same population as the others. It was decided to leave them out and recalculate the results to see if their inclusion caused distortion. These new equations were numbered four through six as each of the price variables were introduced into the equation using the forty observations with only the block pricing system.

Results of equation four, using average price as X_1 variable, were

$$(4) \qquad Y = 307.42 - 829.48X_1 + .0287X_2 - .0114X_3$$

S_b	(137.22)	(.0721)	(.0195)
t	(6.04)	(.3981)	(.5846)

$$+ .0041X_4 + 12.39X_5 + 58.33X_6 - .6616X_7$$

(.0052)	(318.50)	(96.16)	(6.63)
(.7885)	(.04)	(.60)	(.10)

This model has a multiple coefficient of determination (R^2) of 60 percent.

Results of equation five, using marginal price as the X_1

variable, were

$$(5) \qquad Y = 432.72 - 515.01X_1 + .0042X_2 + .0134X_3$$

S_b	(126.94)	(.0774)	(.0200)
t	(4.06)	(.0543)	(.6700)

$$+ .0063X_4 + 359.61X_5 + 17.47X_6 - 7.49X_7$$

(.0060)	(365.03)	(113.61)	(7.93)
(1.0500)	(.99)	(.15)	(.94)

The multiple coefficient of determination (R^2) for this model was 44 percent.

Results of equation six, using the first marginal price as the X_1 variable, were

$$(6) \qquad Y = 268.92 - 4804.49X_1 - .0243X_2 + .0076X_3$$

S_b	(2785.47)	(.0787)	(.0332)
t	(1.72)	(.3088)	(.2289)

$$+ .0098X_4 + 210.47X_5 - 62.95X_6 - 1.85X_7$$

(.0075)	(487.14)	(132.67)	(9.43)
(1.3067)	(.43)	(.47)	(.20)

The multiple coefficient of determination (R^2) for this model was 22 percent, which was the lowest fit of any of the models thus far used.

Simple partial coefficients of determination (r^2) changed as the price variable was changed (the same as they did in the first set of equations) for the association between the price variable and consumption. Table 7 gives simple partial coefficients of determination for this set of equations with the flat rate systems taken out.

Table 7. Simple partial coefficients of determination (r^2) with the flat rate systems out (40 observations)

Independent variable	Dependent variable	Coefficient of determination (r^2)
X_1 (average price)	Y	37.5%
X_1 (marginal price)	Y	40.0%
X_1 (first marginal price)	Y	13.6%
X_2 (median income/capita)	Y	6.0%
X_3 (value of homes/capita)	Y	1.7%
X_4 (lot size/capita)	Y	7.6%
X_5 (percent of homes with complete plumbing)	Y	0.0%
X_6 (average precipitation)	Y	1.7%
X_7 (average maximum temperature)	Y	3.1%

Standard partial regression coefficients for this set of equations were handled the same way as the first set where the flat rate water systems were included. Table 8 gives these coefficients with respect to the price variable used.

Determination of Significant Variables

The coefficient of determination (R^2) for the models with all 43 observations showed the model using average price as the price variable to have slightly the best fit. The R^2 for this model was 55 percent compared to 48 and 54 percent for the other two models using marginal price and first marginal price respectively.

Table 8. Standard partial regression coefficients with flat rate water systems out (40 observations)

Variable	Average price[a]	Marginal price	First marginal price[a]
X_1 (price)	-.7714 (1)[b]	-.5990 (1)	-.3267 (1)
X_2 (income)	.0618 (5)	.0091 (7)	-.05216 (5)
X_3 (value of homes)	-.0760 (4)	.0893 (5)	.0509 (6)
X_4 (lot area)	.1267 (2)	.1945 (2)	.3045 (2)
X_5 (percent complete plumbing)	.0060 (7)	.1741 (3)	.1019 (3)
X_6 (average precipitation)	.0796 (3)	.0238 (6)	-.0859 (4)
X_7 (average maximum temperature)	-.0127 (6)	-.1436 (4)	-.0355 (7)

[a] Average price, marginal price, and first marginal price represent equations four, five, and six respectively.

[b] The number in parenthese is a rank number.

Average price, equation 1, was selected as the best equation for the analysis. The scatter diagram suggests that the fit (R^2) would have been better if a quadratic equation had been used. Also, calculation of the average price variable was more reliable than was the case with the marginal prices. The flat rate systems were left in because cities using this pricing method had strong variation in other variables such as lot area, value of homes, and income per capita. However, the fit was worse with them in; this, of course, means the model was not as efficient with the flat rate systems included as it was without them. This was due to the quadratic relationship of average price and consumption. Therefore, they are included in the analysis of significant variables.

Results for calculated t, partial coefficients of determination, and standard partial regression coefficients were brought together at this point for each independent variable. The independent variables were analyzed separately from the data presented in table 9.

Average price variable

The calculated t value was significant, the coefficient of determination (r^2) was in the high category, and the standard partial regression coefficient was second in importance. Only lot area per capita was ranked higher than this variable. In comparison, all three criteria showed the average price independent variable to be important. It was concluded from these results that average price was one of two very significant variables in this study. Scatter diagrams for the price variables are presented in figures 2,3, and 4.

Median income per capita variable

The calculated t value was not significant at the $\alpha_{.05}$ level, the coefficient of determination was in the medium category, and the standard partial regression coefficient was ranked fourth in

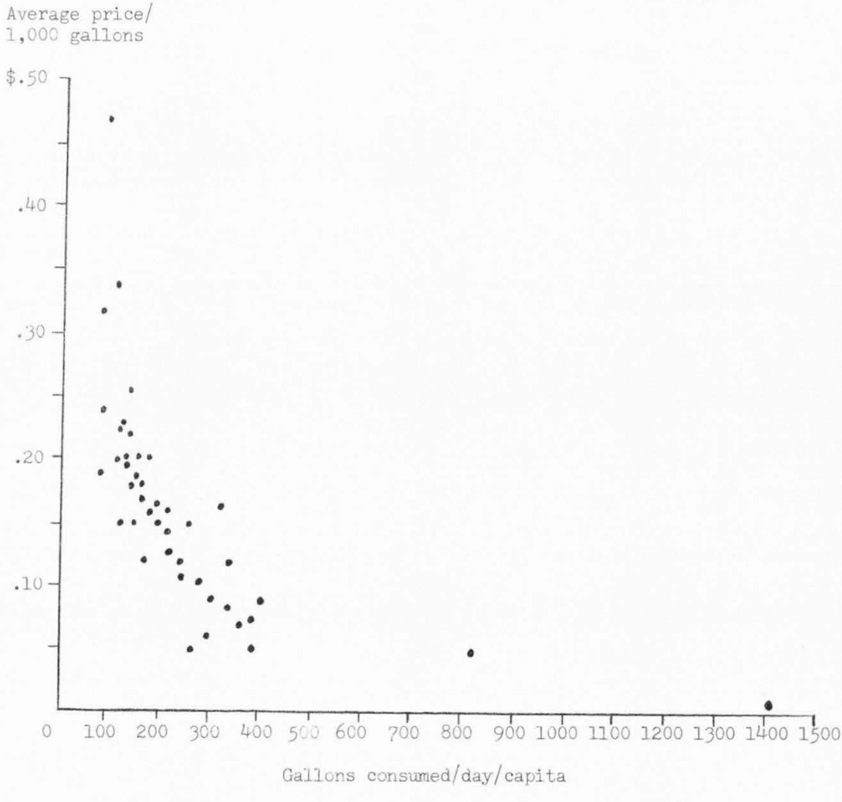

Figure 2. Scatter diagram for average price/1,000 gallons water and consumption of water/day/capita of the 43 water systems observed.

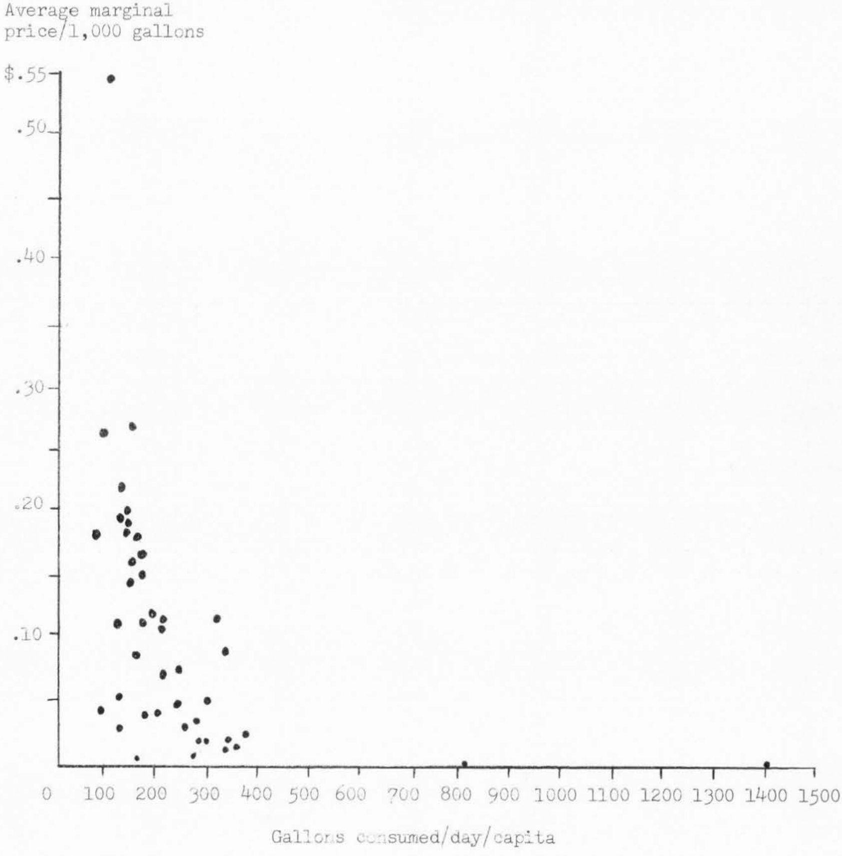

Figure 3. Scatter diagram for average marginal price and consumption of water/day/capita of the 43 water systems observed.

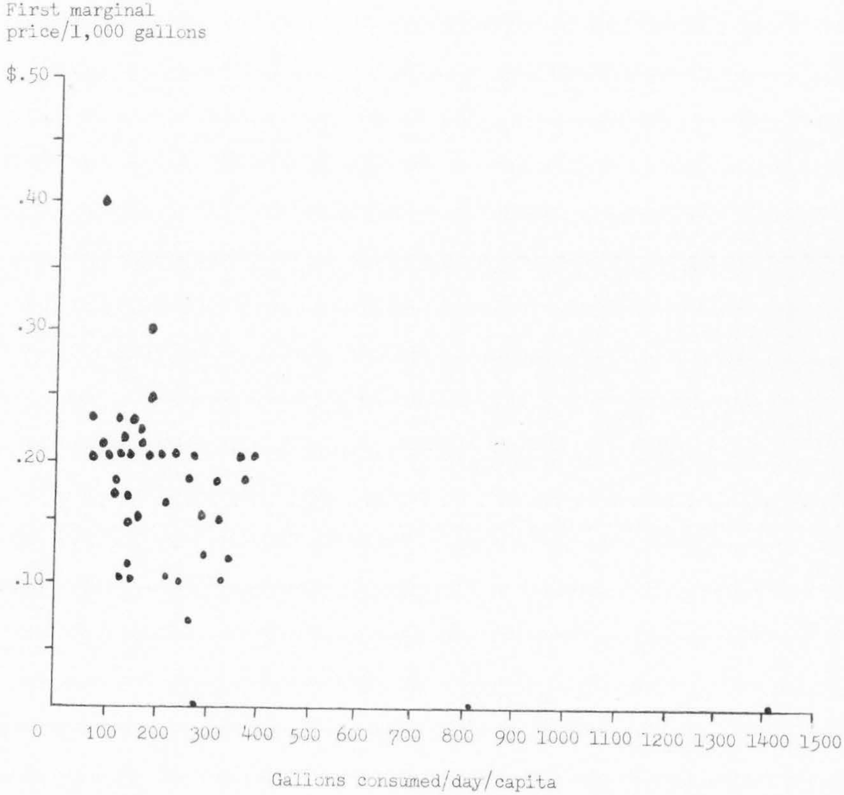

Figure 4. Scatter diagram for first marginal price and consumption of water/day/capita for the 43 water systems observed.

Table 9. Criteria for determining significant independent variables

Independent variable	Calculated t	Coefficient of determination (r^2)	Standard partial regression coefficient
Average price, X_1	2.99[a]	34.2%	-.4011 (2)[b]
Median income/capita X_2	1.0487	16.4%	-.1684 (4)
Value of homes/ capita X_3	.6748	4.0%	.0874 (6)
Lot area/capita X_4	2.8790[a]	31.7%	.5052 (1)
% homes having complete plumbing X_5	3.81[a]	0.7%	.1704 (3)
Average precipitation X_6	1.34	0.0%	.1649 (5)
Average maximum temperature X_7	.1344	5.9%	.0174 (7)

[a] Significant t values when compared to tabular $t_{.05,\ df\ 35} = 2.030$.

[b] The number in parentheses is a rank or order number.

comparison to the other six variables. The latter two criteria may have suggested that this variable was significant, although the significance was weak. However, the t test did not confirm the results of the other indicators. In fact, it indicated strongly that income was not a significant variable. Also, the algebraic sign of the partial regression coefficient for this variable was negative, indicating as income increases water consumption decreases. The scatter diagram for this variable is presented in figure 5. It was concluded that median income per capita cannot be considered

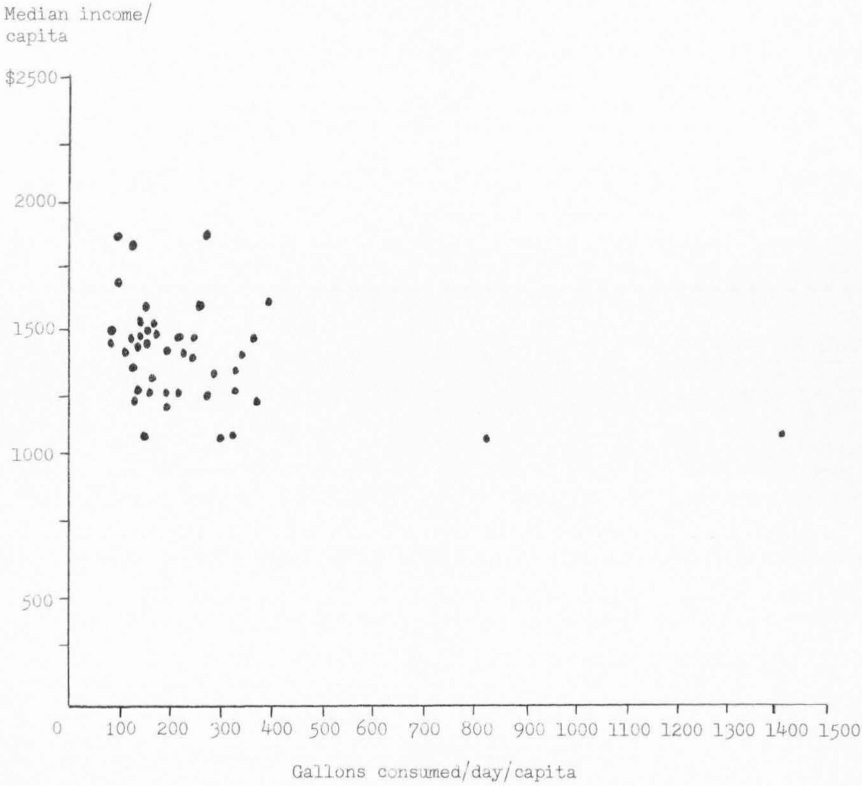

Figure 5. Scatter diagram for median income/capita and consumption of water/day/capita of the 43 water systems observed.

a variable of significant importance.

<u>Value of homes owned per capita variable</u>

The calculated t value was not significant at the $\alpha_{.05}$ level, the coefficient of determination was in the low category, and the standard partial regression coefficient was ranked sixth in importance with respect to the other six variables. The only variable ranked lower in relation to all variables was average maximum temperature, which was ranked last. The scatter diagram is presented in figure 6 for this variable. All three of the indicators have shown the value of homes per capita as an independent variable to be non-significant in all three cases.

<u>Lot area per capita variable</u>

The calculated t value was significant at the $\alpha_{.05}$ level, the coefficient of determination was in the high category, and the standard partial regression coefficient ranked first in importance. Only the average price variable had a higher coefficient of determination. Figure 7 shows the scatter diagram for this variable. All three indicators in this analysis indicated that this variable was important. From these results it was concluded that lot area per capita does significantly affect the consumption of water per capita.

<u>Percent of homes having a complete plumbing unit variable</u>

The calculated t value was significant at the $\alpha_{.05}$ level, the coefficient of determination was extremely low, and the standard

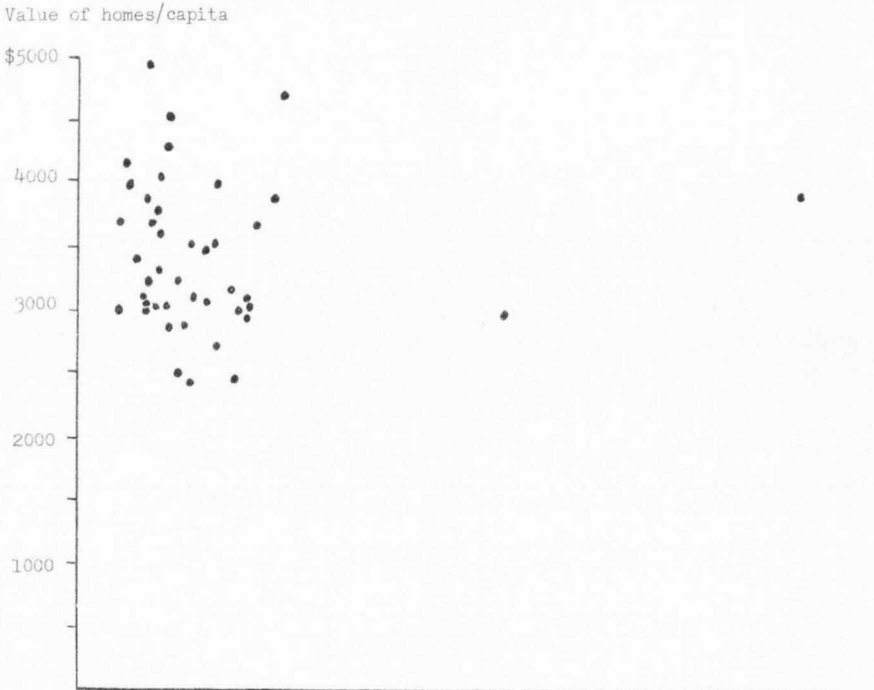

Figure 6. Scatter diagram for value of homes/capita and the consumption of water/day/capita for the 43 water systems observed.

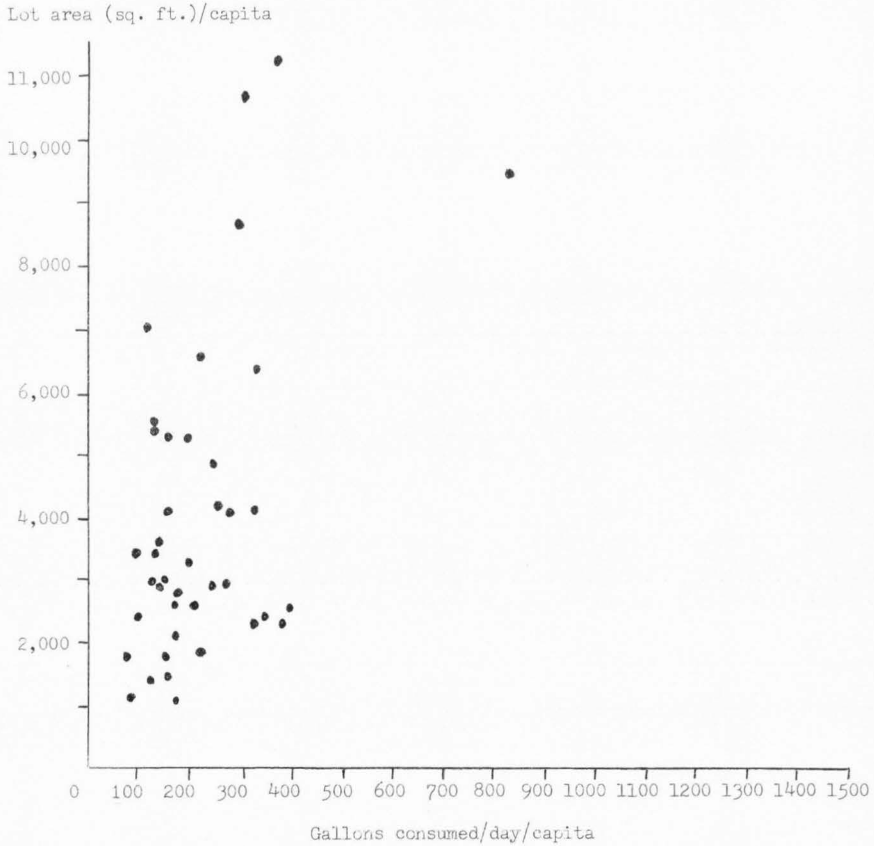

Figure 7. Scatter diagram for lot area/capita and the consumption of water/day/capita of the 43 water systems observed.[a]

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[a] Two observations were not put on the figure because lot area/capita was 13,557 for 1,412 gallons consumption in one case and lot area/capita was 13,301 for 181 gallons consumption in the other case neither of which would fit on the figure.

partial regression coefficient was ranked third in importance, but much less important than lot size and price. These indicators are not consistent. First, the t test indicated the variable did significantly affect consumption of water. Second, the coefficient of determination was completely opposite to the first indicator, showing the variable affecting the total sum of squares for consumption of water by very little. The scatter diagram, figure 8, does not indicate any strong relationship. Third, the standard partial regression coefficient was only ranked third, which was not a strong indication for any decision.

The same indicators were used on the other five equations where other concepts of price were used, and the decision concerning this variable was made from the results of all six equations. The last five equations had no calculated t values that were significant at the $\alpha_{.05}$ level which the first equation reported significant. Also, the rank of the standard partial regression coefficient was second, third, seventh, third, and fourth, which again did not indicate a strong significance. From this comparison it was concluded that the high b value in equation 1 probably can be attributable to chance rather than any real relationship. That is, a statistical error of the second kind was indicated by the t test, which indicated acceptance of the variable even though, in fact, it was not significant.

Average precipitation per month variable

The calculated t value on the regression coefficient was not

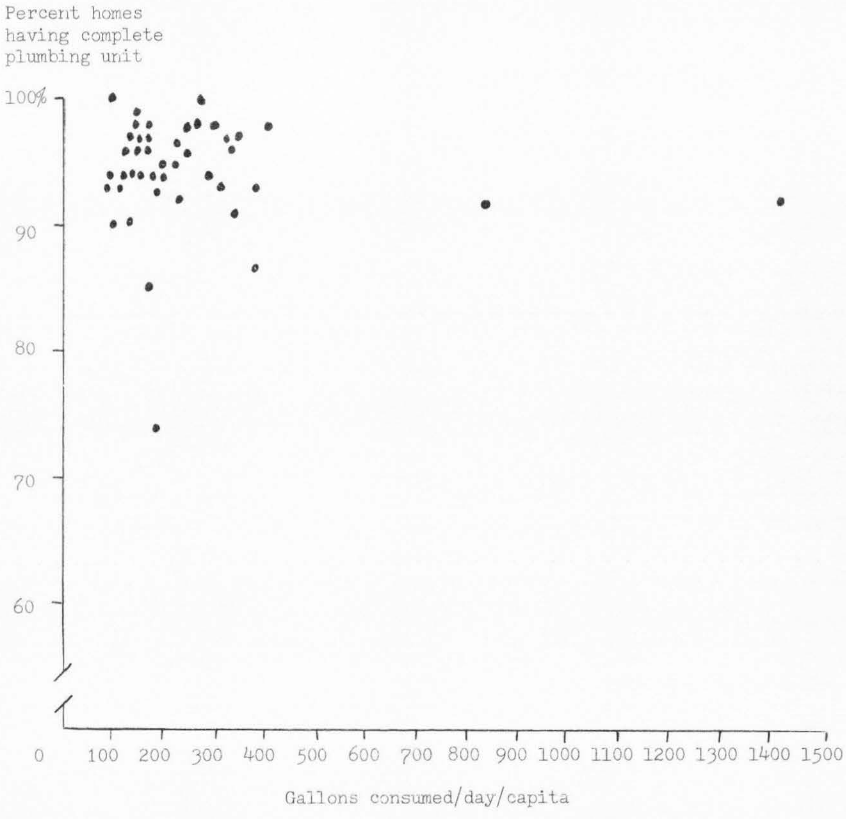

Figure 8. Scatter diagram for percent of homes having a complete plumbing unit and the consumption of water/day/capita of the 43 water systems observed.

significant at the $\alpha_{.05}$ level, and the algebraic sign was wrong. The coefficient of determination was zero carried out to the nearest tenth, and the standard partial regression coefficient was ranked fifth with only two others ranked lower. The scatter diagram is presented in figure 9. All three indicators agree that this variable was of little importance.

Average maximum temperature per month variable

The calculated t value was not significant at the $\alpha_{.05}$ level, the coefficient of determination was in the middle of the low category, and the standard partial regression coefficient was ranked seventh, or last, in importance with respect to the other variables in the model. The scatter diagram for this variable is presented in figure 10. It was concluded from the results of the three indicators that average maximum temperature per month as an independent variable did not significantly affect the consumption of water in this study.

There were two variables found to consistently effect the consumption of water by all criteria. They are average price and lot area per capita. Also, there were five variables tested that did not appear to be significant from the analysis of this study. They were median income per capita, value of homes per capita, percent of homes having a complete plumbing unit, average precipitation per month, and average maximum temperature per month.

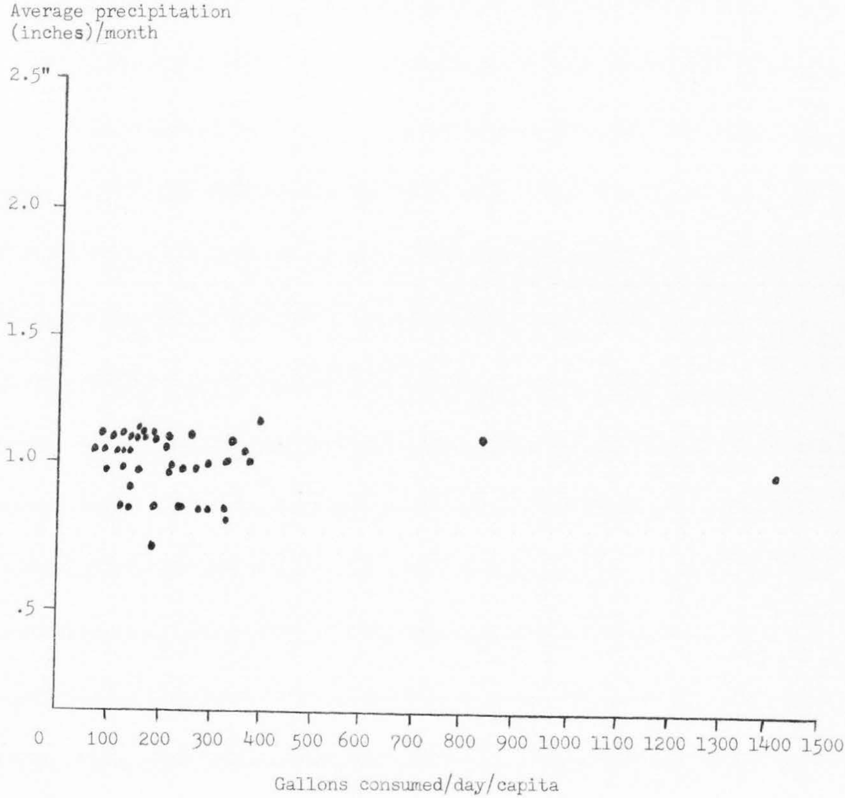

Figure 9. Scatter diagram for the average precipitation/month and the consumption of water/day/capita of the 43 water systems observed.

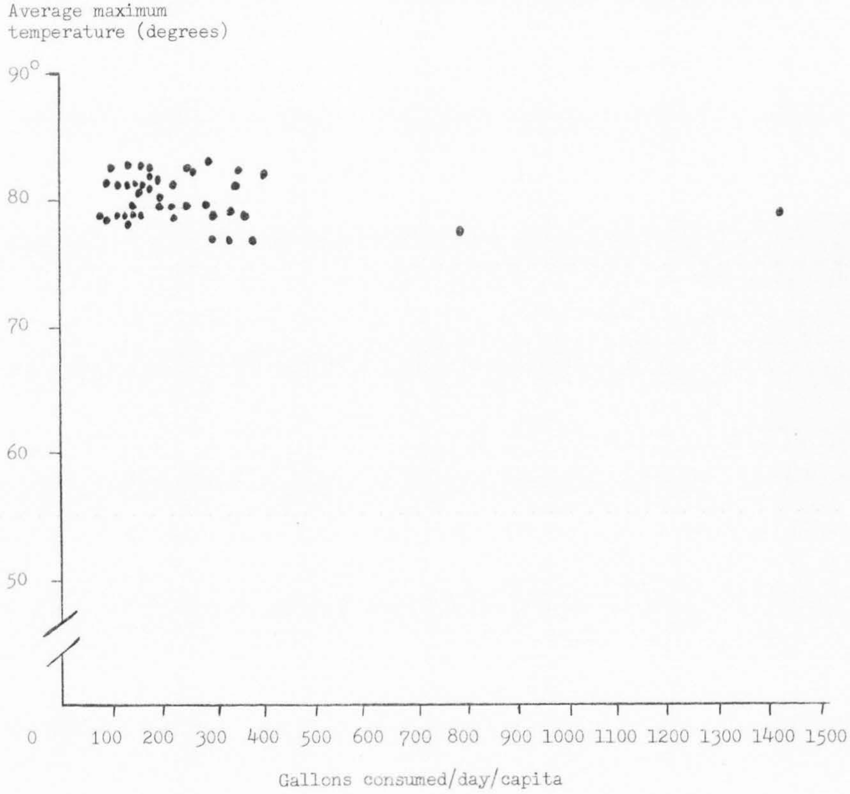

Figure 10. Scatter diagram for average maximum temperature and the consumption of water/day/capita.

Additional test on the five variables not significant

After it was determined that average price and lot area per capita were the only two variables significantly affecting the consumption of water, a new model was formulated using only average price and lot area per capita as independent variables. The remaining five of the original seven variables that did not show significance were left out of thie equation. This was done to determine the change in the multiple coefficient of determination (R^2) for the model if only the significant independent variables were used. If the multiple coefficient of determination did not change by a significant amount, it would mean the five variables not found significant accounted for very little of the total sum of squares for the consumption of water per day per capita.

The six regression equations were then solved using the average price variable and lot area per capita variable as independent variables. The equations using all 43 observations are presented in table 10, and those using 40 observations are presented in table 11.

Equation 7, where only significant variables were used, changed R^2 for the model from 55 percent, found in equation 1, to 51 percent, or a change of 4 percent. All other pairs of equations also showed only a small loss of explanatory power by simplifying the model. This meant the elimination of the five variables (that were not significant according to the analysis) only reduced the percent of the total sum of squares for the dependent variable

Table 10. Regression equations using 43 observations

(Average price)			
	$Y = 302.29 - 1182.49X_1 + .0299X_3$		$R^2 = .505$
(7) S_b	304.05	.0083	
t	3.89	3.6024	
(Marginal price)			
	$Y = 164.40 - 602.46X_1 + .0332X_2$		$R^2 = .390$
(8) S_b	275.68	.0083	
t	2.19	4.0000	
(First marginal price)			
	$Y = 316.01 - 13238.92X_1 + .0336X_2$		$R^2 = .507$
(9) S_b	1067.31	.0071	
t	12.40	4.7324	

Degrees of freedom = 40

Tabular t = 2.021

X_1 = price

X_2 = lot area/capita

Table 11. Regression equations using 40 observations (flat rate systems out)

(Average price)

	$Y = 318.03$	$- 791.60X_1$	$+ .0043X_2$	$R^2 = .592$
(10)	S_b	114.50	.0032	
	t	6.91	1.3438	

(Marginal price)

	$Y = 253.97$	$- 523.14X_1$	$+ .0030X_2$	$R^2 = .409$
(11)	S_b	112.85	.0042	
	t	4.64	.7143	

(First marginal price)

	$Y = 267.19$	$- 5579.73X_1$	$+ .0087X_2$	$R^2 = .209$
(12)	S_b	2150.92	.0049	
	t	2.59	1.7755	

Degrees of freedom = 37

Tabular t = 2.024

X_1 = price

X_2 = lot area/capita

accounted for by the independent variables by 4 percent. The small 4 percent change in the model coefficient of determination is additional proof the variables eliminated were not significant.

Interaction terms were not introduced into the models because of the results of the partial intercorrelation coefficients (R^2) presented in table 12. Most of the coefficients are very low, the highest being intercorrelation between median income per capita and average maximum temperature where $r_{2\,.\,7} = .468$ or $r_2^2 = .212$. Also, it may be argued the correlation between these variables was spurious because there was no logical reason for median income and temperature to vary together.

Logarithm analysis

By observing the scatter diagram, figure 2, for average price it was obvious that a curve would fit the data better than a linear function. When the models were analyzed for their multiple coefficients of determination, by taking out the three flat rate water systems (observations numbers 3, 9, and 19), the coefficients increased 5 percent for the model using the average price variable. For these reasons after the significant variables were found, data for the significant variables were changed to logarithms and analyzed again. The results are presented in tables 13 and 14 for solutions to the regression equations. Coding was accomplished by multiplying the data by 1,000 to avoid working with negative signs.

The logarithmic equation 13 - 18 used only the significant variables. Results of equation 13 demonstrated a 28 percent increase

Table 12. Intercorrelation between independent variables

	Partial intercorrelation coefficients
$r_{1.2}$	.426
$r_{1.3}$	.115
$r_{1.4}$	-.307
$r_{1.5}$	-.022
$r_{1.6}$	.196
$r_{1.7}$	.256
$r_{2.3}$	.430
$r_{2.4}$	-.426
$r_{2.5}$	.265
$r_{2.6}$	.354
$r_{2.7}$	.468
$r_{3.4}$	-.432
$r_{3.5}$	.009
$r_{3.6}$	.257
$r_{3.7}$	.267
$r_{4.5}$	-.463
$r_{4.6}$	-.090
$r_{4.7}$	-.325
$r_{5.6}$	.068
$r_{5.7}$	.185
$r_{6.7}$	.190

Table 13. Logarithmic regression equations using 43 observations

(Average price)

(13)	$Y = 5.9504 - .7662 \log X_1 + .1506 \log X_2$			$R^2 = .826$
	S_b	.0655	.0700	
	t	11.6977	2.1514	

(Marginal price)

(14)	$Y = 4,3086 - .2451 \log X_1 + .2171 \log X_2$			$R^2 = .5731$
	S_b	.0436	.2218	
	t	5.6216	.9788	

(First marginal price)

(15)	$Y = 3.5280 - .1982 \log X_1 + .3327 \log X_2$			$R^2 = .437$
	S_b	.0529	.1136	
	t	3.7467	2.9287	

Degrees of freedom = 40

Tabular t = 2.021

X_1 = price

X_2 = lot area/capita

Table 14. Logarithmic regression equations using 40 observations (flat rate systems out)

(Average price)

(16)		$Y = 6.0414 - .7271 \log X_1 + .1229 \log X_2$		$R^2 = .732$
	S_b	.0781	.0721	
	t	9.3099	.1705	

(Marginal price)

(17)		$Y = 5.2604 - .2928 \log X_1 + .0858 \log X_2$		$R^2 = .497$
	S_b	.0548	.1068	
	t	5.3431	.8034	

(First marginal price)

(18)		$Y = 4.7843 - .5148 \log X_1 + .2490 \log X_2$		$R^2 = .256$
	S_b	.1844	.1082	
	t	2.7918	2.3013	

Degrees of freedom = 37

Tabular t = 2.024

X_1 = price

X_2 = lot area/capita

in the multiple coefficient of determination. This confirmed that a model using quadratic terms would have increased R^2 for the model. Also, the significant variables remained significant in the logarithmic analysis.

Demand Schedule for Household Water

Demand curve determined by arithmetic equation

To derive the demand schedule equation 7, rather than equation 1, was used because this equation contained only significant independent variables. The demand schedule was derived by holding lot area per capita variable constant at its arithmetic mean and varying the average price variable between relatively low prices observed to relatively high prices observed.

The equation used was:

$$(7) \qquad Y = 302.29 - 1182.49X_1 + .0299X_2$$

S_b	304.05	.0083
t	3.89	3.6024

where X_1 (average price) was varied from \$0.00 to \$.40 and X_2 (lot area per capita) was held at 4,458, which was its arithmetic mean. The demand schedule for this equation is presented in table 15.

The demand schedule confirms the theory that as price increases, quantity demanded decreases. Also, when plotted in figure 11, the demand curve has the traditional negative slope.

Table 15. Demand schedule for culinary water in Northern Utah

X_1, average price (dollars)	$\hat{Y}$, estimate of consumption per day per capita (gallons)
.00	435.58
.02	411.93
.04	388.28
.06	368.64
.08	340.98
.10	317.33
.12	293.68
.14	270.03
.16	246.38
.18	222.73
.20	199.08
.25	139.96
.30	80.83
.35	21.71
.40	-37.42

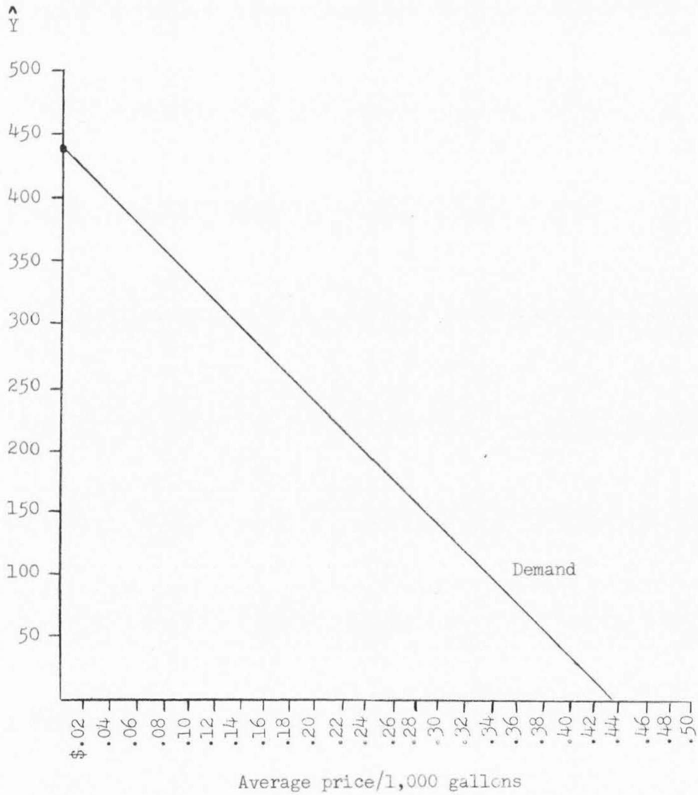

Figure 11. Demand curve for household water in Northern Utah.

$\hat{Y}$ = consumption/day/capita expressed in gallons.

Demand curve determined by logarithmic equation

Equation 13 expresses the demand function for household water in logarithmic terms. The demand schedule was determined from this equation by holding lot area per capita at the arithmetic mean of the logarithmic values and then varying the logarithmic values of average price. The demand schedule formulated is presented in table 16.

The antilog of Y from equation 13 was divided by 1,000 to correct for coding of the original data necessary to remove negative signs. It was then plotted with the antilog of average price on ordinary arithmetic graph paper. The resulting demand curve is presented in figure 12. The curve fits through the scatter diagram for average price per 1,000 gallons and consumption per day per capita. The demand curve has a negative slope as figure 12 clearly demonstrates.

Elasticities of Significant Variables

Elasticity of average price

The regression equation 7 was used to calculate elasticities of price and lot size. In equation 7, X_1 was average price and X_2 was lot area per capita. For average price elasticity it was necessary to hold X_2 at its arithmetic mean and vary the X_1 variable. X_1 was set at \$.013, \$.161, and \$.350 to find the elasticity at the lower end, middle, and top end of the demand curve.

The X_1 value \$.013 was the lowest average price observed, and

Table 16. Demand schedule for logarithmic equation 13

X_1, average price (dollars)	$\hat{Y}$, estimate of consumption per day per capita (gallons)
.02	901
.04	530
.06	388
.08	312
.10	263
.12	228
.14	203
.16	183
.18	168
.20	158
.22	144
.24	134
.26	126
.28	119
.30	113
.32	108
.34	103
.36	98
.38	94
.40	91

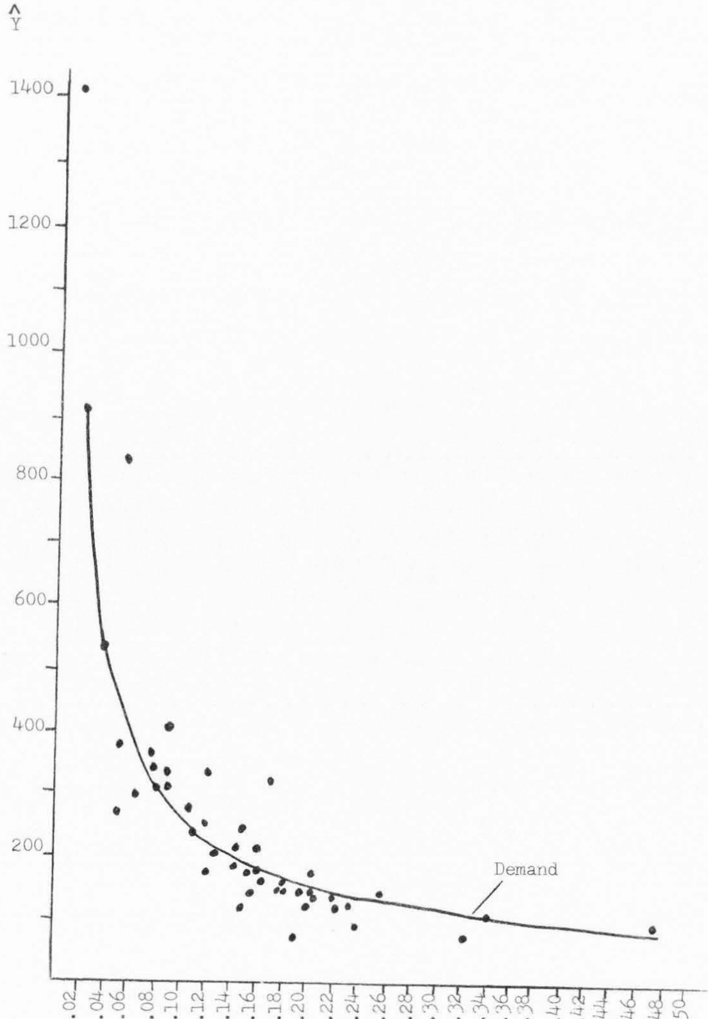

Figure 12. Demand curve for household water in Northern Utah using equation 13, the logarithmic equation.

$\hat{Y}$ = consumption/day/capita expressed in gallons.

X_1 value \$.161 was the arithmetic average of all average prices observed. The X_1 value \$.350 was selected because it was near the top of the average price schedule. The maximum average price (.477) would have been used but it allowed the $\hat{Y}$ (estimated consumption of water) to be negative value.

After the $\hat{Y}$'s had been determined, they were plugged into the formula $b \cdot \frac{P}{Q}$ where $Q = \hat{Y}$. The b value was the regression coefficient for average price, and price was altered between three average price values.

When price was \$.013 the elasticity was equal to $-1182.49 \cdot \left(\frac{.013}{420.21}\right) = -.037$, indicating that elasticity is very inelastic at low prices. With an average price of \$.161, the elasticity was equal to $-1182.49 \cdot \left(\frac{.161}{245.20}\right) = -.776$, which was still inelastic. When average price was increased to \$.350, the elasticity was equal to $-1182.49 \cdot \left(\frac{.350}{21.71}\right) = -19.064$, which was very elastic. This resulted in a highly inelastic demand at low average prices and a highly elastic demand at high average prices. Of course, this result is to be expected along a linear demand curve where elasticity, by definition, increases as you move up the curve to higher prices. Perhaps the most significant was the elasticity of -.776 at the average price of \$.161.

The regression coefficients for the logarithmic equations are equal to elasticity along the entire demand curve. The regression coefficient for price in equation 13 was -.7662. This elasticity of -.7662 determined by the logarithmic equation 13 was very close to the elasticity estimated by the use of the regression coefficient from arithmetic equation 7, when average price was at its arithmetic mean.

Along the linear demand curve the elasticity of price becomes elastic at higher prices. This may also hold in the thinking of the consumer. As price increases he develops substitutes for household water or for water-using facilities. An example of this would be at some higher price the consumer may decide to cover the lawn with concrete or some other substitute for grass. Then as price decreases he may be willing to irrigate more and have more water-using facilities. Also, people consume more water as price is reduced. Their consumption may be increased by using water air conditioners and other water-using facilities as well as being less particular about extent and time of irrigating.

Lot area per capita

The equation used to solve for lot area elasticity was $b \cdot \frac{\text{lot area}}{Q}$ where $Q = \hat{Y}$ and lot area was the independent variable that was allowed to vary from 1,096, 4,458, and 13,557, representing small, medium, and large lot area per capita respectively.

When lot area per capita was 1,096, the elasticity was equal to $.0299 \left(\frac{1096}{144.68}\right) = .226$ indicating an inelastic lot area and consumption relationship when lot area is small (relatively). As lot area per capita increased to 4,458, which was the arithmetic average of the lots observed, the elasticity was equal to $.0299 \left(\frac{4458}{245.20}\right) = .544$, which was also inelastic. The largest lot area per capita observed, 13,557, gave elasticity equal to $.0299\left(\frac{13,557}{517.26}\right) = .784$, which was also inelastic.

The logarithmic equation 13 gave an elasticity for lot area of .1506, which is very inelastic and lower than the elasticity estimated by the arithmetic equation 7 at the mean for lot area. However, it was concluded here that lot area was inelastic which may be caused by part of the larger lots being irrigated by other sources or not irrigated entirely.

SUMMARY OF RESULTS AND RECOMMENDATIONS

Significant Variables

Average price was found to be a significant variable with a partial regression coefficient of -1182.48. This means for a $1,00 per 1,000 gallons increase in price there would be a 1182.48 gallon decrease in consumption of water per day per capita. However, price does not change in such large quantities. It generally changes by cents. Interpreted using cents, the regression coefficient of 1182.48 means for a 1 cent change in average price of water per 1,000 gallons results in a change in consumption of water per day per capita of 11.82 gallons.

Elasticity of .77 for the whole curve, taken from equation 13, means consumption of water was inelastic with respect to average price. When the elasticities of equation 7 for average price are compared, it can be said that at low prices (below unitary elasticity) percent change in quantity is less than percent change in price. This would mean systems wanting to increase their revenue could increase average price up to the point where elasticity equals one and be sure of increasing revenue. Systems operating in the elastic portion could increase revenue by lowering the price if they had excess water or if there was some way to ration it.

Lot area per capita was a significant variable with a regression coefficient of .0299 from equation 7. This interpreted means for a 100 square foot change of lot area per capita, consumption of water per day per capita would increase by approximately three gallons.

The results reported in this study seem to conflict with published statements by some professional people. Some engineers have emphatically expressed their doubts that price affects consumption of water. One engineering firm reported that even an 85 percent change in price may not have any permanent retarding of consumption (3, p.208).

This feeling of doubt about the effect of price consumption deserves more explanation. If the price is low there will be a greater change in quantity due to a change in price than if the price is high and there is a change in price according to the demand curve in figure 12. This is described by the elasticity for demand and needs to be strongly emphasized. If it takes an 85 percent change in price before any change in consumption occurs, it is probably because they are operating at the far end of the demand curve where price must change at greater percentage increments than quantity.

Variables not found significant

It is important to discuss possible reasons why more of the variables were not found to be significant. It is also important to emphasize that conclusions made in this study are pertinent only to the area observed in the study. Adjustments would be needed to apply this to other areas.

The price of fuel used to heat water was not even tested because there was no variation in price between cities observed. If this study could have been extended to an area large enough to capture variation in the price of fuel used to heat water, it may have been a significant variable.

Median income per capita was not a significant variable in this study. This result may be true only for the area covered in the study. If the area was to be extended to include areas where incomes were less homogeneous, the variable may be found significant. After all, the area studied constitutes the industrial economy of Utah, and incomes are not as diverse among communities as a study of the whole state would reveal.

Value of homes per capita was not a significant variable even when observations had a range from $2,486 and $5,000. From the results of this study, one is forced to conclude that value of the home does not significantly affect consumption of water. If another method was used to capture different quantities of water-using facilities, or if culinary water could be distinguished from lawn water, it is possible that the variable would be significant.

The percent of homes having a complete plumbing unit was not a significant variable. However, there were only three observations with a percent figure less than 90. It is possible there was not enough variation to properly test the variable. Again, if a larger area had been tested where variation was greater, this variable may have been significant.

The two weather variables, precipitation and temperature, were not significant. Precipitation had a range of .53 inches per month, and average maximum temperature had a range of 5.6 degrees. It is possible this was not enough variation in the variables to detect variation in consumption caused by them. If temperature for example, was to increase it was expected water consumption would also increase; but there was not enough change in temperature between observations to show this condition. Also, there is the chance that reaction to weather change lagged behind the change and masked the effect.

Coefficients of Determination for Models

Multiple correlation coefficients for the models were not extremely high. Equation one, which was used in most of the analysis to determine significant variables, had a multiple coefficient of 55 percent. When only significant variables were used in this equation, the multiple coefficient of determination dropped to 51 percent, equation 7.

There were several reasons for the fit not being higher than it was in this analysis. Effect of variables thought, a priori, to be important was not completely represented due to lack of variation in data for some variables as explained in the previous section.

The way some of the variables were estimated empirically may have reduced their effect. For example, median income per capita may have accounted for more if it had been median income of wage earners. Often data were not available in most desirable forms and had to be adjusted. Also, some of the variables had a slight amount of interaction which was left out of the model. If interaction terms had been included the coefficient (R^2) would have been larger.

Possibly the most important single factor responsible for not having higher multiple coefficients of determination in the linear relationships was the non-linear nature of some of the data. Evidence of this is brought out by the logarithmic equation where the multiple coefficient of determination was 82.6 percent for equation 13, which was a much better fit. If quadratic terms had been introduced for all variables the fits might have increased in equations one through twelve, although the scatter diagrams reveal that the linearity assumptions were bold only in the case of price.

Recommendations

This study was for six counties in Northern Utah. However, these methods may be applied to other areas. It would be valuable to other areas in the state of Utah to have a study completed in this manner and then a comparison made with this study. Some of the variables not having enough variation in this study to be significant may have the needed variation in other areas.

A study should be completed where the four major uses of water (household, industrial, agricultural, and recreational) are considered. This would be accomplished by developing a better means of allocating water between uses than is presently in use in Utah today.

As was pointed out in this study, there are numerous methods used in pricing water. It is recommended that a study be made where an adequate pricing method could be developed. This should not be a single method because objectives of the various cities may not be the same. Therefore, alternative pricing methods are needed that could be applied to the various objectives.

It is also recommended that studies be made to develop better methods of allocating water within each of the four major uses. This may be partially accomplished for household water in the study on pricing methods.

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