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The Basic Model for Estimation

For the purposes of considering the impact of changes in water usage rates we have analyzed the impact of changes in water and sewer rates on aggregate water use by Kentucky American Water Company (KAWC) customers from 1970 to 1993. Basically we use the same econometric model we developed to forecast use for the entire Kentucky River Basin[1]. The model for the basin predicts water use based on changes in economic and demographic factors, shares of population on public water and sewer, weather conditions, and time of year.

For the KAWC estimation we use a slightly different functional form which fits better, but otherwise the model is similar. An important distinction, however, is the addition of water rates and sewer rates as variables which measure the price of water. We did not use these variables in the basin-wide study because similar rates for the entire basin for the estimation period were unavailable. With the augmented KAWC data we find the elasticities of water use with respect to water rates to be approximately: - 0.6 for peak use, - 0.3 for off-peak use, and - 0.4 for the entire year. Given the nature of the estimates for the KAWC area, these values are quite consistent with the recent AWWA review of demand studies.[2]

Pricing

As block pricing has been used by KAWC, there is no single obvious price to use in our estimation procedure. Indeed, one of the objectives of the study is to determine how changes in the block pricing structure will affect the use of water. Instead of examining a single price, it is desirable to consider the impact of the different block prices on water use.

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[1] UK/WRRI Economics Group. *Water Use Estimation and Forecasting for the Kentucky River Basin: A Preliminary Draft Report*. June, 1996.
[2] Vista Consulting Group. *Managing the Revenue and Cash Flow Effects of Conservation*. (Denver, CO: AWWA Research Foundation and AWWA, 1996.)

Table 1 lists the nominal prices and the ranges for the six different rate blocks for June of each of 1970-1995. As the table shows for most years there is only effectively two or three different rates, however, the quantity at which the different blocks begins has changed since 1970, making the creation of six blocks necessary. For example, in 1992 there are two rates: one for less than 600,000 gallons a month and one for over 600,000 a month. In 1980 there were three brackets: one for less than 12,000 a month; one for between 12,000 and 588,000; and one for over 600,000. The relevant quantity of water for each block, in gallons per month, is listed in Table 1. The rates listed are in dollars per 1,000 gallons.

While Table 1 shows that in general nominal prices have increased, it is the real price of water which should determine the water usage. In Table 2 we list the water rates, by block, in 1993 dollars. As can be seen more clearly in Figure 1, while nominal prices have generally increased, real water rates for the low volume uses dramatically decreased throughout the 1980's, reaching almost a low of 50% of the real rate in the early 1970's. Only with the rate increases of 1992 have this trend been significantly reversed. The trend for high volume users is the reverse of that of low volume users with a steady increase in rates during the past twenty-five years with rates approach a level of three times that of the rates in the early 1970's. The general trend, then, has been a much diminished benefit for high-volume users of water relative to low-volume users.

Rates and Use - A Quick Look

Before examining the results of our estimates it is useful to graphically examine the trend in water use (per capita) relative to real water rates. Figure 2 shows the trend in real rates for block 1 and the trend in per capital water use. Without considering other factors affecting water use such as weather, the link between rate and use appears weak. A similar (lack of) relationship between the rate for high-volume users (block 6) and water use is depicted in Figure 3. As our estimation results will demonstrate, however, once other factors affecting water use have been considered there is a statistically and economically significant relationship between rates and water use.

Estimation Equations

Tables 3, 4 and 5 present the summary of estimation of the impact of changes in (real) water rates on per capita use for KAWC during the period 1970-1993. As we did with our earlier analysis of permitted water use in the entire Kentucky River Basin we consider peak season use (June-September) separately from non-peak use. The estimations shown for both the peak season (Table 3) and the non-peak season (Table 4) are estimated using a log-linear specification. The estimates for the entire year are shown also (Table 5).

This specification is a standard one with the literature on estimating water demand equations.[3] We use this specification for two reasons: 1) the specification does a good job of "fitting" the data, that is, it explains much of the variation in water use of time; 2) using this specification the coefficients on prices and incomes can be interpreted conveniently as elasticities.

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[3] For a cryptic review see UK/WRRI Economics Group. *Estimating Residential Water Demand: An Annotated Bibliography*. January 1996. For a detailed review see the 1996 AWWA report by Vista Consulting group.

Elasticities

Elasticities measure changes in use in percentage terms, thus, price (or rate) elasticity is simply the percentage change in (per capita) water use with respect to a given percentage change in the rate, $\frac{\%\,\Delta(WaterUse)}{\%\,\Delta(Rate)}$. For example, in *Table 3*, examining column (a) we see that the coefficient on the Log(Block 1 price) is -0.69. This coefficient can be interpreted as meaning that a 10% increase in the Block 1 price decreases per-capita water use in the peak summer months by 6.9%. For another independent variable which is not a logarithmic transformation, then the coefficient on it can simply be interpreted as the percentage change due to an increase (of one unit) in the variable. For example, the coefficient on *Trend* in Table 3, column (a) equals -.05. This is interpreted as a 5% decrease in peak season, per capita water use per year independent of any other determinants of water use.

In the estimates reported in Tables 3, 4 and 5 we consider the impacts of income, employment and manufacturing, time of the year (month indicator variables), weather (temperature and rainfall for peak use), any trends in water use over time (*Trend*) in addition to the impact of water and sewer rates. This multivariate specification is necessary to isolate the impact of changes in rates on water use from other determinants of water use that also may have changed over time.

Which Water Rate?

Ideally it would be desirable to estimate an equation that included all (or most) of the different block rates together. Estimates including more than one block price have not provided satisfactory results. The reason the results have not been particularly successful is probably due to the problem of *multicollinearity*. Essentially, the problem we have is that at the same time that the real price of the lowest block changes, either because of inflation or KAWC rate changes generally so do the rates for the other blocks, so we have little independent variation in rates. The existence of this multicollinearity is suggested by the parallel movement (and identical rates) of the blocks in Figure 1. Thus, to get an indication of the impacts of the different rates we have used the approach of estimating a separate equation for each rate. While this approach has some statistical problems, given our multicollinearity problems, we had little other choice. Essentially we are searching for the one block rate which best represents the structure of rates across different classes of users.

The block rate which performs the best is the rate for the lowest block and that is the variable labeled "log (Real Water Price)" in the tables. According to KAWC data approximately ¾ of customers are residential and commercial users and are highly likely to be in this first bracket. In addition to testing for which marginal water rate fit best we tested for average water rates.[4] Using data on the distribution of users across consumption classes we also created a variable which is the average marginal rate weighted by the share of users in each class.[5] None of the alternative rate variables performed better than the rate for the first block and the price elasticity estimates reported in the tables are for the first block rate. The first rate represents the entire rate structure. We should remember that in our estimates an increase in block 1 rate tends to mean an increase in other block rates too.

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[4] KAWC Water Demand Model output from a run made August 2, 1996 and graciously supplied by Linda Bridwell.

[5] For these data for KAWC we thank Thomas McKitrick of American Water Works Service Company.

Estimates of the Elasticities of Water Use with Respect to Water Rates

Estimates based on our model show that increases in water rates lead to statistically and economically significant changes in water use. It is also interesting to note, though not surprising, that peak water use is more responsive to price changes (-0.69)than rate increases in the off-peak season (-0.30). The elasticity estimate for the entire year (-0.43) is between the peak and off-peak values as we expect.[6]

We can use these elasticities to get an idea of the impact of a change in water rates on per capita use in Fayette county. For example, if the (real) rate increases from $1.80 to $2.16, an increase of 20%, peak per capita use would decrease by (.69)(20) = 13.8%. Based on June 1993 per capita use the reduction would be approximately 27.9 gallons per capita.

Elasticities for Sewer Rates and Weather

The influence of variables other than the water rate changes depending upon the period we consider. Consider, for example that while the point estimate of the impact of the sewer rate on water use is always negative, the effect is larger and statistically significant in the off-peak period. The sewer rate elasticity during the off-peak period is approximately 1/3 the size of the elasticity for the water rate. The sewer rate does not have a significant effect during the peak period. For the weather variables, note that the elasticities are larger during the peak demand season as we expect.

Conservation Pricing

In our example above we used a 20% increase in water rates. We illustrate how a 20% increase would lead to a 13.8% reduction in peak season, aggregate use of water. Obviously, a long-term policy of rate increase would reduce the demand for water and mitigate potential water deficits during drought. While a 20% increase is nontrivial by most standards, we think it is reasonable to consider as a conservation technique. This increase would be substantially smaller than the increases for large users in 1983 and again in 1992. Conservation pricing is a drought management policy which has costs in the form of the value of water not used. But, it should be a policy considered along with alternatives which increase water supply. The response of water users to water rates is noticeable especially during the summer months of peak demand.

[6] A potential source of bias with our model is first order serial correlation. We reestimated our models using a Cochrane-Orcutt correction and found that our elasticities are reasonably robust. They tend to be about 15% smaller than the values reported in the text.

Table 1: Nominal Rates ($ per 1,000 gallons), 1970-1995							
Year	Block 1 <12,000 (gallons per month)	Block 2 12,000-37,500	Block 3 37,500-262,500	Block 4 262,500-600,000	Block 5 600,000-2,512,500	Block 6 >2,512,500	Gallons per Capita
1970	0.59	0.59	0.43	0.25	0.25	0.17	185
1971	0.91	0.91	0.66	0.38	0.38	0.25	175
1972	0.91	0.91	0.66	0.38	0.38	0.25	160
1973	0.91	0.91	0.66	0.38	0.38	0.25	150
1974	0.73	0.73	0.53	0.31	0.31	0.20	150
1975	0.83	0.83	0.60	0.35	0.35	0.23	151
1976	0.83	0.83	0.60	0.35	0.35	0.23	153
1977	0.83	0.83	0.60	0.35	0.35	0.23	167
1978	0.83	0.83	0.60	0.35	0.35	0.23	172
1979	0.93	0.93	0.67	0.39	0.39	0.26	165
1980	0.93	0.93	0.67	0.39	0.39	0.26	187
1981	0.98	0.98	0.71	0.41	0.41	0.27	177
1982	1.18	1.18	0.86	0.50	0.50	0.33	168
1983	1.11	0.87	0.87	0.87	0.77	0.77	175
1984	1.15	0.91	0.91	0.91	0.83	0.83	196
1985	1.15	0.91	0.91	0.91	0.83	0.83	168
1986	1.23	0.96	0.96	0.96	0.87	0.87	212
1987	1.34	1.05	1.05	1.05	0.95	0.95	199
1988	1.32	1.03	1.03	1.03	0.93	0.93	246
1989	1.32	1.03	1.03	1.03	0.93	0.93	159
1990	1.48	1.16	1.16	1.16	1.05	1.05	165
1991	1.48	1.16	1.16	1.16	1.05	1.05	189
1992	1.80	1.80	1.80	1.80	1.41	1.41	173
1993	1.80	1.80	1.80	1.80	1.41	1.41	202
1994	1.80	1.80	1.80	1.80	1.41	1.41	.
1995	1.80	1.80	1.80	1.80	1.41	1.41	.

Table 2: Real Rates (1993 $ per 1,000 gallons), 1970-1993							
Year	Block 1 <12,000 (gallons per month)	Block 2 12,000-37,500	Block 3 37,500-262,500	Block 4 262,500-600,000	Block 5 600,000-2,512,500	Block 6 >2,512,500	Gallons per Capita
1970	1.98	1.98	1.44	0.84	0.84	0.57	185
1971	2.90	2.90	2.11	1.22	1.22	0.81	175
1972	2.79	2.79	2.02	1.17	1.17	0.77	160
1973	2.63	2.63	1.91	1.11	1.11	0.73	150
1974	1.94	1.94	1.40	0.82	0.82	0.54	150
1975	2.01	2.01	1.45	0.85	0.85	0.56	151
1976	1.91	1.91	1.38	0.80	0.80	0.53	153
1977	1.80	1.80	1.31	0.76	0.76	0.50	167
1978	1.68	1.68	1.22	0.71	0.71	0.47	172
1979	1.71	1.71	1.24	0.72	0.72	0.48	165
1980	1.60	1.60	1.16	0.67	0.67	0.44	187
1981	1.54	1.54	1.12	0.65	0.65	0.43	177
1982	1.75	1.75	1.27	0.74	0.74	0.49	168
1983	1.58	1.24	1.24	1.24	1.10	1.10	175
1984	1.58	1.26	1.26	1.26	1.14	1.14	196
1985	1.53	1.22	1.22	1.22	1.10	1.10	168
1986	1.59	1.25	1.25	1.25	1.12	1.12	212
1987	1.68	1.32	1.32	1.32	1.19	1.19	199
1988	1.59	1.25	1.25	1.25	1.13	1.13	246
1989	1.53	1.20	1.20	1.20	1.08	1.08	159
1990	1.64	1.29	1.29	1.29	1.16	1.16	165
1991	1.58	1.24	1.24	1.24	1.12	1.12	189
1992	1.86	1.86	1.86	1.86	1.46	1.46	173
1993	1.80	1.80	1.80	1.80	1.41	1.41	202

Figure 1: Real Water Rates by Block, 1970-1993

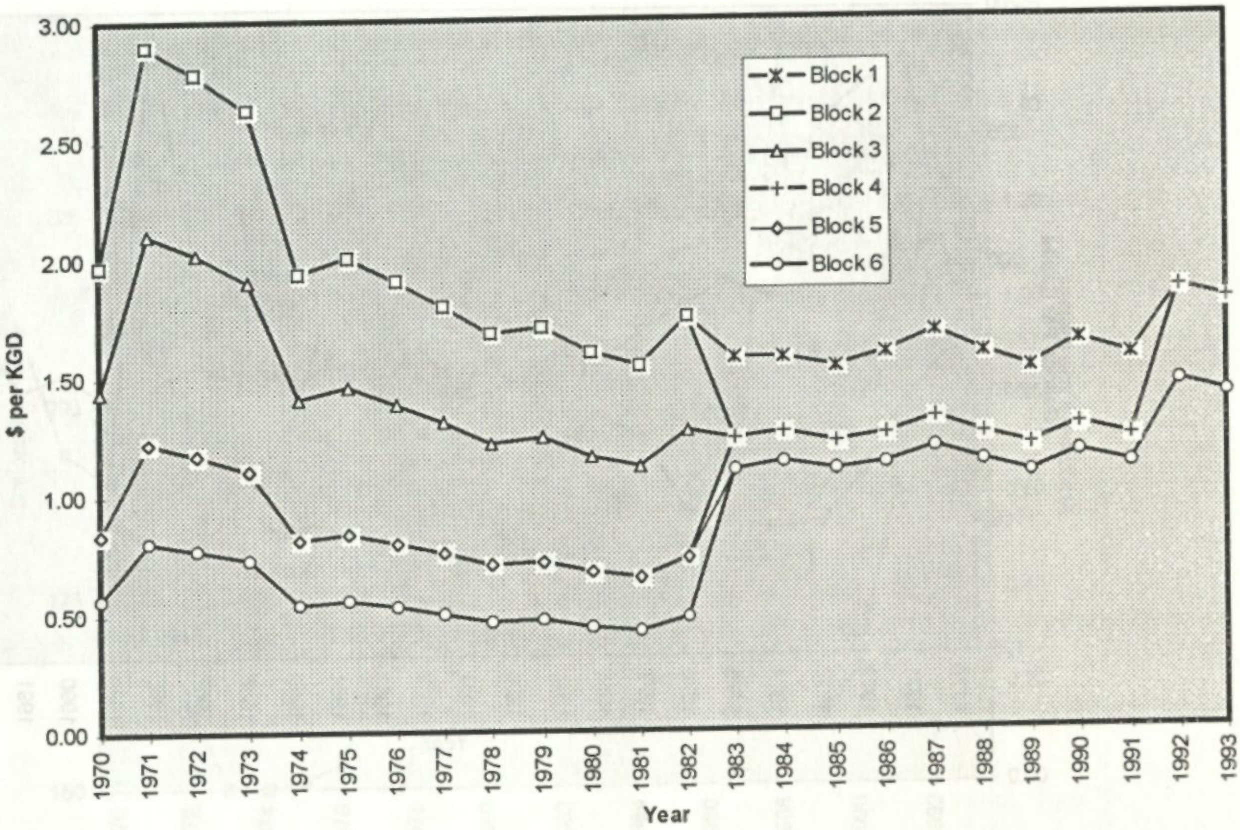

Figure 2: Real Prices (Block 1) versus Gallons Per Capita, 1970=1993

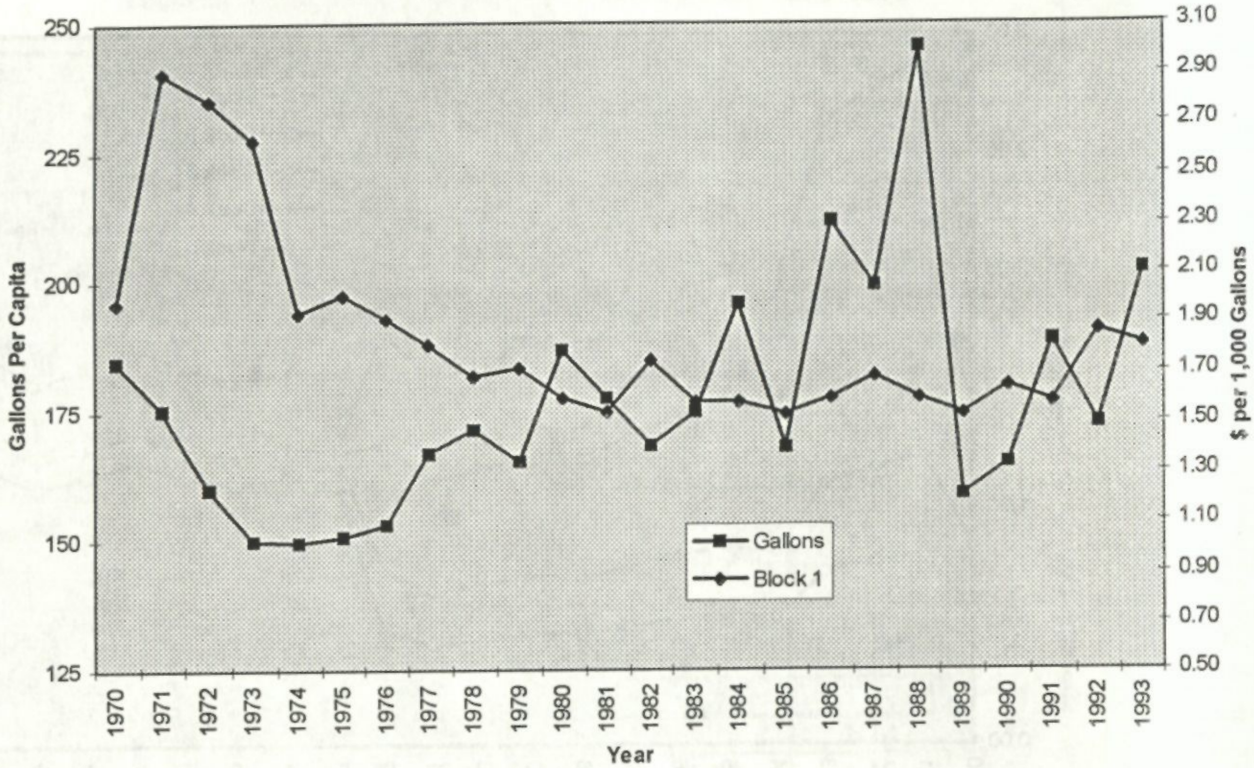

Figure 3: Real Prices (Block 6) versus Gallons Per Capita, 1970-1993

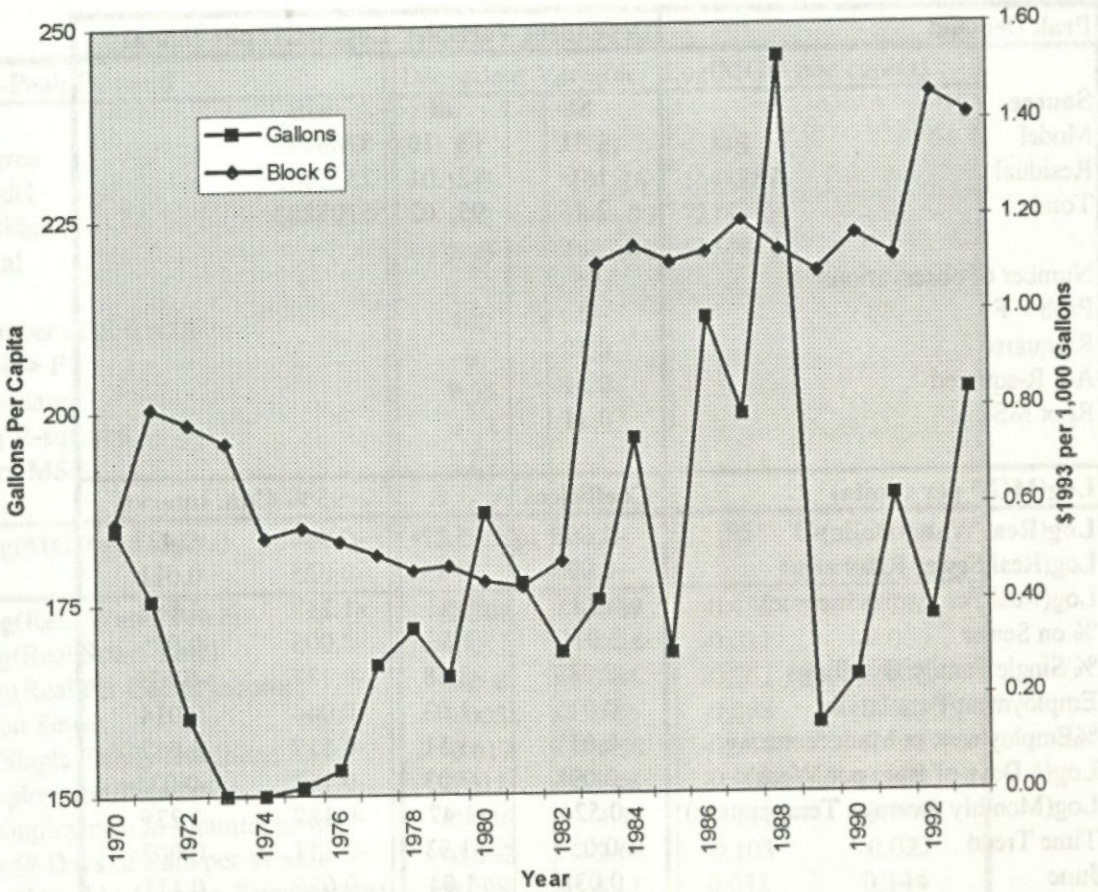

Table 3: Estimates of Peak Season Water Demand for KAWC, 1970-1993 (monthly)

Peak Demand	**Dependent Variable: Log(MGD per capita)**			
Source	**SS**	**df**	**MS**	
Model	1.41	13 .10	8783493	
Residual	1.03	82 .01	2535043	
Total	2.44	95 .02	5705883	
Number of observations	96			
Prob > F	0			
R-squared	0.58			
Adj R-squared	0.51			
Root MSE	0.11			
Log(MGD per capita)	**Coefficient**	**t**	**95% Con. Interval**	
Log(Real Water Price)	**-0.685**	-5.27	-0.944	-0.427
Log(Real Sewer Rate)	-0.007	-0.80	-0.025	0.011
Log(Real Per Capita Income)	0.335	0.43	-1.217	1.888
% on Sewer	0.015	1.52	-0.005	0.035
% Single Family Dwellings	-0.088	-3.58	-0.137	-0.039
Employment/Population	-0.015	-1.03	-0.044	0.014
%Employment in Manufacturing	-0.051	-1.51	-0.119	0.017
Log(# Days of Rain per Week)	-0.098	-3.03	-0.163	-0.034
Log(Monthly Average Temperature)	0.526	1.47	-0.187	1.239
Time Trend	-0.054	-1.93	-0.111	0.002
June	0.038	1.04	-0.035	0.111
July	0.041	0.82	-0.059	0.141
August	0.029	0.65	-0.060	0.118
Constant	8.857	4.19	4.654	13.060

Table 4: Estimates of Off-Peak Water Demand for KAWC, 1970-1993 (monthly)

Off-Peak Demand	**Dependent Variable: Log(MGD per capita)**			
Source	**SS**	**df**	**MS**	
Model	1.62	10 .16	1544287	
Residual	1.32	181 .00	7278045	
Total	2.93	191 .01	5354812	
Number of observations	192			
Prob > F	0			
R-squared	0.55			
Adj R-squared	0.53			
Root MSE	0.09			
Log(MGD per capita)	**Coefficient**	**t**	**95% Confidence Interval**	
Log(Real Water Price)	-0.301	-4.39	-0.436	-0.166
Log(Real Sewer Rate)	-0.012	-2.48	-0.022	-0.003
Log(Real Per Capita Income)	0.268	0.64	-0.563	1.100
% on Sewer	0.003	0.55	-0.008	0.014
% Single Family Dwellings	-0.017	-1.28	-0.044	0.009
Employment/Population	0.012	1.48	-0.004	0.027
%Employment in Manufacturing	-0.076	-4.21	-0.111	-0.040
Log(# Days of Rain per Week)	-0.062	-3.04	-0.103	-0.022
Log(Monthly Average Temperature)	0.098	4.12	0.051	0.144
Time Trend	-0.042	-2.72	-0.073	-0.012
Constant	5.572	6.57	3.899	7.244

Table 5: Estimates of Year-Round Water Demand for KAWC, 1970-1993 (monthly)

Entire Year	**Dependent Variable:**	**Log(MGD per capita)**		
Source	**SS**	**df**	**MS**	
Model	4.248	10 .42	4838207	
Residual	3.023	277 .01	914853	
Total	7.272	287 .02	5337269	
Number of observations	288.000			
Prob > F	0.000			
R-squared	0.584			
Adj R-squared	0.569			
Root MSE	0.104			
Log(MGD per capita)	**Coefficient**	**t**	**95% Confidence Interval**	
Log(Real Water Price)	**-0.426**	-6.22	-0.561	-0.291
Log(Real Sewer Rate)	-0.010	-1.94	-0.019	0.000
Log(Real Per Capita Income)	0.344	0.82	-0.480	1.167
% on Sewer	0.007	1.25	-0.004	0.017
% Single Family Dwellings	-0.039	-2.96	-0.066	-0.013
Employment/Population	0.002	0.31	-0.013	0.018
%Employment in Manufacturing	-0.064	-3.58	-0.100	-0.029
Log(# Days of Rain per Week)	-0.087	-4.65	-0.125	-0.050
Log(Monthly Average Temperature)	0.216	10.54	0.175	0.256
Time Trend	-0.046	-3.02	-0.077	-0.016
Constant	6.606	7.70	4.917	8.295