

SECTION III

ARTESIAN WATER CONSERVATION IMPACT STUDY: OBJECTIVES AND METHODOLOGY

This project analyzes water consumption impacts of three among the Artesian water DSM measures: conservation-oriented rates (CR), conservation education, and conservation kit programs. For this analysis, we used household-level data, gathered from telephone and mailing surveys from the customers in the part of New Castle County served by Artesian Water Company, Inc. In this Section, the objectives of this project are stated, and methodological issues related to sampling and surveys are discussed, along with brief reviews of water DSM-related literature.

III - 1. Objectives

The objective of this project is to evaluate the performances of the selected DSM measures undertaken by Artesian Water Company, Inc. Specifically, this project evaluates potential impacts of Artesian's conservation-oriented inclining rates on customer water use.⁹ Additionally, the impacts of Artesian's conservation education and conservation kit programs on water consumption are examined on the basis of the existing data from our surveys and from Artesian. This project seeks to analyze the water conservation impacts of:

- Conservation-oriented rates;
- Conservation information and education; and
- Conservation kit programs.

The analysis is further broken down by the three residential customer subgroups identified earlier. Several tasks were carried out to achieve these objectives:

- A stratified sample was selected from Artesian's residential customer file.
- Telephone and mail surveys were conducted with the sampled customers to obtain housing and household information. This information was merged with monthly water consumption data acquired from Artesian.

⁹ Artesian Water Company, Inc.'s filing of inclining water rates was approved on August 18, 1992 by the Delaware Public Service Commission (Docket 92-05).

- An evaluation model was constructed to measure the impacts of CR, education and conservation kit programs.
- Policy suggestions were made on the basis of the findings of this study.

III - 2. Random Sampling and Original Sample Size

A stratified random sampling by water consumption subgroup was conducted in this analysis in order to more accurately reflect the characteristics of the population that contribute to variation in water consumption. Required sample size of each target subgroup was based upon its proportion in the target population. The sampling procedures were:

- From the Artesian customer file, the water consumption characteristics of each consumption subgroup was identified.
- The sample size was determined on the basis of the mean and standard deviation of water consumption for each subgroup of Artesian’s residential customers during the peak consumption period (third quarter of 1991).
- Required sample size by each target subgroup was adjusted for historical rates of household turnover due to relocation and interview refusal.

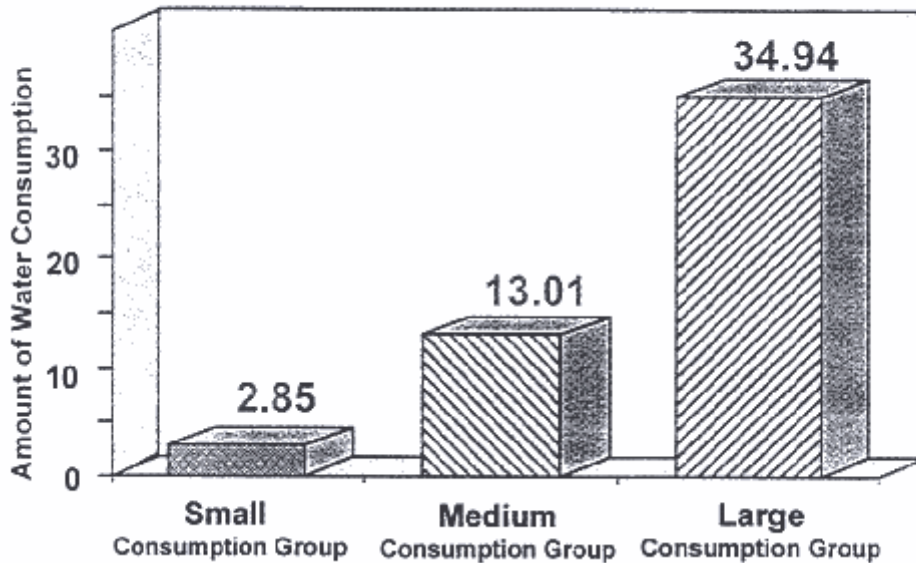
The mean and standard deviation of water consumption during the third quarter by each target subgroup are shown in Table 2 (also see Figure 1).

Table 2
Mean and Standard Deviation of Water Consumption by Target Subgroups
(3rd Quarter of 1991)

Customer Group	Amount of Water Consumption (000 Gallons)	
	Mean	Standard Deviation
Small Consumption Group	2.853	1.155
Medium Consumption Group	13.005	4.453
Large Consumption Group	34.943	20.538

Note: This information was provided by the Artesian Water Company, Inc.

Figure 1
Residential Summer Water Consumption per Capita by Consumption Group



On the basis of the mean (M) and standard deviation (SD), the size of the minimum sample for each target subgroup was determined by the following formula:¹⁰

$$\text{Sample Size (S)} = \{(T^2 * SD^2) / (A^2 * M^2)\}$$

- where, T: Student's t-value for the designated confidence level
 SD: Standard deviation
 A: Designated accuracy level
 M: Mean

Using a 95% confidence level (t-value = 1.965) and a ±5% accuracy level (A), the size of minimum

¹⁰ When the fraction of the determined sample size (S) to population size (P) is not negligible, the sample size is adjusted downward by the following formula:

$$\text{Adjusted Sample Size (AS)} = \{S / (1 + (S / P))\}$$

See "The Estimation of Sample Size" in William G. Cochran. 1977. *Sampling Techniques* (New York: John Wiley & Sons).

sample was estimated for each target subgroup, requiring the total minimum sample of 916. To achieve the required minimum sample, the sample was adjusted by an attrition rate of 13 percent (turnover rate of 9%¹¹ and refusal rate of 4%). The additional sample of 119 ($916 * 0.13$) was distributed across consumption subgroup on the basis of proportional consumption subgroup size in the 3rd quarter of 1991. The adjusted sample size of 1,035 was the total number of customers to be interviewed by telephone.

¹¹ This information was furnished by the Artesian Water Company, Inc. Artesian experienced 4,495 customer turnovers in the residential class during 1991, equivalent to 9% turnover rate.

III - 3. Mixed Survey Modes: Telephone Interview and Mail Survey

A telephone survey was originally designed to obtain information on the sample households' housing and household characteristics, including outdoor watering activities. Attitudinal information was also sought, along with the level of household knowledge of pricing and of Artesian's water conservation efforts. The sample household interviews include questions on the following:

- Use frequency of indoor water appliances and outdoor water activities
- Number of toilets and full-size bath
- Estimated value of housing
- Landscape features
- Size of household and number of children
- Household income (including public subsidies)
- Number of cars currently in use
- Frequency of sprinkling and car washing
- Swimming pool or any types of swimming facilities
- Knowledge of conservation efforts by Artesian, including mass media messages, bill pamphlets, etc
- Use of water conservation kits provided by Artesian
- Knowledge on the level of water consumption and its pricing
- Knowledge of the current rate structure, including minimum charge and flat rate
- Perception of the water supply situations in New Castle County (quantity and quality, currently and in the near future)

This survey was conducted during the spring of 1993, incorporating questions involving 87 variables relating to water conservation practices and orientation (see Appendix A for the survey instrument). Out of the optimal sample size of 1,035 households, the Center for Applied Demography and Survey Research (CADSR)¹², a subcontractor for the survey, was able to match 696 households who have telephone numbers listed. Artesian supplied an additional list of 129 customers with telephone numbers from its conservation program file, making 825 households available for telephone interviews. Fifteen professional interviewers trained by CADSR conducted our interviews.

Responses from 515 households were completed, registering 62.4% of response rates. Mail surveys were sent to 339 additional households to increase our response rates. The survey instruments were mailed to the households whose telephone numbers were not identified and also to those whom interviewers were unable to reach after 5 calls. From the mail survey, 166 additional households were

¹² The Center is a unit of the College of Urban Affairs and Public Policy, University of Delaware. Its mission is to ensure that the best possible data and information on important public issues are made available to the public. The Center conducted more than 10,000 interviews during the last year.

included in our analysis.

Mixed survey modes raise a concern as to whether survey results from both telephone and mail interviews can be pooled together. The t-test was used to compare the mean differences in the variables between the telephone survey group and the mail survey group. The variables included in this test are the ones that are considered to significantly affect water consumption. They are:

- the frequency of clothes washer uses per month;
- the frequency of dish washer uses per month;
- the use frequency of other indoor appliances consuming a considerable amount of water;
- the ownership and frequency of refilling of pool;
- the frequency of watering lawns during the summer months;
- the frequency of car washing at home;
- the conservation orientation perceived by customers;
- the income of household;
- the size of household;
- the average price of water; and
- the amount of water consumption in the third quarter of 1992.

An evaluation criterion of this test is the t-statistic. The critical t value is 1.965 at the level of significance of 95%. A t-value above this indicates a statistically significant difference between the two survey groups. Out of the 9 variables compared, only one variable, the size of household, was statistically significant (Table 3). The telephone survey group tends to have a higher household size than that of the mail survey group (3.0 vs. 2.7). Basically, no significant differences exist between the two groups. Also, water consumption between the two groups was not statistically different. Therefore, we combine these two survey groups for our subsequent analyses.

Table 3
Comparison between Telephone and Mail Survey Groups: t-Test

Variable	Group	Number of Cases	Mean	Standard Deviation	t Value	2-tail Probability
Household Size	1	495	3.00	1.44	1.99	0.047
	2	158	2.74	1.26		
Clothes Washer Uses	1	501	17.39	14.39	-0.12	0.898
	2	156	17.55	13.19		
Pool Ownership	1	504	0.23	0.64	-0.39	0.696
	2	158	0.25	0.68		
Dish Washer Uses	1	502	9.97	9.85	0.71	0.480
	2	157	9.34	9.90		
Household Income	1	503	4.95	1.81	-1.20	0.231
	2	148	5.16	1.84		
Lawn Watering	1	483	5.12	6.28	-1.56	0.118
	2	148	6.03	5.87		
Conservation Orientation	1	481	0.55	0.66	1.33	0.185
	2	152	0.47	0.60		
Average Price	1	504	0.38	0.24	-0.80	0.423
	2	158	0.40	0.31		
Water Consumption	1	504	18282	12003	-0.84	0.399
	2	158	19228	13202		

Note: The group 1 denotes the telephone survey group and the group 2 denotes the mail survey group.

III - 4. Sample Size of 662 and Its Accuracy Level

The sample size of 662 households in the original study conducted in 1993 is 72.3% of the required sample size of 916 households. Because of this undersampling, there was a concern that the accuracy level of the current sample far exceeds that of the original sample. The original sample size was estimated on the basis of the accuracy level of $\pm 5\%$ for each target subgroup. For comparison purposes, the accuracy level of the current sample size was calculated using the mean and standard deviation of water consumption during the summer months of 1992 by each subgroup. The overall accuracy level of the current sample size (662 households) turns out to be $\pm 5\%$. The small consumption group has a wider margin of error compared to that of the medium consumption group ($\pm 7\%$ vs. $\pm 4\%$). The lower accuracy level in case of the small consumption group is considered to be not a significant problem because its contribution to Artesian's peak water loads is minimal.

Table 4
Sample's Accuracy Level by Subgroup
(1992)

Customer Group	Mean	Standard Deviation	Sample Size	Accuracy Level
Small Consumption Group	3,360	1,033	73	± 0.07
Medium Consumption Group	13,284	4,306	327	± 0.04
Large Consumption Group	29,646	12,362	262	± 0.05
Total Consumption Group	18,665	12,556	662	± 0.05

Note: The figures representing the mean and standard deviation denote gallons in water consumption.

III - 5. Water DSM-Related Research

Literature related to the residential DSM of water resources was collected for this project from major water journals published during the period of 1985 to 1997 including *Journal of AWWA*, *Water Resources Bulletin*, *Land Economics* and *Water Resources Research*.

Almost 22% of the identified literature has been devoted to conceptual arguments on the roles and necessities of DSM in water resource planning (Schultz, 1997; Lund, 1995; Child and Armour, 1995; Beecher, 1993; Vickers, 1991; Macy, 1991; Viessman, Jr., 1990; Kreutzwiser and Feagan, 1989; and Grisham and Fleming, 1989). The remainder of the literature has dealt with the impacts of DSM measures on water conservation.

Heavy emphasis in the literature has been on conservation rate impacts, whereas other DSM measures have been less emphasized. Literature reviewed for each DSM measure is as follows:

- Overall programs: Chitale, 1997; Grigg, 1996; Deyle, 1995; Weber, 1993; Vickers and Markus, 1992; Nieswiadomy, 1992; Little and Morean, 1991
- Conservation rate: Dandy, et al., 1997; Espey, et al., 1997; Hansen, 1996; Hewitt and Hanemann, 1995; Duke and Montoya, 1993; Mann and Clark, 1993; Woo, 1992; Rothstein, 1992; Russell and Woodcock, 1992; Nieswiadomy, 1992; Niewiadomy and Molina, 1991; Martin, 1991; Briggs, 1989; Cuthbert, 1989; Billings and Day, 1989; Bruvold and Smith, 1988; and Martin and Thomas, 1986
- Voluntary reduction: Cameron and Wright, 1990; and Olsen and Highstreet, 1987
- Audit: Bruvold and Mitchell, 1993; Nelson, 1992
- Mandatory reduction: Rubin, 1994; Dandy, 1992; Shaw, Henderson and Cardona, 1992; Gilbert, Bishop and Weber, 1990; Shaw and Maidment, 1988; and Bruvold and Smith, 1988
- Education: Nieswiadomy, 1992; Billings and Days, 1989; Bruvold and Smith, 1988; and Olsen and Highstreet, 1987
- Water reuse: Foster and DeCook, 1986
- Meter installation: Maddaus, 1987
- Landscape: Nelson, 1987

- Conservation kit: Vickers, 1993; Whitcomb, 1990; Anderson and Siegrist, 1989; and Vickers, 1989
- Public attitude: Lant, 1993; Rothstein and Jones, 1993; Flack and Greenberg, 1987

The literature on water cost and revenue effects is important and is reviewed here: Hansen, 1996; Rubin, 1994; Beecher, et al., 1994 and 1990; Auerbach, 1994; Howe, 1993; Duke and Montoya, 1993; Boland and Summer, 1993; Miller, 1993; Stevens, Miller and Willis, 1992; Collinge, 1992; Martin and Wilder, 1992; Woo, 1992; Martin and Kulakowski, 1991; Brook, et al., 1990; Gilbert, et al., 1990; Goldstein, 1988; Moncur and Polloxk, 1988; Mann, 1987; and Crew and Kleindorfer, 1985.

A critical issue revealed in this literature is that most studies were based on aggregate data to measure the DSM impacts. Their analysis units have been:

- Water utilities: Duke and Montoya, 1993; Russell and Woodcock, 1992; Nieswiadomy, 1992; Little and Moreau, 1991; Martin, 1991; Gilbert, Bishop and Weber, 1990; Billings and Day, 1989; and Bruvold and Smith, 1988
- Cities or states: Weber, 1993; Woo, 1992; Shaw, Henderson and Cardona, 1992; Vickers, 1989; Shaw and Maidment, 1988; Maddaus, 1987; Martin and Thomas, 1986; and Foster and DeCook, 1986

The studies using household-level data were mostly limited to conservation rate impacts (Nieswiadomy and Molina, 1991; Briggs, 1989; Cuthbert, 1989; Bruvold and Smith, 1988). Our study used micro-level data (household-level monthly water consumption) gathered from a randomly-sampled household survey.