

SECTION VII

CHARACTERISTICS OF RESIDENTIAL PEAK WATER CONSUMPTION

In this section, residential water consumption during the peak summer month is analyzed to examine the characteristics of peak water demand. In this peak demand analysis, we used monthly water consumption data. Even though Artesian Water Company, Inc. currently adopts a quarterly billing system, they provided data on monthly water consumption during May through October in both 1992 and 1993. Our analysis showed that the month of June-July has the highest consumption among the three summer months.¹

Analysis of variance (ANOVA) and the t-test were employed to examine peak demand characteristics. We examined bivariate relationships between the June-July actual water consumption of the sample households and their housing and household characteristics that are expected to influence peak water consumption.² The housing and household characteristics include income, age, family size, the presence of children, appliance stock and appliance use frequency, lot size of the household's property, and perceptions and attitudes.

For the numerical independent variables, the scale was divided into four groups of equal size (quartiles). ANOVA was conducted to examine whether there were significant differences among the four groups in terms of influencing peak water consumption. If the calculated F value with a 5% significance level is above the critical F value (2.99), the differences in mean values among the groups are considered statistically significant.

For dichotomous variables, the t-test was used to examine whether there were any statistical differences in water consumption between the two groups. As in ANOVA, the significance level of this test is 5%. If the calculated t-value is greater than the critical t-value (1.965), the mean values between the two groups are considered significantly different.

¹ Due to the fact that individual billing cycles of customers do not start on the first day of month, it is not possible to identify the peak month in a calendar term. Our preliminary analysis shows that peak water consumption occurs during the period from mid-June to mid-July. Without daily or hourly water consumption data, the monthly consumption is assumed to be a better indicator of peak water demand (than the currently available quarterly consumption).

² Water consumption was adjusted for weather differences, using maximum daily temperatures in relation to a 25-year average for 1969-1993.

The results from the analysis show that the following customer groups and water-consuming activities were major contributors to residential peak water demand:

- The high income group (approximately an annual income of \$60,000 and above);
- The middle age group (approximately in the range of 39 to 46 years old);
- Those customers who had the large household size (5 persons and over);³
- Those customers who had children under the age of 5 years old and/or had teenagers;⁴
- Those customers in housing units with the highest assessed values (over \$85,000);
- The group of households having the largest lot size (in this case, over 0.34 acres);
- Those customers who had relatively new housing units (less than 9 years old);
- Those households having more than 3 toilets and/or 2 bathtubs;
- Those households which frequently used dishwashers (more than 9 times per month) and/or clothes washers (approximately 17 to 28 times per month);⁵
- Those customers who frequently watered their lawn or garden (especially, those customers who watered 1 to 3 times per month and those who watered over 7 times per month);⁶
- Those households that washed car(s) at home most frequently (over 9 times during the summer);

³ Those households with 5 persons and over consumed more water than those with 3 to 4 persons, but their consumption growth rate was negative (-8%) compared to a 6% increase by those of the moderate household size (3-4 persons).

⁴ The households with children under the age of 5 years old reduced their consumption by 7% between the peak summer months of 1992 and 1993.

⁵ Those households who used clothes washers over 29 times per month consumed more water than the households with the use frequency of 17-28 times per month, but their consumption growth rate was negative (-7%).

⁶ Those households which watered lawn or garden 4 to 6 times per month during the summer months showed a negative consumption growth rate (-4%).

- Those customers who made a substantial investment in landscape plantings;
- Those customers who owned a pool;

More detailed information on the peak demand characteristics is presented below in terms of household characteristics, housing characteristics, major water-consuming appliances or activities, and conservation devices and information.

VII - 1. Household Characteristics

The household characteristics examined in this analysis are household income, age of household head, presence of children between 0 and 5 years, presence of teenagers (ages between 13 and 19 years old), and size of household (number of people).

As expected, the higher income groups consumed more water, and their consumption increased more during the study period than the lower income groups. The calculated F-values (13.678 in 1992 and 35.232 in 1993) clearly show that the peak-month water consumption among the income groups was significantly different in both 1992 and 1993. The average water consumption by the highest income group was twice as large as that of the lowest income group. When comparing their peak water consumption between 1992 and 1993, the higher income groups increased their consumption, whereas the lower income groups maintained or reduced their consumption. The highest income group (annual income of \$60,000 and above) increased their consumption by 9% while overall, households increased their consumption by only 1%.

Table 52
Peak Month Water Consumption by Income Group
 (Unit: Gallons)

Income Group	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
Under \$29,999	118	3,801	3,810	0.00
\$30,000-\$49,999	223	6,943	6,192	-0.11
\$50,000-\$59,999	117	8,830	9,482	0.07
\$60,000 and	166	8,995	9,779	0.09
Total	624	7,249	7,312	0.01
		F = 13.638	F = 35.232	

Water consumption was significantly different among the age groups in both 1992 and 1993 as shown in the F values (8.709 in 1992 and 19.843 in 1993) in Table 53. As expected, the peak month water consumption by the elderly (over 61 years of age) was lowest among the age groups. The age group between 39 and 46 years old, which is expected to represent a large number of households and a higher annual income, was distinguishable both in the peak month water consumption and in its growth rate between 1992 and 1993. Compared to the other age groups, this middle age group contributed most to peak consumption in both 1992 and 1993, and its consumption grew more between 1992 and 1993 (a 8% increase).

Table 53
Peak Month Water Consumption by Age Group
 (Unit: Gallons)

Age Group	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
22-38 years	152	7,420	7,264	-0.02
39-46 years	145	8,800	9,525	0.08
47-60 years	160	7,355	7,682	0.04
61 years and	139	4,788	4,403	-0.08
Total	596	7,128	7,263	0.02
		F = 8.709	F = 19.843	

Approximately one-fifth (18.9%) of the sample households had children under 5 years old. These households consumed more water than their counterparts during the peak months of 1992 and 1993. The calculated t-value is greater than the critical value, indicating that the peak month consumption between the two groups was significantly different. The consumption growth rates between the two groups were also different: the households with children reduced their consumption by 7% compared to a 5% increase in consumption by those with no children.

Table 54
Peak Month Water Consumption by Household with Children
 (Unit: Gallons)

Presence of Children	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No Group	484	6,550	6,866	0.05
Yes Group	113	9,602	8,964	-0.07
Total	597	7,128	7,263	0.02
		t = 4.31	t = 3.42	

The households with teenagers (ages between 13 and 19 years old) consumed almost 4,000 gallons more water than those without teenagers during the peak months in both 1992 and 1993. As shown in the t-statistics, the differences in the mean consumption between the two groups were statistically significant. Water consumption growth rates were identical between the two groups.

Table 55
Peak Month Water Consumption by Household with Teenagers
(Unit: Gallons)

Presence of Teenagers	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No Group	447	6,119	6,226	0.02
Yes Group	150	10,132	10,353	0.02
Total	597	7,128	7,263	0.02
		t = 6.38	t = 7.74	

Table 56 shows a strong positive relationship between the peak month water consumption and the size of households. As shown in the F-values in both 1992 and 1993, the means of the peak consumption among the four groups were significantly different (28.035 in 1992 and 51.128 in 1993). The peak consumption by the largest household group (5 and over) exceeded that of the smallest household group (single-person households) by more than four times. It is noted, however, that the single-person household group and the largest household group reduced their peak month consumption between 1992 and 1993 (-21% and -8%, respectively).

Table 56
Peak Month Water Consumption by Household Size
(Unit: Gallons)

Household Size	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
1 person	102	3,021	2,379	-0.21
2 persons	179	5,990	6,254	0.04
3-4 persons	260	8,327	8,868	0.06
5 persons and	84	11,945	10,974	-0.08
Total	625	7,278	7,343	0.01
		F = 28.035	F = 51.128	

VII - 2. Housing Characteristics

The housing characteristics examined in this analysis include information on the housing values assessed by New Castle County for tax purposes, the size of lots, landscape planting investments, the age of housing units, and the number of toilets and bathtubs in use.

Table 57 shows a positive relationship between the assessed housing values and the peak water consumption. Overall, the differences in peak water consumption among the four groups were statistically significant as shown in the F-values (11.421 and 48.807, respectively). While the consumption growth rates of those customers who have properties with lower assessed values (less than \$62,000) were negative (-14% and -15%), those with higher assessed values were positive.

Table 57
Peak Month Water Consumption by Housing Value
(Unit: Gallons)

Assessed		June-July Mean Water Consumption		
Housing Value	No. of Observ.	1992	1993	(93-92)/92
\$14,800-\$47,200	155	5,196	4,441	-0.15
\$47,500-\$62,100	154	6,825	5,852	-0.14
\$62,300-\$85,000	157	6,894	7,472	0.08
\$85,400-\$98,460	155	9,987	11,443	0.15
Total	621	7,225	7,305	0.01
		F = 11.421	F = 48.807	

Those households with larger lots tended to consume more water in the peak summer months than those with smaller lots. As shown in the F-values in Table 58 for both 1992 and 1993, the differences in water consumption among the four groups were significant. Especially in 1993, the households with the largest lots (0.34 acres and over) consumed twice as much water as those households with the smallest lots (under 0.15 acres). The water consumption growth rates between 1992 and 1993 among the four groups were also significantly different. Compared to the overall 1% increase in peak consumption, those households with the smallest lot-size group decreased consumption by 19%, while the largest group increased their's by 15%.

Table 58
Peak Month Water Consumption by Lot Size
(Unit: Gallons)

Lot Size	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
Under 0.15 acres	179	5,752	4,663	-0.19
0.16-0.19 acres	138	6,661	6,913	0.04
0.20-0.33 acres	155	7,504	7,570	0.01
0.34 acres and	149	9,226	10,566	0.15
Total	621	7,225	7,305	0.01
		F = 6.229	F = 30.491	

Around 20% of the sample households invested in landscape plantings such as shrubs and trees in 1992. Those customers who made landscape investments consumed more water in the peak summer months of both 1992 and 1993 than those without any investments in landscaping. However, the consumption difference between the two groups was only significant in 1993 (the calculated t-value of 4.866). In terms of the consumption growth rates between 1992 and 1993, those customers who made a substantial investment in landscape plantings had rates that grew by 7%, whereas the consumption rate of those households without any landscaping investments decreased by 5%.

Table 59
Peak Month Water Consumption by Landscape Plantings
(Unit: Gallons)

Investment in Landscape	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No Group	511	7,110	7,055	-0.05
Yes Group	121	7,826	8,386	0.07
Total	632	7,247	7,309	0.01
		t = 0.879	t = 4.866	

Compared to old housing units, newly constructed housing units tend to be bigger in size, and the housing lots are also likely to be larger. New landscape plantings in new housing units need more water. The income of households living in new units is likely to be higher than that of old housing units, leading to more water consumption even though new housing units may have more water-efficient appliances. It is expected, therefore, that newly constructed housing units would

consume more water than old housing units. Table 60 clearly shows the expected negative relation between the peak water consumption and the age of housing for both 1992 and 1993. Mean consumption was significantly different among the four groups. It is noticeable that the peak consumption growth rate between 1992 and 1993 of newly-built housing units was positive (13%), whereas old housing units showed a negative growth rate (-10%).

Table 60
Peak Month Water Consumption by Housing Age
(Unit: Gallons)

Age of Housing	No. of	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
1-9 years old	132	8,742	9,850	0.13
10-24 years old	157	7,657	7,522	-0.02
25-36 years old	150	6,571	6,753	0.03
37 years old and	140	6,148	5,552	-0.10
Total	579	7,258	7,377	0.02
		F = 3.201	F = 13.028	

Table 61 shows a positive relation between the number of toilets in use and the peak water consumption. This positive relationship may be due to more people in the house. Those customers who have more than 3 toilets consumed over 1.5 times more water compared to the one-toilet households. The consumption differences among the four groups were statistically significant in both 1992 and 1993. When comparing the growth rates, only those households with 3 or more toilets showed positive growth between 1992 and 1993 (an 11% increase).

Table 61
Peak Month Water Consumption by Number of Toilets
(Unit: Gallons)

Number of Toilets	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
1 toilet	131	5,520	5,092	-0.08
2 toilets	218	6,889	6,525	-0.05
3 toilets and over	239	8,551	9,518	0.11
Total	588	7,259	7,422	0.02
		F = 7.168	F = 28.420	

Table 62
Peak Month Water Consumption by Number of Bathtubs/Showers
(Unit: Gallons)

Number of		June-July Mean Water Consumption		
Bathtubs/Showers	No. of Observ.	1992	1993	(93-92)/92
1 bathtub	295	6,075	6,019	-0.01
2 or more bathtubs	293	8,452	8,835	0.05
Total	588	7,259	7,422	0.02
		t = 5.74	t = 3.80	

Because, in hot summer weather, customers usually take more frequent baths and showers, the number of bathtubs in use is an important indicator to explain water consumption during the summer peak months. As shown in Table 62, a positive relation exists between the number of bathtubs/showers in use and water consumption: the more bathtubs/showers in use, the more water consumption. As shown in the t-values for 1992 and 1993, the differences in the peak consumption between the two groups were significant. In terms of the consumption growth between the peak months of 1992 and 1993, the one-bathtub households decreased consumption by 1%, whereas the other groups (with two bathtubs and more) increased consumption by 5%.

VII - 3. Major Water-Consuming Appliances or Activities

Major water-consuming appliances or activities examined here include indoor water use frequencies from dishwashers and clothes washers and outdoor water-consuming activities involved in watering the lawn or garden, washing car(s) and (re)filling pools.

The use frequency of a dishwasher had a strong positive correlation with water consumption in both 1992 and 1993. The water consumption of those households who did not own dishwashers or did not use dishwashers was much lower compared to the other groups who frequently used dishwashers. The consumption differences among the four groups in both 1992 and 1993 were statistically significant (F values of 15.044 and 32.015, respectively).⁷ Although the frequent users of dishwashers tended to have a positive consumption growth rate, no significant differences in growth existed among the four groups.

Table 63
Peak Month Water Consumption by Use Frequency of Dishwashers

(Unit: Gallons)

Use Frequency		June-July Mean Water Consumption		
of Dishwashers	No. of Observ.	1992	1993	(93-92)/92
0 per month	190	5,104	5,003	-0.02
1-8 per month	164	6,153	5,922	-0.04
9-16 per month	146	8,689	9,160	0.05
Over 17 per	131	10,056	10,228	0.02
Total	631	7,235	7,301	0.01
		F = 15.044	F = 32.015	

The use frequency of clothes washers is expected to have a positive influence on water consumption. Unlike dishwashing, there is no commonly-used practical non-machine alternative. The peak water consumption by those households with the highest use frequency of clothes washers (over 29 times per month) was twice as large as those households with the lowest use frequency (less than 8 times per month). As shown in the calculated F values, significant differences in peak water consumption existed among the four groups.⁸

⁷ It should be noted, however, that a full load of dishwashing does not take appreciably more water than doing the same dishes in the sink. Therefore, it may be that high frequency dishwasher use is an indicator of more, or larger, meals at home rather than dishwasher use per se.

⁸ Contrary to previous findings that those customers who consumed more water tended to have a positive consumption growth rate, those households with the highest use frequency of clothes washers

Table 64
Peak Month Water Consumption by Use Frequency of Clothes Washers
 (Unit: Gallons)

Use Frequency of Clothes	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
0-8 per month	228	5,001	5,136	0.03
9-16 per month	169	7,544	7,394	-0.02
17-28 per month	150	8,491	9,062	0.07
Over 29 per	82	10,499	9,789	-0.07
Total	629	7,233	7,285	0.01
		F = 14.043	F = 20.768	

Lawn-watering has a significant impact on water consumption during the summer months. As expected, water consumption increased as the frequency of lawn-watering increased. Compared to those households with no lawn watering, those customers who frequently watered their lawn showed significantly higher water consumption in both 1992 and 1993 (F values of 6.640 and 13.487, respectively). In terms of the consumption growth rates, there was no significant pattern among the four groups.⁹

Table 65
Peak Month Water Consumption by Watering Frequency of Lawn/Garden
 (Unit: Gallons)

Watering Frequency of Lawn/Garden	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
0 per month	161	5,134	4,883	-0.05
1-3 per month	119	7,524	8,592	0.14
4-6 per month	123	7,930	7,587	-0.04
Over 7 per month	200	8,103	8,433	0.04
Total	603	7,161	7,344	0.03
		F = 6.640	F = 13.487	

decreased consumption between the summer peak months of 1992 and 1993 (-7%).

⁹ It is noticeable, however, that those customers who watered their lawn 1 to 3 times per month showed the highest positive consumption growth between the peak summer months of 1992 and 1993 (a 14% increase).

Car washing at home is expected to have a positive relationship with water consumption. However, as shown in Table 66, the positive relationship was not clearly shown in 1992.¹⁰ Also, the peak water consumption among the four groups was not significantly different in 1992, even though the relationship was significant and positive in 1993. At any rate, those households who most frequently washed car(s) at home showed the highest water consumption, and their consumption growth rate was also highest (a 13% growth compared to the average increase of 1%).

Table 66
Peak Month Water Consumption by Frequency of Carwash
 (Unit: Gallons)

Frequency of Carwash	No. of	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
0 during summer	204	6,442	6,585	0.02
1-4 during summer	193	7,723	7,202	-0.07
5-8 during summer	123	7,156	7,250	0.01
Over 9 during summer	102	8,077	9,094	0.13
Total	622	7,249	7,319	0.01
		F = 1.431	F = 4.092	

Table 67
Peak Month Water Consumption by Ownership of Pool
 (Unit: Gallons)

Ownership of Pool	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No	559	6,833	6,876	0.01
Yes	75	10,255	10,564	0.03
Total	634	7,238	7,304	0.01
		t = 3.73	t = 5.18	

The use of an indoor or outdoor pool is a significant contributor to peak water consumption during the summer months. As shown in Table 67, those customers who have pools consumed a little over 3,000 gallons more water than those without pools in the peak months of both 1992 and 1993. The consumption differences between the two groups were statistically significant. No significant differences in consumption growth rates existed between the two groups.

¹⁰ Those households who washed car(s) one to four times during the summer months in 1992 consumed more water than those with more frequent car washes (five to eight times).

VII - 4. Conservation Information and Devices

This sub-section examines the impacts on peak water consumption of conservation-related information. The conservation-related information tested was the awareness of Artesian's sprinkling regulations and of the installation of conservation devices delivered by Artesian.

Table 68 compares the peak water consumption between those customers who were aware of water conservation information from Artesian through water bills or pamphlets and those customers who were not. The differences in water consumption during peak months of 1992 and 1993 were not statistically significant between the two groups (t-values of -0.26 and 0.72, respectively). However, both groups showed differences in consumption growth rates between 1992 and 1993. The informed group reduced their water consumption by 3%, whereas those who were not informed increased consumption by 3%.

Table 68
Peak Month Water Consumption by Awareness of Conservation Information
(Unit: Gallons)

Awareness of Conservation	No. of	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No	318	6,896	7,279	0.03
Yes	316	7,582	7,329	-0.03
Total	634	7,238	7,304	0.00
		t = 1.15	t = 0.11	

The awareness of Artesian's summertime sprinkling regulations is expected to have a negative relationship with water consumption during the peak summer months. Table 69 shows no significant differences in water consumption between those who were aware of the regulation and those who were not in both 1992 and 1993. But the consumption growth rates were statistically different between the two groups: those who knew about Artesian's summertime sprinkling regulations decreased water consumption by 3%, whereas the other group increased consumption by 5%.

Table 69
Peak Month Water Consumption by Awareness of Sprinkling Regulations
(Unit: Gallons)

Awareness of Sprinkling	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No	277	6,931	7,312	0.05
Yes	355	7,462	7,269	-0.03
Total	632	7,229	7,288	0.01
		t = 0.88	t = 0.09	

Approximately 61% of the sample households (383 of 627) had installed water conservation fixtures such as low-flow showerheads, faucet restrictors, ultra low-consumption toilets, showerhead flow restrictors and toilet dams or bags prior to the 1992 period. Table 70 reveals that those households having conservation appliances tended to consume more water than those without installed conservation fixtures. However, the differences in consumption among the four groups were not statistically significant in both 1992 and 1993. These results should be carefully interpreted because consumer-initiated voluntary conservation measures already installed prior to the evaluation period of 1992 could have had impacts that this analysis is unable to evaluate. No significant pattern was exhibited with respect to the consumption growth rates among the four groups.

Table 70
Peak Month Water Consumption by Installation of Conservation Fixtures
 (Unit: Gallons)

Installation of Conservation Fixtures	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
0 fixture	244	6,721	6,559	-0.02
1 fixture	179	7,670	7,759	0.01
2 fixtures	107	7,744	8,299	0.07
3 fixtures and over	97	7,281	7,315	0.00
Total	627	7,253	7,316	0.01
		F = 0.733	F = 2.593	

Of the 634 sample households, 82 households received and installed conservation devices provided in 1992 by Artesian Water Company, Inc. as part of the joint Customer Conservation Program (CCP) with the State's Department of Natural Resources and Environmental Control (DNREC). Table 70 contrasts the peak water consumption and growth rates between those who received devices from Artesian and those who did not. The differences in water consumption between the two groups were not statistically significant in both 1992 and 1993. It should be noted, however, that the consumption growth rates were significantly different: those who received conservation devices from Artesian had a negative growth rate (a 7% decrease), whereas those who did not had a 2% positive growth rate.¹¹

¹¹ It is possible that receiving a conservation device in 1992 may stimulate further attempts at water conservation by the customer.

Table 71
Peak Month Water Consumption by Conservation Devices from Artesian
 (Unit: Gallons)

Devices from Artesian	No. of Observ.	June-July Mean Water Consumption		
		1992	1993	(93-92)/92
No	552	7,137	7,298	0.02
Yes	82	7,920	7,344	-0.07
Total	634	7,238	7,304	0.01
		t = 0.88	t = 0.06	