Aquacraft inc
WATER ENGINEERING & MANAGEMENT

March 17, 2005

Tom Reynolds, President
Mark Sanders, Chairman
Barnacle Water Saver, LLC
13450 US Highway 42
Suite 214
Prospect, KY 40059

Re: Analysis of bathroom faucet use

Dear Mr. Reynolds and Mr. Sanders:

As requested, we have prepared an analysis of bathroom faucet usage using the water use data collected as part of the AWWA Residential End Uses of Water study (REUWS). The purpose of this analysis was to develop more accurate estimates of bathroom faucet use for the purpose of determining the potential water savings from the Barnacle Water Saver greywater recovery system. This system uses water recovered from the bathroom faucet to flush the toilet. There is little reliable data available on the volume of water used through the bathroom faucet.

Summary of Findings
Table 1 presents a brief summary of the bathroom faucet use findings from this research, which examined water use in 162 homes with only 1 bathroom. More detailed results and an explanation of the methodology are presented later in this report.

Table 1: Summary findings

	Average (gal.)	Std. Deviation (gal.)	Median (gal.)
Daily household bathroom faucet use	6.23	3.81	5.29
Daily per capita bathroom faucet use	3.40	2.77	2.81

Residential End Uses of Water Study
The REUWS (AWWA, 1999) was a detailed study of water consumption patterns in 1,188 single-family homes selected from 12 cities in the United States and 2 cities in Canada. Peter Mayer, P.E. and William DeOreo, P.E. of Aquacraft were the principal investigators for this study. In this study, water use in each of the study homes was disaggregated into component end uses (toilets, showers, clothes washers, faucets, dishwashers, baths, irrigation, etc.) using the flow trace analysis technique developed by Aquacraft. In this study it was found that 10.9 gallons per capita per day (gcd) were used for faucet purposes. Faucets accounted for 15.7% of all indoor water use. Although faucet usage was a key component of the REUWS analysis, previously there had been no attempt to distinguish between bathroom faucet usage and faucet usage elsewhere in the house such as the kitchen or a utility sink. Barnacle Water Saver

contracted with Aquacraft to more closely examine the faucet use category and develop estimates of bathroom faucet use from this data set.

Methodology

Since the flow trace analysis technique does not readily permit the determination of which specific fixture (i.e. master bathroom faucet or kitchen sink) is being used at any given time, Aquacraft developed a methodology for estimating bathroom faucet use specifically for this study. While these results should not be viewed as physical measurements of bathroom faucet use, we believe they provide a reasonable level of accuracy and the range of bathroom faucet demands estimated in this study should provide Barnacle with useful data for evaluating the potential impacts of their reuse technology. These results, when coupled with pump measurements from the Barnacle system, should provide a more complete and convincing picture of volume of bathroom faucet usage.

To simplify the disaggregation of faucet usage into the two desired categories: (1) bathroom faucets; and (2) kitchen/other faucet use, the REUWS database was queried and homes with only one bathroom sink were selected for analysis. A total of 162 homes (14%) of the 1,188 total met these criteria. All indoor water use data and demographic data for these 162 single-bathroom homes were extracted from the REUWS database. The overall average per capita faucet use in these 162 homes was found to be 10.93 gcd – virtually identical to average from the full 1,188 home sample.

To disaggregate faucet use into bathroom and kitchen/other categories, a complex set of data filters were implemented. Typically, bathroom faucets are installed with an aerator that regulates maximum flow to about 1.5 gpm or less. Kitchen faucets tend to have higher-flow aerators, approximately 2.2 gpm and in some cases higher. Utility sinks typically have no aerator, and are used more intensively (at a higher peak flow) than other fixtures. Analysis for this project started with the raw data, and began drawing inferences based on descriptive statistics. These inferences were adapted into filters. Filtering disaggregates one large distribution into two or more smaller non-overlapping ones.

There were a total of 117,987 separate faucet end use events recorded from the 162 single-bathroom homes extracted for this analysis. The criteria that differentiated the faucet end use data fell into three categories: (1) time of day, (2) flow characteristics, and (3) the timing in relation to other fixtures such as dishwashers and toilets. All three categories contributed factors to the filtering system developed for this analysis. Figure 1 shows individual filters acting separately to divide usage into seven subcategories. As soon as a water use fit into a filter criterion it was assigned a subcategory designation. If a water use did not meet a filter criterion it passed on to the next filter.

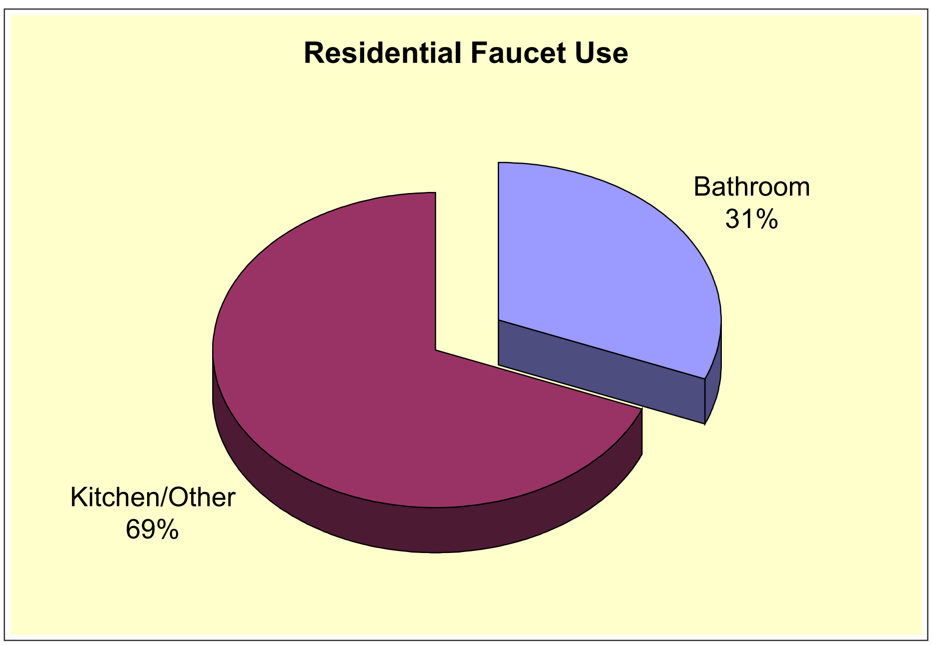
Figure 1: Database filters used to disaggregate faucet use

<table>
<tr><td colspan="7">Filter #1
Homes with 1 bathroom sink
End use category = Faucet</td></tr>
<tr><td rowspan="4">Filter #2
If peak flow rate > 2.5 gpm Then faucet category ↓</td><td colspan="6">Peak flow rate > 0 and <= 2.5 gpm</td></tr>
<tr><td rowspan="3">Filter #3
If water use started < 120 seconds after a toilet flush Then faucet category ↓</td><td rowspan="3">Filter #4
If water use occurred between 10 p.m. and 7 a.m. Then faucet category ↓</td><td colspan="4">Water use not meeting Filter 2-4 criteria</td></tr>
<tr><td rowspan="2">Filter #5
Dinner prep. If faucet use occurred between 4 and 8 p.m. Then faucet category ↓</td><td rowspan="2">Filter #6
If water use started < 900 seconds before a dish washer Then faucet category ↓</td><td colspan="2">Water use not meeting Filter 2-6 criteria</td></tr>
<tr><td>Filter #7
If peak flow rate > 1.5 gpm Then faucet category ↓</td><td>Water use not meeting Filter 2-7 criteria Then faucet category ↓</td></tr>
<tr><td>kitchen/ other</td><td>bathroom</td><td>bathroom</td><td>kitchen/ other</td><td>kitchen/ other</td><td>bathroom</td><td>kitchen/ other</td></tr>
</table>

Results

Of the 117,987 faucet events associated with the 162 single-bathroom homes, 64,725 (54.9%) events were classified as "bathroom" faucet use and 53,172 (45.1%) events were classified as "kitchen/other" faucet uses. Figure 2 is a pie chart showing the breakdown of total water use volume from each faucet category. Although there were more bathroom faucet events, the volume of those events was substantially less than the events in the kitchen/other category. Bathroom faucet use accounted for 31% of the total faucet volume. Kitchen/other faucet use accounted for 69% of the total faucet volume.

Figure 2: Faucet use pie chart



Bathroom faucet use was analyzed on the household and the per

capita level. Table 2 presents
the summary statistics from these analyses. Figure 3 is the histogram of household bathroom faucet use and Figure 4 is this histogram of per capita bathroom faucet use.

Table 2: Summary bathroom faucet use statistics

	Daily bathroom faucet use (gal.)	
	Per Household	**Per Capita**
Average	6.23	3.40
Standard deviation	3.81	2.77
Median	5.29	2.81
Minimum	0.26	0.53
Maximum	19.79	19.79
Standard error	0.30	0.22

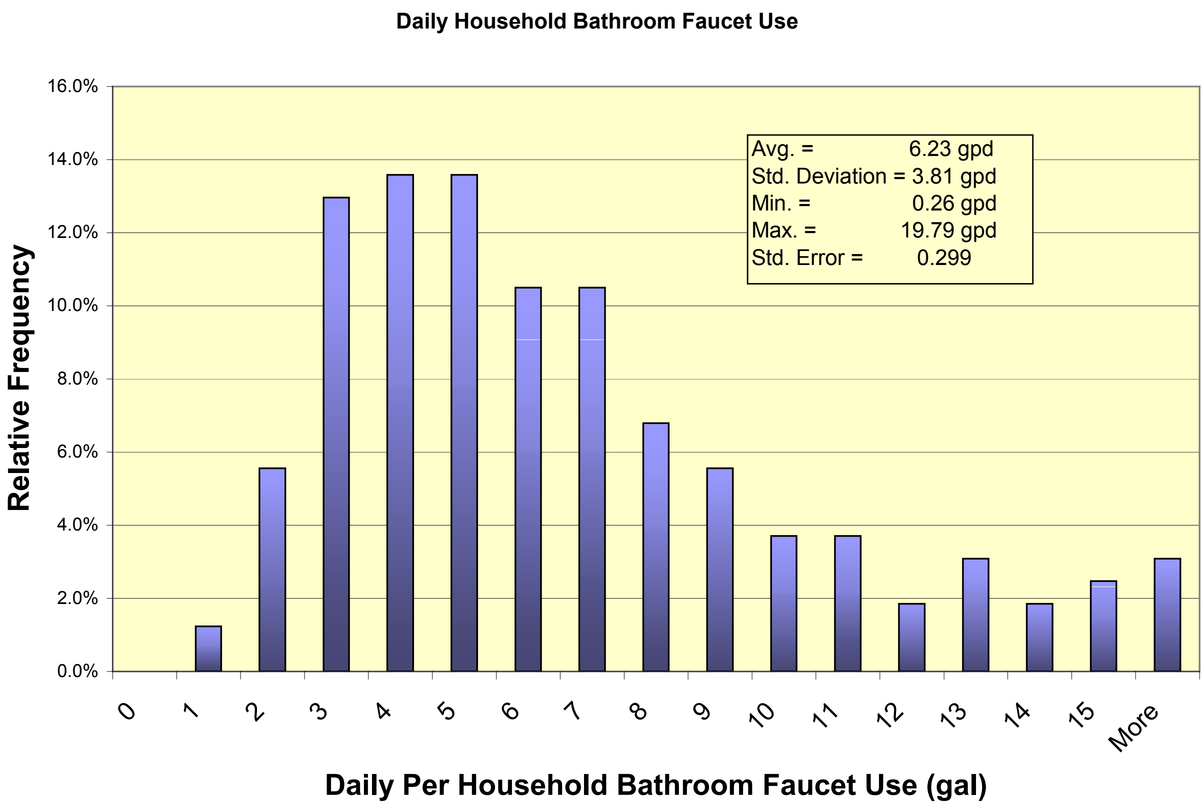


Figure 3: Frequency distribution of daily household faucet use

This sample of 162 homes used an average of 6.23 gallons per day in their bathroom faucets. The average daily per capita bathroom faucet usage was found to be 3.40 gcd. The median (50^{th} percentile) values were slightly below the mean, which is typical for water use data, which is almost always lognormally distributed as shown in Figures 3 and 4. Average daily household bathroom faucet use ranged from 0.26 gpd up to 19.79 gpd. The expected range of household bathroom faucet use (plus or minus one standard deviation from the mean) is between 2.42 and 10.04 gallons per household per day. The expected range of per capita faucet use (plus or minus one standard deviation from the mean) is between 0.63 and 6.17 gallons per capita per day.

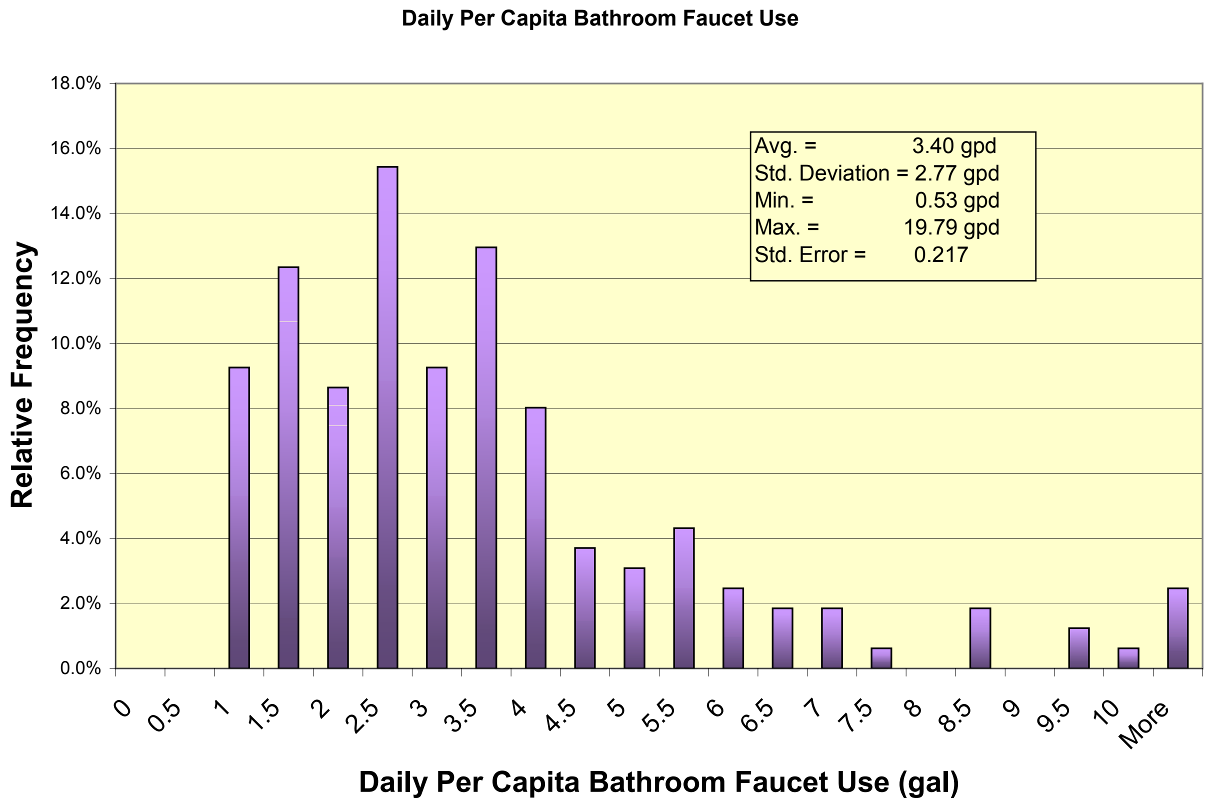


Figure 4: Frequency distribution of daily per household faucet use

The results from this study suggest that single-bathroom homes use a little more than 6 gallons per day through their bathroom faucet. Some of this water may be consumed and hence not available for use in the Barnacle Water Saver system. However, the volume of water consumed from the bathroom faucet is beyond the scope of analysis for this study. For the purpose of estimating potential water savings it seems reasonable to use an estimate of 3.4 gallons per capita per day. Because the per capita use of this 162 single-bathroom home sample was virtually identical to the 1,188 home sample, it is reasonable to assume the per capita bathroom faucet use estimates will be similar in homes with more than one bathroom as well.

We should stress again that the bathroom faucet use values developed in this study are *estimates* and are not physical measurements of bathroom faucet use. Hopefully future studies will provide physical measurements of bathroom faucet use from a large enough research sample to be deemed useful.

Thank you for giving us the opportunity to prepare this analysis for you. Please don't hesitate to contact me if you have any questions about this report, the results, or the analysis methodology.

Sincerely,

Peter Mayer, P.E.
Vice President