SEATTLE HOME WATER CONSERVATION STUDY

THE IMPACTS OF HIGH EFFICIENCY PLUMBING FIXTURE RETROFITS IN SINGLE-FAMILY HOMES

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Seattle Public Utilities
and
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EXECUTIVE SUMMARY

In the past 10 years considerable money and effort has been expended on residential water conservation retrofits, often subsidized by municipal water providers. While many of these programs have proved popular with customers, there remains a lack of sufficient hard information on the actual effects of residential retrofits on per-capita and per household water use – particularly on individual end uses over time. Reliable measurements of water savings are essential for long-range projections of the impacts of conservation projects on urban water demands. As water providers fund water conservation practices, whether voluntarily or by regulatory requirements, the need for precise measurements of actual water savings has intensified.

In 1996 the Seattle Public Utilities (SPU), along with 11 other water providers, participated in the Residential End Uses of Water Study (REUWS) research project headed by Aquacraft Inc., of Boulder Colorado (Mayer and DeOreo, et. al. 1999). This project assembled a complete data set of water use from a cross section of single family customers. The data includes approximately four weeks of continuously monitored water use from a total of 1,188 homes in 12 study sites (including 14 cities) disaggregated into individual end-use events such as individual toilet flushes, clothes washer cycles, faucet uses, etc. These data were obtained using battery powered flow data loggers set to record at 10-second intervals (DeOreo et. al. 1996). The resulting flow trace was then analyzed and disaggregated into end uses with Aquacraft's Trace Wizard™ software. This data set contains the most complete picture available to date of how water is used indoors by single-family customers.

The REUWS project was a baseline study, and homes were chosen at random. Using a random approach selection resulted in relatively few homes equipped with water conserving fixtures and appliances, particularly conserving clothes washers. As a consequence, the REUWS final report does not shed sufficient light on the potential impacts of water conservation retrofits with high efficiency plumbing fixtures and appliances. One of its recommendations was that samples from its homes be selected for future intervention studies, such as interior retrofit programs.

The Seattle Home Water Conservation Study (SHWCS) is the first intervention study using samples taken from the original REUWS group. The SHWCS provides important information on water conserving fixtures and appliances through a before-and-after paired comparison of water use patterns from a sample of 37 single-family homes in Seattle, Washington. The SHWCS measured the impact of a variety of indoor water conservation measures on both aggregate and individual water use patterns. Separate meters were installed to measure hot water usage, adding a valuable new dimension to the data obtained. Study participants also rated their old fixtures and appliances while they were still in place, and then rated the new retrofit devices after using them for more than six months.

In the Seattle Home Water Conservation Study, two-weeks of specific baseline water use data were obtained from a sample of 37 homes.[1] Next, these homes were retrofit with high efficiency toilets, clothes washers, showerheads, and faucets. Two weeks of flow trace data were collected from these homes about a month after the completion of the retrofit and then a second set of post-retrofit data was obtained six months later. All of the pre and post-retrofit flow trace data were disaggregated into relevant end use categories by Aquacraft Inc, as was done for the REUWS project. Paired t-test analyses were used to evaluate the demands for each end use measured at the study homes in the pre and post-retrofit periods. This allowed a thorough analysis of the impacts of the retrofits on the end uses of water in the study homes.

Historic water use patterns of the sample selected for this study were quite similar to those from the population of single-family homes in Seattle. As such, the results should provide a good indication of the impacts of retrofits in the wider population. It is not possible, nor it is the object of this study to provide conclusive data for the entire nation. The study provides a blueprint for planned additional studies in other cities.[2]

RESULTS

The mean daily indoor demand, was 150.7 gpd per household during the baseline period, and dropped 39 percent to 92.1 gpd after the installation of the new high-efficiency fixtures and appliances. On an annual basis this equates to an average indoor use of 55.0 kgal for baseline conditions and 33.6 kgal with the retrofit. These data are plotted as a histogram (frequency diagram) in Figure ES.1. Here the change in demand brought about by the retrofit can be seen in the shift of the demand distribution to the left-hand side of the graph. The effectiveness of the

[1] Thirty-five of these homes were participants in the original Residential End Uses of Water study.

retrofits in reducing daily demand can be seen from the fact that while during the baseline period indoor use fell below 175 gallons 66 percent of the time, in the post-retrofit period it fell below this level 90 percent of the time.

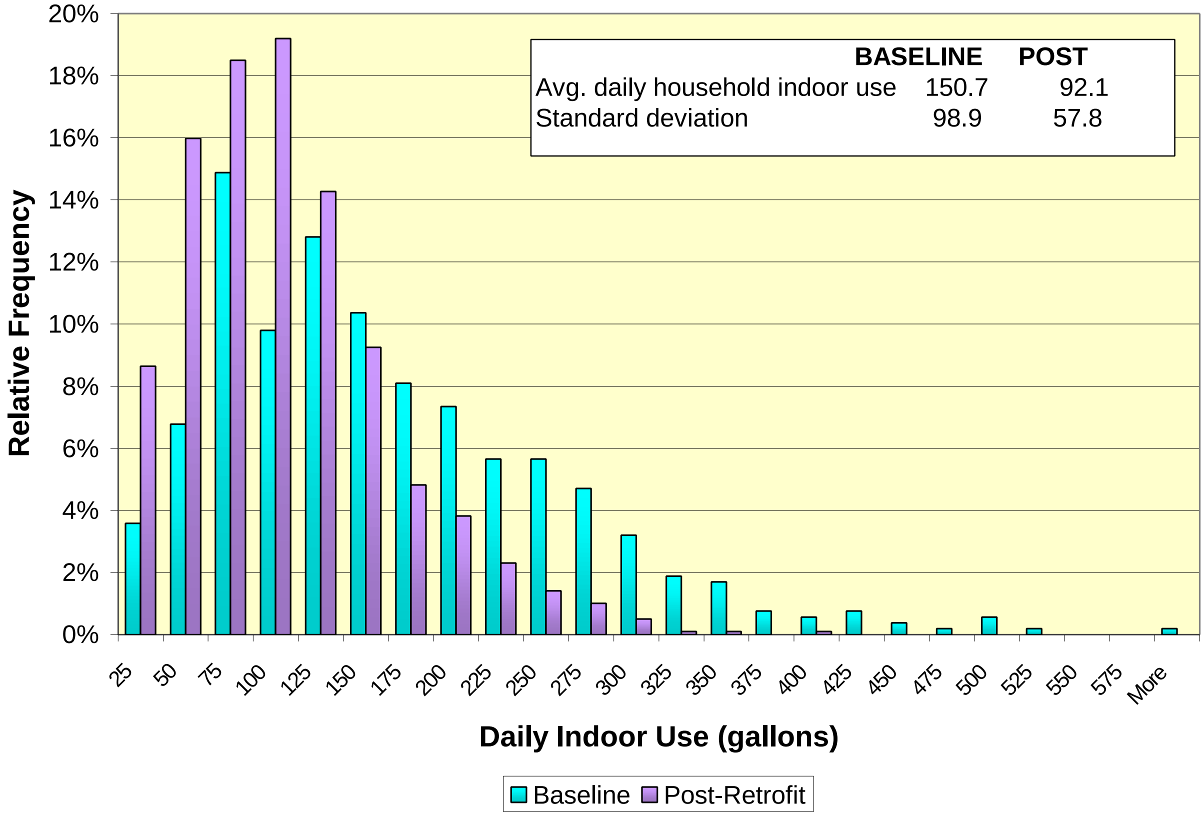

Figure ES.1 Daily per household indoor water use distributions, pre and post-retrofit

Per Capita Demand

Indoor water use patterns changed dramatically after the conservation retrofit. Average daily per capita use decreased in 35 on the 37 study homes. After the retrofit, toilet usage, which had previously been the largest component of indoor use dropped below faucets into fourth place. Clothes washers became the largest indoor water use followed by showers, and faucets. The combination of showers and baths actually form the largest block of indoor use in the post-

[2] Similar studies are planned for Oakland, California and Tampa, Florida.

retrofit era at 28.4 percent. A pie chart showing the relative importance of each per capita end use is shown in Figure ES.2.

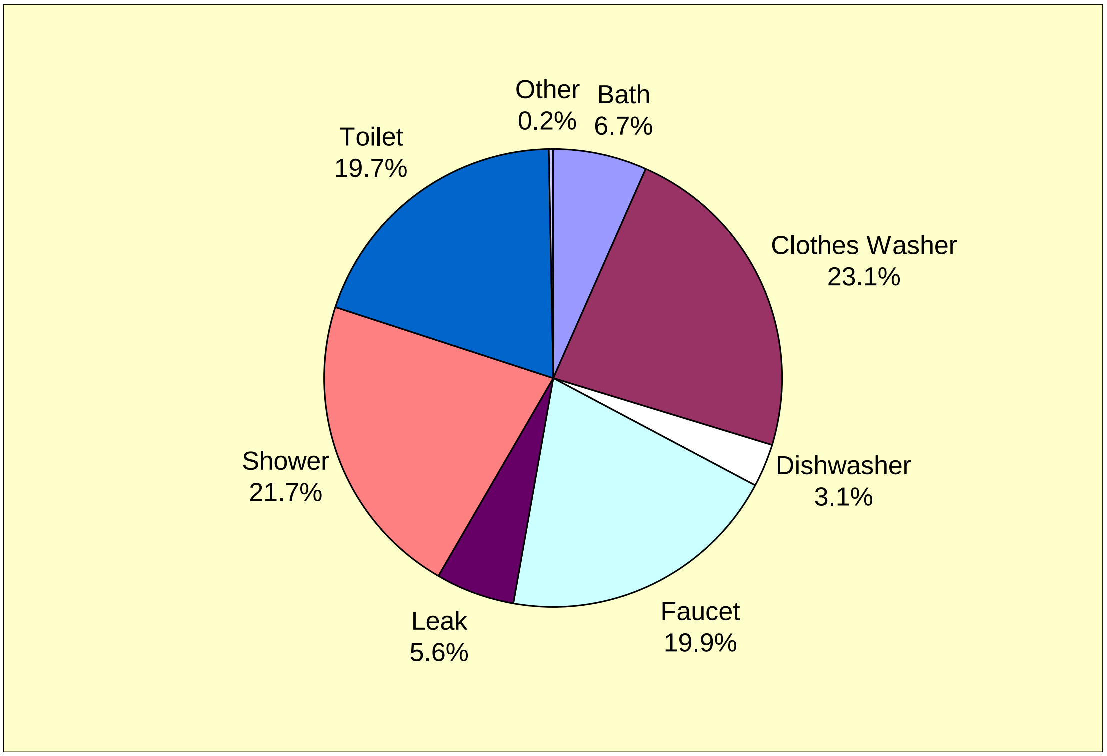

Figure ES.2 Post-retrofit indoor per capita water use percentage including leakage

Table ES.1 presents a comparison of the mean indoor per capita water use from the baseline and post-retrofit data collection periods. Overall, indoor water use decreased by 23.6 gpcd – a 37.2 percent drop. A series of unpaired *t-tests* were performed on each end use in these two data sets to determine which changes in water use are statistically significant at the 99 percent confidence level. The results of this analysis are also presented in Table ES.1 as the t-Value and P-Value from the t-test. In order for a difference in means to qualify as statistically significant, the P-Value must be less than the alpha level of 0.01, the 99 percent confidence level. Statistically significant changes in water use were detected for clothes washers, faucets, leaks, toilets, and total indoor use.

More than 20 gallons of the 23.6 gpcd average saved through the retrofit was the result of three end uses: toilets, clothes washers, and leaks. Installation of ULF toilets, including some dual flush models saved an average of 10.9 gpcd. The new conserving clothes washers saved an average of 5.6 gpcd. A reduction in leakage resulted in savings of 4.3 gpcd. The leakage savings were almost certainly the result of the toilet retrofit. Toilet leaks, primarily flapper leaks, are the single largest contributor to household leakage. In this study, replacing old toilets through the retrofit eliminated almost all of these toilet leaks and resulted in substantial savings. None of the other measures implemented through this study (clothes washers, showerheads, or faucet aerators) should have had any impact on the leakage rate, although it is known that at least one study participant repaired a substantial faucet leak (44 gpcd) about the time of the retrofit.

Statistically significant reductions in water use occurred in most of the end use categories impacted by the retrofits: toilets, faucets, leaks and clothes washers. Showers did not show any significant water use reduction, even though new showerheads were installed. The remaining categories not targeted by the retrofit (baths and dishwashers) also showed no change. Mean per capita faucet use was reduced by 1.2 gpcd (13.1 percent) after the installation of faucet aerators. But mean per capita shower usage only decreased by 0.3 gpcd (3.8 percent) in spite of the installation of LF showerheads in many of the study homes.

Table ES.1 Mean indoor per capita water use, baseline and post-retrofit

Category	Baseline (gpcd)	Post-Retrofit (gpcd)	Difference in Means (gpcd)	% Change	t-Value	P-Value	Statistically significant difference? *
Bath	3.7	2.7	-1.0	-27.9%	2.443	0.0147	No
Clothes Washer	14.8	9.2	-5.6	-37.7%	5.157	<0.0001	Yes
Dishwasher	1.4	1.2	-0.2	-13.6%	1.460	0.1446	No
Faucet	9.2	8.0	-1.2	-13.1%	3.310	0.0010	Yes
Leak	6.5	2.2	-4.3	-66.0%	9.891	<0.0001	Yes
Shower	9.0	8.7	-0.3	-3.8%	0.740	0.4596	No
Toilet	18.8	7.9	-10.9	-58.1%	25.29	<0.0001	Yes
Indoor	63.4	39.8	-23.6	-37.2%	13.935	<0.0001	Yes
Other/Unknown	0.2	0.1	-0.1	-46.9%	1.570	0.1166	No
Total	63.6	39.9	-23.7	-37.2%	13.927	<0.0001	Yes
Avg. # of Residents per household	2.54	2.51					

*99 percent confidence level

Customer Satisfaction Ratings

About seven months after installation of the new fixtures and appliances the study participants were asked to rate their performance. Each participating household was asked to complete a nine page, 44 question "New Product Information and Satisfaction Survey" that sought information about customer satisfaction with each of the products installed and with participation in the study. Many of the questions were intentionally made identical to questions asked on the initial Audit Survey so that responses could be compared.

The results of the survey were extremely favorable to the high efficiency fixtures and appliances particularly toilets and clothes washers. This is perhaps surprising given the often repeated assertions (often based on unscientific anecdotal evidence) that these devices are less satisfactory.

Toilets

Table ES.2 shows the results of the questions regarding toilet performance. Two trends are evident in these results: the new ULF toilets were uniformly rated higher in performance than any of the old toilets and second, looking strictly at the old toilets, the customers preferred the ULF models to the standard toilets. With respect to the new ULF toilets used for this study, it should suffice to note that they were rated higher in every category.

Table ES.2 Pre and post-retrofit toilet rating

Rating Category	Pre-Retrofit Non-ULF Toilets (n=37)	Pre-Retrofit ULF Toilets (n=8)	Post-Retrofit ULF Toilets (n=36)
Bowl Cleaning	3.76	3.38	4.03
Flushing performance	3.54	3.63	4.50
Appearance	3.70	3.75	4.67
Noise	3.32	3.63	4.69
Leakage	3.70	4.25	4.81
Maintenance	3.89	4.25	4.61
Overall Average	3.65	3.81	4.55

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

Clothes washers

Most of the respondents (86 percent) liked their new clothes washer better than their old one and only 5.5 percent like it less. Eighty-nine percent said they would recommend the machine to a friend while 11 percent were unsure. None of the respondents indicated that they could not recommend their washer. An impressive 72 percent of the respondents agreed that if they were in the market for a washer they would be willing to pay a premium of $150 to get an equivalent quality conserving washer. Fourteen percent said they would not be willing to pay the extra money and another 14 percent were unsure.

Study participants rated the performance of their existing clothes washers during the initial audit interview. As part of the New Product Information and Satisfaction Survey they were asked to rate their new washer on exactly the same points. The responses to both surveys are shown in Table ES.3. Participants rated the new clothes washers higher in every single category. Of note were the substantially higher ratings of the new machines for cleaning of clothes, noise, moisture content of the clothes, and cycle selection. The new machines did not score below 4.5 in any category. The old machines did not score above 4.5 in any category. Respondents also expressed satisfaction with the wash cycle time and the detergent use of the machines. A number of respondents made comments and suggestions regarding the machines.

Table ES.3 Comparison ratings of non-conserving and conserving clothes washers

Rating Category	**Non-Conserving Clothes Washer** (n=37)	**Conserving Clothes Washer** (n=36)
Cleaning of clothes	3.86	4.83
Reliability	4.44	4.92
Noise	3.32	4.81
Moisture content of clothes	3.50	4.64
Cycle selection	4.06	4.80
Capacity	4.30	4.56
Wash cycle time	NA	4.58
Detergent use	NA	4.61
Overall Average	3.91	4.72

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

CHAPTER 1 METHODOLOGY

The Seattle Home Water Conservation Study is a detailed study on the impacts and acceptance of high quality water conservation products in single-family homes funded by the U.S. Environmental Protection Agency (EPA) and Seattle Public Utilities (SPU). Aquacraft, Inc. (the consultant) and Tim Skeel and Al Dietemann of SPU are conducting this study. Work on the project commenced in September 1999.

In this study, 37 participating single-family homes will be equipped with new water conservation fixtures including toilets, clothes washers, showerheads and faucet aerators. Extensive data is being collected before and after the installation of these products and the changes in water use will be measured. In addition, participants will rate satisfaction level with their old fixtures and the new products.

The Seattle Home Water Conservation Study consisted of:

1. Selection of study participants
2. Initial site visit audits and data collection
3. Retrofit planning and installation
4. Post-retrofit data collection and customer survey
5. Analysis of results and report writing

This chapter provides an overview of the work done on each of the tasks in completion of this study.

TASK 1: SELECTION OF STUDY PARTICIPANTS

Work on the project began during the first week of September 1999. The goal of the first task was to select a group of approximately 35 homes to participate in the retrofit study. It was desired to select participants from households that had also participated in the 1996 American Water Works Association Research Foundation (AWWARF) Residential End Uses of Water Study (REUWS) (Mayer, DeOreo, et. al 1999), and to focus on homes located within the City of Seattle. Selecting participants from the AWWARF study was important because these households were part of a representative random sample of single-family households in Seattle and each of these households completed a detailed water use survey in 1996. Using the AWWARF group will also allow comparisons to be made against the water use data collected on these homes during 1996 and 1997 as part of that study of residential water use. Selecting homes from just the Seattle service area was done to reduce the administrative and co-ordination problems associated with working with customers from several utilities.

In 1996 a total of 469 homes in the City of Seattle received a detailed water use survey as part of the AWWARF study. A total of 248 surveys (53 percent) were completed and returned. The surveys provided considerable information on the physical features of the building, lot, and home. It also provided information on the number of occupants, their age, employment and other relevant demographic data. This survey information was coupled with historic billing data, which together gave an excellent profile of both water use and physical/demographic characteristics in this sample henceforth called the AWWARF survey group. The AWWARF survey group was chosen as a random cross section of single family customers in Seattle. This made the survey group a logical target for selection of the retrofit study.

As part of the AWWARF study, a group of 52 homes in Seattle were chosen from the survey respondents for a higher level of data collection. These homes were each fitted with a portable data logger attached to the main water meter which recorded flows with sufficient precision to allow water use to be disaggregated into individual end uses using signal processing software (DeOreo, et. al. 1996). Each home was logged for a total of four weeks during two, two-week periods one during the rainy season and the second during the dry season. Each data set obtained was referred to as a flow trace, because it appears as a continuous graph (or trace) of the water use over the two week sampling period. A database was then constructed which allowed daily use for each major residential end use to be quantified. This data set provided a highly detailed and accurate picture of water use in this group of single family homes. Having this kind of baseline data made the AWWARF study group all the more valuable as participants in the Retrofit project, since we would be able to compare the impact of the retrofits to a longer period of baseline use.

First Team Meeting

On September 24th, 1999 a meeting was held in Seattle between SPU and Aquacraft staff members to finalize the work plan and schedule. A number of decisions were reached at this meeting concerning how the project should proceed. A time line was prepared to insure that all of the initial site visits would be done, and the initial flow trace data obtained prior to the Thanksgiving holiday. Selecting the study group and completing the initial visit by that time was deemed critical in order to maintain momentum and avoid delaying the entire operation until after the Christmas/New Years holidays.

The content of the letter of invitation was discussed at the meeting, and the mechanics of the retrofits was outlined. It was decided to install separate water meters on the supply lines for the hot water tanks in approximately ten of the study homes. This would provide a way of quantifying the savings in hot water use.

The list of fixtures and appliances to be used for the retrofits was finalized at the meeting. These included 1.0 and 1.5 gpm faucet aerators, 2.5 gpm Brass Craft ™ showerheads, 1.6 gallon per flush (gpf) Toto ™ toilets and 1.6/0.8 gpf dual flush Caroma ™ toilets. An equal number of clothes washers were to be purchased from Frigidaire, Maytag and Whirlpool. A few homes with very large dishwashing water use were to receive new water efficient dishwashers, which use 7 gallons per load. The only other device slated for inclusion in the retrofit program was a hands free activator for the kitchen faucet, called the Aqua Lean™. This device allows the user to turn the sink on and off without use of hands, by leaning on an activating bar mounted on the cabinet face under the sink. It was thought that this product offered the possibility of less continuous faucet use during food preparation and dish washing. However, because this product had not been approved and accepted into the Seattle plumbing codes it was impossible to include the Aqua Lean in the retrofit program.

It was agreed that the actual selection of the brand of toilet and clothes washer to be placed in the homes would be made by Seattle Public Utilities rather than the homeowners. This was done to prevent people from feeling disappointed if they didn't get their first choice in machines or toilets, and it also allowed the most suitable equipment to be used in each home.

During the initial visit, it was decided, a plumber should be present to verify that there would be no problems with the retrofit due to structural problems. The plumber will also be responsible to installing the hot water meters at the time of the initial visit. Other matters discussed at the team meeting were the questions to be asked during the audit, the need for a set of tips and instructions to be left with the customers after the retrofits, and the information to be obtained during the post retrofit surveys.

Creation of Seattle Retrofit Database

To assist with the collection and analysis of the large amounts of data required for this study, the consultant created a Microsoft Access™ database. This database contains several important tables, queries and forms that allow input of information about the customers and extraction of data needed to meet specific criteria for the selection or analysis processes. All information generated in the study including the audit surveys and results of the pre and post-retrofit data collection periods will be entered into the database, and it will serve as the main repository of information about the project.

Billing Data

Seattle Public Utilities provided historic water consumption data from billing records for the 248 homes in the City of Seattle that responded to the original AWWARF mail survey. These billing records included the name of the current occupant/bill payer, bi-monthly consumption for the household from January 1996 through July 1999 in hundreds of cubic feet, meter read dates, and other water billing information. From these records it was apparent that the occupants had changed in about 30 percent of these homes.

These billing data were organized into a single record per household format to assist with analysis and the table was included in the Seattle Retrofit database described above.

Invitation to Participate

In order to solicit willing participants for the retrofit study, an invitation letter from Seattle Public Utilities was mailed out to 102 homes during the first week of October. The letter, printed on Seattle Public Utilities letterhead and signed by project manager Tim Skeel, briefly described the study and the free products available. The letter invited the recipients to phone for more information or sign up to participate. A copy of this letter is provided in Appendix A.

A total of 35 homes were sought to participate in the retrofit study. Ideally these homes would come from the 52 homes that participated in the data-logging portion of the AWWARF study. But such a high participation rate was not expected. To increase the chances of finding 35 willing participants, an additional 50 homes from the AWWARF mail survey response group were selected.

The selection of these additional 50 homes involved first screening out renters and households without clothes washers. This was accomplished using the survey responses from the AWWARF study. An important goal of the study was to measure the impact of horizontal axis clothes washers so it was necessary for each participating home to have some type of clothes washer in place initially. Renters were excluded to avoid the extra complication of negotiating with both the occupant and the owner regarding the retrofit. Accounts that met the criteria of owner occupancy and clothes washer ownership were then sorted from by annual water use from lowest to highest. A systematic random sample of 50 accounts were drawn from this population and added to retrofit study invitation list. This yielded a group of 102 homes as candidate participants in the retrofit study.

The letter of invitation was followed-up by a phone call from the Seattle Public Utilities Office of Water Conservation. During the phone interview, the customer was asked if they had received the letter, and whether they would be willing to participate in the study. The letter also gave a phone number for persons who were interested in participating to call in order to schedule a site visit and audit.

All customers that indicated a willingness to participate were placed on a schedule for an initial site visit and audit. By the second week in October approximately 24 homes from the initial invitation mailing had indicated an interest in participating in the study. This was insufficient to proceed with any confidence of attaining the desired 35 homes for the final group by the deadline of October 25th, so a second mailing was sent out to 110 homes from the survey group. These 110 homes were all of the remaining homes in the survey sample that met the owner occupancy and clothes washer criteria described above. The same procedure of follow-up phone calls was used. The process of phoning and scheduling appointments was continued until a total of 37 homes were scheduled for site visits. It was hoped that from these, 35 would prove viable candidates for the study.

All candidates were mailed a second, more complete explanation of the project that described the study in more detail, identified the free products to be installed, and listed the requirements for participants. A copy of this information packet is also included in Appendix A.

Quality Assurance and Quality Control

Annual water use in 1996, 1997, and 1998 were calculated for the AWWARF mail survey sample of 248 accounts and for the 36 audited homes in Seattle from the billing data provided by SPU. The average annual water use for these two groups in all three years was virtually identical. A z-test for significance found no significant difference in the water use characteristics of the audit group and the survey response group at the 95 percent confidence level. This confirmed that the retrofit sample was representative of the population from which it was drawn in terms of annual water use. Since it was previously established that the annual water use in the original survey group was representative of the single family homes in Seattle it can safely be concluded that the Retrofit Study group is representative of the population of single family homes in the city as a whole. Details of this analysis are presented in the Results section of the report.

Solicitation of Support from Manufacturers

Early in the project the consultant and SPU contacted the manufacturers of water conserving fixtures including Frigidaire, Maytag, Whirlpool, American Standard and others. It was hoped that price reductions or donations could be obtained which would save money for the project. A number of responses were received expressing interest and support for the project. All of these were forwarded to the SPU for follow-up since they were making the actual purchases. In the end, the only outright offer of donations came from a maker of nozzles and showerheads, of which SPU already had an ample supply.

The American Standard Company expressed an interest in participating in the study by providing ULF toilets. However, in an effort to reduce the number of variables in the analysis, the decision was made to use the highly rated Toto 1.6 gpf toilet and the Australian Caroma

1.6/0.8 gpf dual flush toilets. The contact with American Standard may be pursued if more toilets are required to meet the goal of 100% replacement within the project budget.

A wide number of manufacturers were contacted regarding this project. In most cases, even though the contacts were started well even before work on the project officially began, there was not enough time to fully explore the project with the manufacturers and bring them to the point where they were able to make a decision to participate. Consequently, we were not able to obtain the sizable discounts or donations we had hoped for from the large appliance makers. The Frigidaire Company came the closest to agreeing to participate by supplying both horizontal axis clothes washers and high efficiency dishwashers, but we were still in discussions with their engineering and marketing group when the project began, and purchases had to be made.

Another, more significant, obstacle to obtaining manufacturers' support is the natural desire on the part of any manufacturer who contributes to the project to be the exclusive supplier of equipment, and to exert a certain degree of control over and ownership of the design and analysis of the study. This desire clearly conflicted with the need for impartiality and objectivity on the part of the study team. During the team meeting this issue was discussed, and the decision was made to de-emphasize our search for "free" appliances and simply obtain the products for the best price available on the retail market.

The Conservative Concepts Company, which manufactures the hands free faucet controller called the Aqua Lean, agreed to offer his product at a 50% discount. The Aqua Lean is a brand new product that operates using diaphragm valves on the supply lines of a sink – typically a kitchen sink. Leaning on a bar that is mounted under the sink board activates the valves. This allows the water to be turned on and off without touching the faucet handles. In theory, this device could reduce water use at the sink by eliminating long faucet runs when people wash dishes and prepare food. Water is only used in short bursts when it is needed. Because the Aqua Lean is a new product it does not yet have plumbing code approval within the City of Seattle it was not possible to include it in the retrofit study.

Selection of Study Participants

Selection of the final group of participants was an iterative process that started with mailing the invitation, included phone contact with each potential study household, and continued through the audit process. The reason for this is that the process by its nature required several decisions on the part of both the homeowner and the City before an individual was finally selected.

Each potential participant was a member of the initial AWWARF survey group; preferably, part of the group of 52 homes that were logged. The survey group was screened to exclude renters and those households without a clothes washer. Households that expressed an interest in participating were provided with more detailed information and were scheduled for an audit. Any renters or households without clothes washers that made it past the initial screen were excluded at this point.

A total of 212 letters of invitation were mailed out between October 1st and October 24th in two mailings, as discussed above. Some individuals responded by telephone to indicate their willingness to participate in the study. It was considered critical to complete the audits and baseline data collection prior to the start of the holiday season. Consequently there was not enough time in the schedule to rely exclusively on volunteers to contact the City, and the pro-active approach of phoning each recipient was adopted. Starting during the second week of October, just after the invitations were mailed out, a member of the Seattle staff began to phone the people to whom invitations had been mailed in order to solicit their participation. Each individual who agreed to participate was scheduled for an audit. By November 8th this process had yielded a total of 38 homes for the audit list, which included the two homes from Bellevue and Kent.

A plumber was present on each audit visit to verify that there were no physical or structural obstacles to installing the new equipment. It was made clear to the homeowners that they would be exchanging their present washers and toilets for new ones. Anyone wishing to keep his or her old machine was required to store the washer. At least one individual considered dropping out at this point because the new washer would not be compatible with the stacked appliance system in the house. In other homes wall mounted toilets and other out dated plumbing fixtures presented challenges.

At the conclusion of the audit, each homeowner was left with a project participation agreement. This agreement was to be read, signed, and returned to the SPU. This step was critical for participation in the study. Once this form was signed and returned to the SPU, the customer had met the selection criteria for the study, had been provided complete information about the project, and had agreed to participate in writing.

Two additional customers were selected from outside the Seattle service area at the end of the audit process. These customers were included so that the project would have representatives from more than just the City of Seattle. One customer was in the City of Bellevue (just east of Seattle) and the other was from the City of Kent (just south of Seattle). Neither of these customers was part of the original AWWARF mail survey group, but both were audited and included in the baseline data collection effort that will allow for valid comparisons of their water use to be made before and after the retrofit.

TASK 2: INITIAL SITE VISITS AND AUDITS

Visit Protocol

There were at least three persons present from the study team for each audit: one representative from Aquacraft, one from SPU, and the contracted plumber. During the first few days there were frequently five persons present since both Aquacraft and SPU sent an additional person to work out any problems with the procedure.

The audit questionnaire form was developed by Aquacraft and was based on a recent residential audits conducted in Westminster, Colorado and San Jose, California. The questionnaire contained approximately 40 questions about the size and composition of the household – number of adults, teens, and children, year of construction, the existing water using fixtures in the house, typical water use habits of the residents, satisfaction ratings of existing fixtures, etc. The questionnaire was reviewed, edited, and printed by SPU staff. A copy of this questionnaire is included in Appendix A.

The audits began on Monday, October 25th. The goal was to collect two weeks of pre-retrofit baseline water use data from each participating household. Upon arrival at each house a data logger was placed on the water meter and set to begin recording water use. These loggers were scheduled to be in place for a total of 15 days each. Seattle Public Utilities arranged for the standard mechanical water meter at each home to be replaced with a new magnetic drive meter, compatible with the data logging system used by the consultant. Each logger had previously been initialized for local time and synchronized closely to the auditor's watch. Each data logger was removed only at the conclusion of the 15-day logging period.

Once the logger was in place, the team moved inside and began to collect the information from the home. The Aquacraft staff member administered the audit questionnaire, which involved sitting down with the customer and asking approximately 40 questions about the home. Each questionnaire took approximately 20 minutes to complete.

While the questionnaire was being administered, the plumber located the hot water tank and, if feasible, installed a 5/8th-inch water meter on the cold water feed line. This turned out to be a fairly simple process, and in all cases the meter was installed in line above the tank with a few standard fittings. Normally, the installation of the meter was completed at approximately the same time as the audit. This process was repeated until hot water meters were installed on 10 homes. Each hot water meter was then fitted with a data logger so that simultaneous water use data could be obtained for both hot and cold water in the home prior to the retrofit.

Measuring hot water usage was not part of the original project work plan. The decision to install meters and loggers on the hot water lines was made at the team meeting in Seattle. Even though this added to the complexity of the project everyone felt it was worth the extra effort since it will provide some hard information on the important question of energy savings associated with retrofits, and it can demonstrate the feasibility of using flow trace analysis in this manner. The meters cost approximately $60 each and a like amount to install, allowing for one half hour of plumbing time and the cost of fittings.

After installing the hot water meter, the plumber then inspected the toilets, showers, and faucets in the home to determine if any existing problems that would make the retrofit impractical. In a few houses, old faucets without threaded outlets will make it impossible to install an aerator. In these homes it will be necessary to replace the entire faucet for the study. Another problem that was noted came from the limited room in some bathrooms for installation of the Caroma toilets, which require enough clear space to accommodate a 32" tank and sufficient room to allow operation of the flush buttons located on top of the tank. Caroma toilets will be excluded from homes that feature a counter behind the current toilet. In these home the more standard Toto design will be used.

While the plumber was conducting his survey the auditor from Aquacraft, who had by this time completed the audit, operated each fixture in the home and noted the time of each operation. This was intended to provide a signature trace of each fixture to be captured by the logger. The key to obtaining good signature traces was to operate each faucet or shower or bath for a long enough time to get a good sample with the logger that records flow in 10-second intervals. Each fixture was operated individually for at least 1-3 minutes and each toilet was flushed individually. The next important step was to allow at least 30 seconds between the operation of each fixture to allow for clear, discreet water use events. The focus of this process was to get accurate maximum flow rates for each sink, bathtub and shower so that during the analysis it would be easier to assign fixture designations for individual events. For example, if the maximum flow rate of the kitchen sink is 2.5 gpm then this fixture can be confidently excluded as the source of any event with peak flows significantly above 2.5 gpm, even if the volume of the event is comparable with a kitchen sink. Generally, the more accurate the flow information available the easier it becomes to obtain accurate disaggregation of water use events.

As a check, the analyst also measured the flow of the fixtures using a calibrated pitcher that converted a volume captured in 5 seconds to a gallon per minute flow rate. This type of device can provide flow estimates up to 6 gpm. This calibrated flow measuring device proved to be useful because during the audit visits it was discovered that several homes had not been equipped with magnetic water meters required for the data loggers, and instead had the mechanical meters in general use by SPU. Rather than delay the audits while these meters were replaced, the decision was made to proceed with the audit and return later to install a logger. Without a logger in place at these homes during the audit, signature traces could not be obtained. A missing signature trace is more of an inconvenience than a serious problem, especially because the flow measurements were taken using the calibrated pitcher. An experienced water use analyst can normally identify the various fixtures in houses without any flow measurements since they do not vary significantly from house to house. While additional information is always welcome, the audit data and flow rate information from the hand measurement provides a good substitute to the signature traces.

The final task during the visits was for the SPU staff person to explain the participation agreement to the customer and leave a copy of this document for the customer to read, sign and return using the stamped return address envelope provided. The terms and conditions of participation in the study were carefully explained to each customer before the conclusion of the site visit. It was critical that customers understand and feel comfortable with the participation agreement, because there is no assurance of participation until the customer returned the signed agreement.

The entire audit process typically took less than 45 minutes per household.

Audit Data Entry and QA/QC

Audit data from each household was entered into the Access database using a customized data entry form. This form contained numerous data quality checks and data restrictions to prevent inadvertent data entry errors. Data entry accuracy was independently checked for each household at the conclusion of the process to ensure the quality of the database.

Retrieval and Verification of Initial Data

The retrieval of the data loggers began 15-days after their installation. Seattle Public Utilities staff retrieved the loggers installed early in the audit process, and an Aquacraft staff member returned to collect the loggers installed at the end of the audit process. As each logger was retrieved the ending water meter reading was recorded on a form and the logger was turned off to end the recording session.

Aquacraft staff members downloaded all the data stored in the loggers to a PC on-site in Seattle. Each file was checked for accuracy against the water meter reading to ensure it was operating properly. If a logger failed to record data or did not record accurate data, a replacement flow trace was obtained by installing a new data logger on the house and collecting another two weeks of data.

If necessary, replacement homes were to be selected for any household that failed to return a participation agreement or indicated that they did not wish to participate in the study. Fortunately, only a single home dropped out of the study, so it was not necessary to make replacements.

At two homes it proved impossible to install a logger until the week of November 15th. One home had a broken water meter that had to be replaced, at the other home a data logger problem was encountered. Seattle Public Utilities staff logged these two homes and the data sent to Aquacraft for analysis.

Pre-Retrofit Logging Report

During the first pre-retrofit logging period a total of 46 data loggers were installed at 36 homes – 36 loggers on the main water meter outside the home, and 10 loggers on new hot water meters installed above the hot water tank. From these 46 installed loggers, accurate data were obtained from all of the hot water loggers and from 33 of 36 main meter loggers. The three traces that could not be used were caused by complete logger failure due to water damage in one case, and abnormal data in two other cases. These homes were re-logged.

Re-Logging Effort

David Lewis of Aquacraft traveled to Seattle during the week of November 15th to download the first 46 data loggers, determine the re-logging requirements, and install additional data loggers as required. A total of seven data loggers were installed as part of the re-logging effort. Three loggers were installed at the homes where good data were not obtained during the first logging period. Because one of these homes had been equipped with a hot water meter, an additional logger was installed on the hot water meter there. The remaining three loggers were installed on three homes for the following reasons: (1) A magnetic water meter was not available during the initial logging period; (2) the residents were out of town for one week during the initial logging period so additional baseline usage data were desired; (3) a home in Bellevue was selected for participation.

At the conclusion of the pre-retrofit logging period, the study group contained 37 homes – 35 in the City of Seattle, 1 home in the Highline water service area, and 1 home in Bellevue.

Pre-Retrofit Flow Trace Analysis

Recorded flow traces from the 37 participating homes (37 main meter traces and 10 hot water traces) were disaggregated into specific end uses by Aquacraft using the Trace Wizard© Water Use Analysis Software developed specifically for this purpose. A more detailed description of the software and the flow trace analysis process is presented in Appendix B.

During the flow trace analysis process, the recorded water use flow traces are disaggregated into water use events using signal processing technology and then fixture designations are assigned to these events using a pattern recognition algorithm. Specific statistics are calculated for each individual water use including the volume, start time, stop time, duration, peak flow rate, and mode flow rate.

Water use in each flow trace is shown on an interactive graph in Trace Wizard. The analysis must visually inspect each portion of the trace to ensure proper identification of all water use events. Analysis for each 15-day flow trace took approximately two hours to complete.

Once the analysis of each trace was completed, two separate water use tables were created in the database – one for water use recorded from the main water meters and a second for the water use recorded from the hot water meters. Each water use event (toilet flush, faucet use, dishwasher cycle, etc.) is included in the database and is associated with a unique keycode number which identifies the house from with the water use was recorded. An example of this database is shown in Table 1.1.

Table 1.1 End use data table example

KEYCODE	USETYPE	DATE	START TIME	DURATION (seconds)	END TIME	PEAK (gpm)	VOLUME (gal.)	MODE (gpm)	MODE NO
12137	TOILET	5/21/99	12:28:14 AM	40	12:28:54 AM	4.60	1.65	0.46	2
12137.	SHOWER	5/21/99	5:38:54 AM	270	5:43:24 AM	3.45	8.32	1.61	9
12137.	FAUCET	5/21/99	5:39:44 AM	10	5:39:54 AM	1.15	0.19	1.15	1
12137	FAUCET	5/21/99	5:40:24 AM	20	5:40:44 AM	1.15	0.31	1.15	1
12137	FAUCET	5/21/99	5:45:24 AM	10	5:45:34 AM	0.46	0.08	0.46	1
12137	SHOWER	5/21/99	6:01:24 AM	600	6:11:24 AM	3.68	25.76	2.76	29
12137	TOILET	5/21/99	6:14:04 AM	90	6:15:34 AM	2.99	3.53	2.99	4
12137	FAUCET	5/21/99	6:32:14 AM	10	6:32:24 AM	0.69	0.12	0.69	1
12137	TOILET	5/21/99	6:36:14 AM	40	6:36:54 AM	4.14	1.57	4.14	1
12137	TOILET	5/21/99	6:53:14 AM	30	6:53:44 AM	4.37	1.34	4.37	1

Quality Assurance and Quality Control

Numerous quality assurance and quality control measures were taken during the data collection and analysis process to ensure the quality and accuracy of the data obtained in this study. These measures are described in detail below.

- **Data logger preparation** - Each data logger/flow recorder was charged, initialized, and tested prior to installation in the field. Loggers were bench tested by Aquacraft by running a known quantity of water (usually 10 or 20 gallons) through a test meter. This verified proper operation of the logger and ensured recording accuracy. Loggers that failed any portion of the testing regime were returned to the manufacturer for repairs. Only fully charged, fully functional data loggers were installed in the field.
- **Water meter calibration –** The data obtained from the flow recorders is only as accurate as the water meter it is attached to. Seattle Public Utilities understood this concept during the AWWARF REWUS project and replaced all water meters used in that study with brand new Trident T-10 meters. Only 9 houses from the original REUWS were able to participate in the retrofit study. These homes all had relatively new water meters from 1996. In the remaining 28 homes (and for the 10 hot water meters) new Trident T-10 meters were installed by SPU for this study. These new water meters are tested by the manufacturer and offer high-resolution magnetic pulse output to the flow recorders.
- **Field verification of data logger operation –** The Meter-Master flow recorders used in this study have a special sensor which is strapped to the water meter using a heavy-duty Velcro strip. Once the sensor and logger are in place it is important to verify that the logger is installed properly and is picking up the magnetic pulses from the water meter. This was accomplished by running water through an outside hose bib once the logger was installed. The Meter-Master logger has an indicator light that flashes after a specific number of magnetic pulses have been recorded. This flash is repeated 12 times at which point the light shuts down to conserve battery power. The flashing indicator light signals that the logger is installed properly and it recording flow through the meter. This proper functioning was verified during each data logger installation.
- **Water meter readings upon installation and removal of the data logger –** A key to verifying the accuracy of the data recorded with the Meter-Master flow recorders is to compare the volume of water measured by the water meter with the volume measured by the data logger. These volumes are compared when the data stored in the flow recorder is downloaded to a PC at the conclusion of the logging period. Careful, accurate water meter readings were taken when the data logger is installed and again when it is removed.

These readings are recorded on a log sheet and then used as a check against the volume recorded by the data logger. Agreement between the meter and logger within 5% is the goal.

- **Fixture signature traces –** To improve the accuracy of the flow trace analysis process, fixture signatures were obtained during the audit process in each home. The Aquacraft auditor intentionally operated each faucet, shower, bath, and toilet fixture individually during the audit, allowing a minimum of 30 seconds in-between each fixture, and noted down the time of each operation. During the analysis process these fixture signatures are carefully examined and used to help identify regular fixture usage during the 15-day logging period.
- **Customer log sheets-** Each customer was left with a log sheet on which the number of persons staying at the house each day was recorded along with the times at which the clothes washer and dishwasher were operated. This provided better information on occupancy for calculating per capita consumption, and assisted with recognition of the two appliances.
- **Flow rate calibration –** During the audits, a special calibrated vessel was use to measure the maximum flow rate in faucets, showers, and baths or all participants. To use this device, water is run into the vessel for exactly 5 second. The resulting volume collected in the vessel is then translated into a flow rate in gallons per minutes using graduated markings. An attempt was made to measure the maximum possible flow rate from each faucet, shower, and bath in the audited study homes. These flow rates were noted on the audit form and entered into the Access audit database.
- **Alignment of flow traces with calibrated flow rates –** As a check on the accuracy of the flow traces, the logged flow rates from the signature draws were compared against the physical measurements of flow made with the calibrated vessel. Any discrepancy between the data logged flow rate and the measured flow rate was carefully investigated and if necessary the flow trace was scaled to match the measurement.
- **Systematic quality checks of analyzed flow traces –** The process of flow trace analysis with Trace Wizard contains some subjective components. To ensure the accuracy of the flow trace analysis, two different analysts examined each flow trace in its entirety. The results from each analysis were compared by summarizing the fixture volumes and

calculating the differences. If any significant discrepancies existed, the traces were re-examined and finalized in consultation with both analysts.

- **Database integrity testing –** Once all the water use events were assembled into the Access database, sorting queries are performed to examine peak flow rate, maximum volume, and duration for each end use category. A screen for obvious errors is performed (toilets with a volume of more than 8 gallons, flow rates exceeding meter capacity, etc.). Any database errors are noted and investigated by reviewing the analyzed flow trace data in Trace Wizard. Appropriate corrective action is taken.

TASK 3: PLAN RETROFITS AND INSTALL CONSERVING FIXTURES

In this task a retrofit plan was developed and implemented for the study. The goal of the retrofits was to select and install high quality indoor water fixtures on existing housing to determine the water savings that might be available from the use of these products.

Draft Retrofit Plan

The basic retrofit plan was developed by SPU staff members Al Dietemann and Tim Skeel in conjunction with William DeOreo and Peter Mayer of Aquacraft, Inc. during the initial team meeting in Seattle.

Results from the AWWARF Residential End Uses of Water Study showed that toilets, clothes washers, showers, and faucets are comprise more than percent of indoor water use in a typical single-family home. Because these are the primary end uses of water it was decided to focus the retrofits on reducing water use in the following four categories: toilets, clothes washers, showers, and faucets.

The widest variety of conservation options is available for reducing toilet water use. All toilets currently manufactured in the United States must conform to the Federal Energy Policy Act standards that mandate a maximum flush volume of 1.6 gallons (6.0 liters). These ultra low-flush (ULF) toilets represent a substantial reduction in water usage over previous 3.5 and 5.0 gallon per flush (gpf) models. There are toilets on the market that use even less water than the standard 1.6 gpf ULF models. These include dual flush toilets that offer two flushing modes – one at 1.6 gpf and one at 0.8 gpf, and super high-efficiency dual flushing models that flush at 1.0

and 0.5 gpf. Composting toilets that do not use water are also available, but these are primarily designed for houses without central plumbing, campers, and boats.

In the 1990s a number of manufacturers began offering high efficiency clothes washers that purport to use less water and energy than traditional models. Most of the high efficient washers operate on a horizontal axis (h-axis), which means they open on the front of the machine instead of the top. Manufacturers that offer h-axis machines include Maytag, Frigidaire, and Asko. Recently Whirlpool entered the high efficiency washer market with a top-loading machine. These washers are shown in Figures 1.1 – 1.3.[3]

Figure 1.1 Frigidaire Gallery clothes washer

Figure 1.2 Maytag Neptune clothes washer

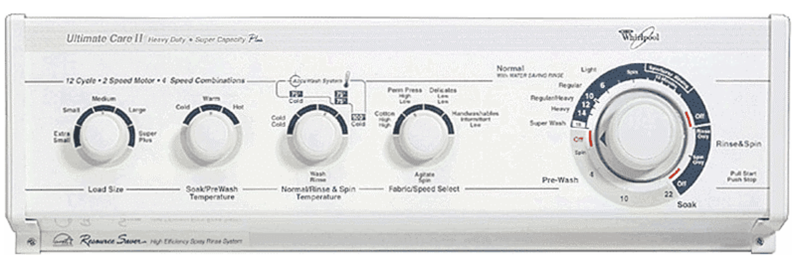

Figure 1.3 Control panel of Whirlpool Super Capacity Plus clothes washer

[3] Photos printed with permission courtesy of Frigidaire, Maytag, and Whirlpool

Showerheads and faucets, like toilets, are now regulated under the Federal Energy Policy Act. Showerheads must restrict flow to 2.5 gpm and faucets must restrict flow to 1.5 gpm. A wide variety of products are available from numerous manufacturers in the U.S.

The list of fixtures and appliances to be used for the retrofits was finalized at the first team meeting. These included 1.0 and 1.5 gpm faucet aerators, 2.5 gpm Brass Craft ™

Figure 1.5 Toto Drake ULF toilet

Figure 1.4 Caroma Caravelle dual flush ULF toilet

showerheads, 1.6 gallon per flush (gpf) Toto ™ toilets and 1.6/0.8 gpf dual flush Caroma ™ toilets. Toto and Caroma toilets, like the ones installed for this study, are shown in Figure 1.4 and Figure 1.5.[4] Clothes washers were to be purchased from Frigidaire and Maytag along with two of the new efficient Whirlpool machines. A few homes with high dishwashing water use were to receive new water efficient dishwashers, which use 7 gallons per load.

Final Retrofit Plan

A final retrofit plan for each of the participating households was developed based upon the physical requirements of the home (some houses could only have a Toto toilet installed because of space limitations), requests from the homeowners (some people expressed a product preference), and the availability of various fixtures. Al Dietemann of SPU was in charge or ordering the products for the retrofit and finalizing this list of products to be installed.

Because of cost constraints, fewer Maytag clothes washers were purchased than originally planned. Additionally, a few homes were to be retrofit with efficient dishwashers – probably manufactured by Frigidaire. The determination of which households to retrofit will be based on results from the baseline data analysis.

Perform Retrofits

Seattle Public Utilities contracted with several plumbers to remove old fixtures and install new ones for this study. Plumbers were responsible for installing toilets, faucets, and showerheads in study homes. The appliance dealer who sold the conserving clothes washers also performed the installation.

The contracted plumbers encountered infrequent difficulties in performing their assigned task. In 10 homes it proved impossible to install kitchen sink and/or bathroom faucet flow restrictors because of various incompatibilities. In some homes it was necessary to install a floor closet flange to properly anchor the new toilet. Some homes required a new shower arm in order to receive a new showerhead. In one or two homes it was not possible to install one of the new toilets because of space constraints or impending remodeling plans. Table 1.2 shows the number and make and model of all fixtures installed for this study.

Validate and Tabulate Retrofits

Audit Installation Quality Assurance and Quality Control

To ensure that the proper fixtures were actually installed at the 37 study homes, the responsible plumber was asked to complete a product installation and removal form for each house. This survey specified the exact fixtures (make and model) installed at each home. Initial audit data also included a detailed list of existing fixtures in each study home.

In the follow-up retrofit satisfaction survey, participants were asked to list the products installed at their home as part of the study. They were also asked to report on the survey any installation problems or dissatisfaction.

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[4] Photos printed with permission courtesy of Toto and Caroma.

Table 1.2 Conserving fixtures installed in 37 study homes

Product	Quantity	Make	Model
Showerhead	51	Brass Craft	2.5 GPM, LM39709
Bathroom faucet aerator	60	New Resources Group	TS 100 and TS 005 with pressure compensating feature
Kitchen faucet aerator	27	New Resources Group	TS 100 and TS 005 with pressure compensating feature
Clothes washer	12	Maytag	Neptune (MAH4000)
Clothes washer	23	Frigidaire	Gallery (FWT449)
Clothes washer	2	Whirlpool	Super Capacity Plus (LSW9245EQ)
Toilet	40	Caroma	Caravelle 305 (0.8/1.6 gpf dual flush)
Toilet	34	Toto	G Max C744-s-01 and MS853113-s-01

As a final check, the toilet, faucet, and clothes washer installation was inspected by a project team member during installation of the hot water meter data loggers. This took place in only 10 of the 37 homes.

Post Retrofit Logging Quality Assurance and Quality Control

There were two post retrofit logging sessions. Each involved the same procedures for installation and calibration of the data loggers. The only homes that the study team entered, however, was those with the hot water meters. A postage paid mail-back log sheet was left at the home similar to the initial log sheets. The customers were asked to note the operation times of all of the new fixtures and appliances in the home to assist with the post retrofit analysis.

CHAPTER 2 BASELINE WATER USE

To determine the effect of the conservation retrofit on water use in the study homes, baseline water use data were collected from the study group. Obtaining high quality baseline use data was critical for this study because all impacts of the retrofit were measured by comparing baseline use patterns against water use after the retrofit. Historic billing data were obtained so that the overall impacts of the retrofit could be measured. Disaggregated flow trace data from the residential end use study, and a new two-week set of flow trace data were obtained so that the impacts on each specific end use could be evaluated.

Seattle Public Utilities (SPU) provided historic water consumption data from billing records for the 248 homes in the City of Seattle that responded to the original AWWARF mail survey[5]. This random sample was selected by SPU Economist Tim Skeel in 1996 to be representative of single family households in the City of Seattle. The billing records provided included the name of the current occupant/bill payer, bi-monthly consumption for the household from January 1996 through February 2000 in hundreds of cubic feet (ccf), meter read dates, and other water billing information.

ANNUAL WATER USE

Using the data from the random sample of 248 homes, annual use frequency distributions for the years 1996, 1997, 1998 and 1999 were developed and plotted on the same axis. These results are shown in Figure 2.1. These distributions show clearly that annual water use in these homes remained quite consistent over the four years. The average annual demand over the four years was 66.4 kgal (88.8 ccf) and the average annual demand differed by less than 5 percent between any of these four years. The consistency in demand of this group is important because 213 of these homes that did not participate in the conservation retrofit will be used as a control group. The control group will be used test if the expected changes in water use in the study group are in fact due to the retrofit and not some other factor affecting all households in Seattle.

[5] The 1996 REUWS survey included 1000 homes in Seattle and several surrounding communities. Only homes in the city limits of Seattle were included in this study, which simplified its administration and co-ordination. Annual water use in the Seattle homes was less than that in the total survey sample from 1996. (66 kgal/yr vs. 80 kgal/yr). The mean demand in Seattle was closer to the 1000 home median, which was 55 kgal/yr.

The group of 35 homes, which received new fixtures and appliances in this study (the study group), was selected from the population of 248 homes. Table 2.1 compares the annual average water use over three years of the population (n=248), the study group (n=35), and the control group (n=213).

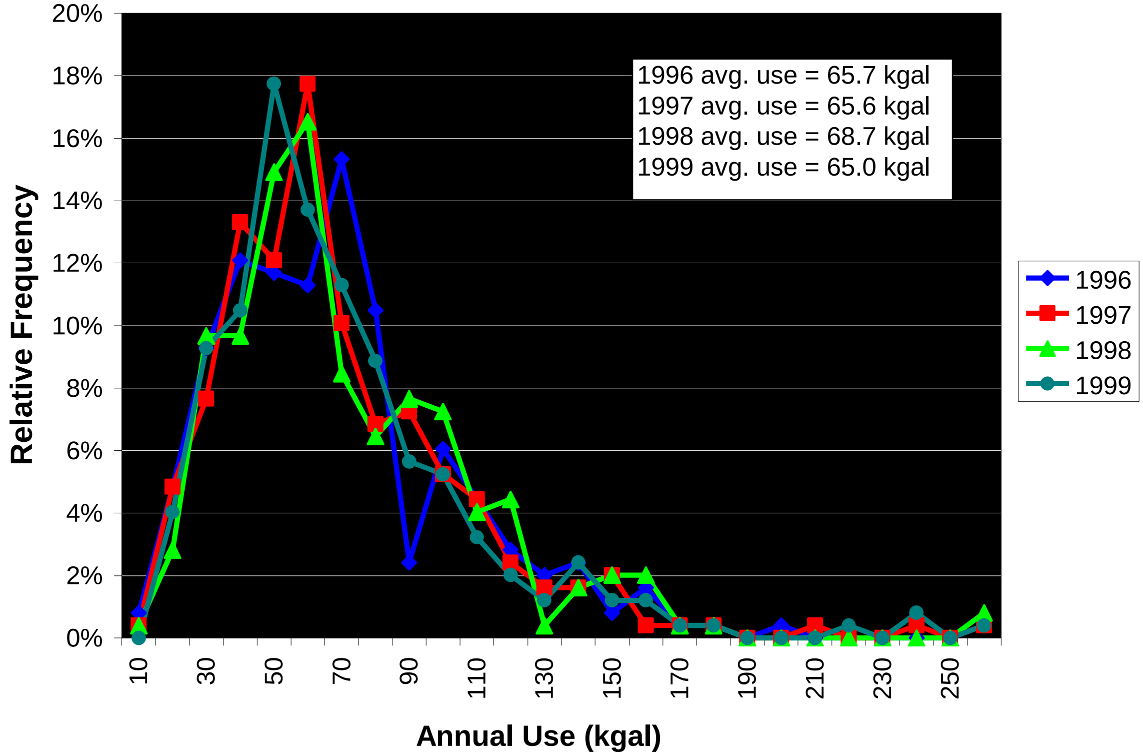


Figure 2.1 Annual use distributions, 1996-98, Seattle control group (n=248)

Table 2.1 Average annual water use (from billing data)

	AWWARF Survey group (n=248)		**Seattle Retrofit Study group (n=35)**		**Seattle Control Group (n=213)**	
	kgal	**ccf**	**kgal**	**ccf**	**kgal**	**ccf**
1996 avg. annual use	65.7	87.8	66.9	89.5	65.5	87.5
1997 avg. annual use	65.6	87.6	67.6	90.3	65.2	87.2
1998 avg. annual use	68.7	91.9	70.4	94.1	68.5	91.5
1999 avg. annual use	65.0	87.0	62.5	83.6	65.5	87.6
4 year average	66.4	88.8	66.8	89.4	66.2	88.5

To ensure that the study group of 35 homes is not biased and is in fact representative of the customers comprising the survey sample of 248 accounts a unpaired *t*-test was performed on the mean annual use data from each group at an alpha level of 0.05 (95% confidence level). The null hypothesis was that the two means were equal. The statistical test found that the difference between the mean water use of the two groups was not significant at the 95 percent confidence level. given the p-value of 0.94. This value indicates that there is a 94% chance that the differences observed between the two means was due strictly to chance. The conclusion here is that, prior to the retrofit, the annual water use of the retrofit sample was not significantly different from the annual water use of the survey population.

Seasonal Water Use

Seasonal variations in billed consumption provide an indication of the amount of water that is used for indoor and outdoor uses. The bi-monthly consumption records for the retrofit group is shown in Figure 2.2 for the period from 1995 to 1999. These data show that the average bi-monthly minimum demand for the group was 8.9 kgal. If one assumed that all use above this was outdoor, then it establishes a lower limit estimate for indoor use of 53.4 kgal per year. In fact, it is highly unlikely that Seattle customers use water for outdoor purposes in 10 months of the year, so that the actual indoor use is almost certainly well above this level. As discussed later in this report, the measures indoor use in the study homes was 63.6 gpcd, which is equivalent to an annual indoor demand of 55.7 kgal, which seems to agree well with the pattern of bi-monthly data shown in Figure 2.2.

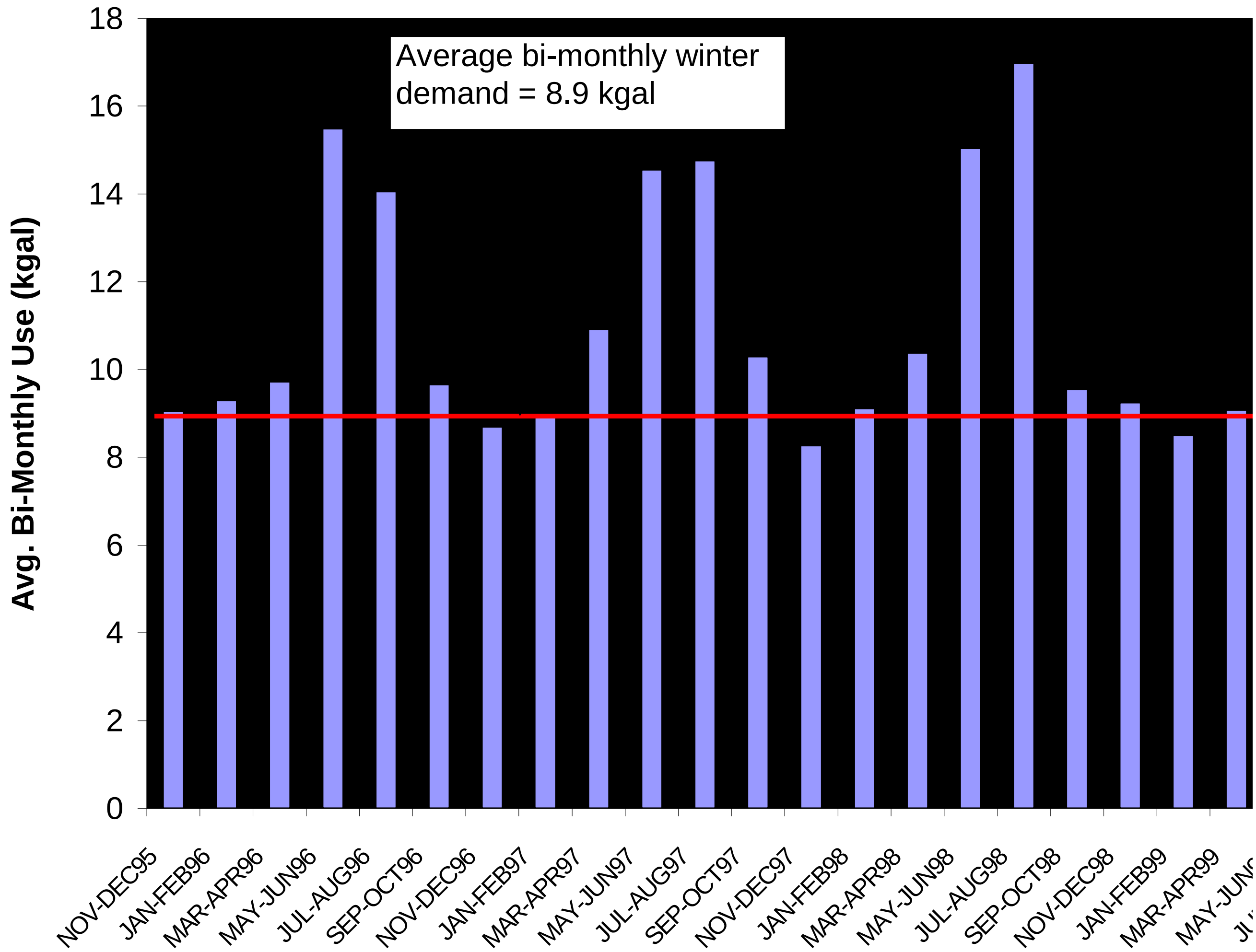


Figure 2.2 Average bi-monthly water use, Seattle retrofit group (n=35)

DEMOGRAPHIC INFORMATION

During the site audits that were performed on the retrofit study group a limited amount of household level demographic data were collected. These data help describe the households participating in the study and place them in the context of the population of single family homes in Seattle and across the United States.

Number of residents per household

The households in the retrofit study had an average of 2.51 full time residents. There were an average of 2.16 adults, 0.32 children (0-12 years old), and 0.03 teens (13-19 years old). Nearly 50 percent of the households were composed of only 2 adults as sole occupants, and 16 percent had either one or three adults. Figure 2.3 shows the frequency of different numbers of adults, teens, and children in the 37 retrofit homes. Only one household had a teenager, but nearly 22 percent of the households had one or two children. None of the study homes had more than two children. About 35 percent of the households had more than 2 adults residing full time. One house reported seven full time adult residents.

During the data logging period each household was asked to report the number of people staying at the house during each day. This was done so that more accurate measurements of per capita water use could be made. The average number of people per household during the logging period was 2.54, which is slightly higher than the 2.51 full time residents reported during audits. This suggests that there was a night or two during the logging period where there were guests in one or more of the participating houses.

Household Information

All houses in the study are owner-occupied. Study participants have lived in their current house nearly twenty years on average. The average move in date was 1981. The earliest reported move-in date was 1941 and the most recent was 1999. The houses themselves are somewhat older housing stock. The median age of the houses was 55 years old (build in 1945). The oldest house was built in 1885 and the newest house was built in 1979. Since many newer houses are already equipped with conserving fixtures, it is perhaps not surprising that the owners of older houses volunteered to participate in the study.

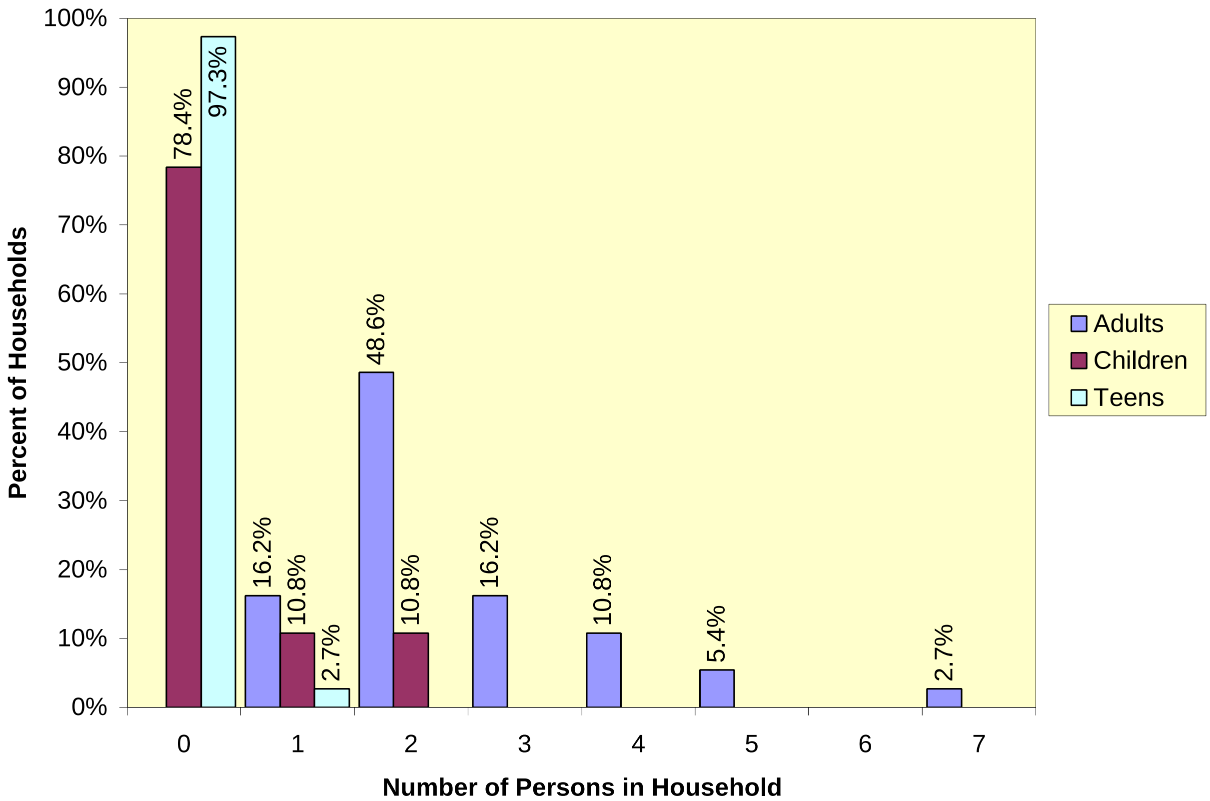


Figure 2.3 Household size distribution, (n=37)

The average floor area of the study houses was 1879 square feet (sf). The minimum size was 850 sf and the maximum was 3400 sf. The typical study house was 2 stories two stories tall, had a 1-car garage, 3 bedrooms, 1 full bath, and 1 ¾ bath. None of the houses had more than 3 bathrooms. Five of the houses (14 percent) already had at least one ULF toilet installed. Five of the houses (14 percent) had hot tubs.

Nine houses (24 percent) had automatic sprinkler systems, but only two of the households indicated that they intended to do any irrigation during the two-week logging period. Ten houses (27 percent) had home offices that were used for telecommuting and other work from home activities. Three of the households (8 percent) reported doing laundry (dry cleaning, etc.) outside the home from time to time.

Fixture Performance

As part of the audit, homeowners were asked to report on and describe problems with their existing toilets. They were also asked to rate their primary toilet and clothes washer on the same performance measures as would be applied to the ULF retrofits later.

Thirteen households (35 percent) reported experiencing a problem with their primary toilet within in the past 6 months. None of these toilets was a ULF model. Twelve households (32 percent) reported experiencing a problem with their toilet in the past 2 years. The problems reported ranged from leaking flapper valves to broken chains to clogs. Another twelve households reported never experiencing a problem with their toilet.

Thirty-eight percent of the households reported that their toilets never required plunging. Forty-six percent reported infrequent plunging ranging from every other month to every other year. Sixteen percent of the households reported that more frequent plunging was required for their toilet(s). The worst case was a homeowner who reported plunging his non-ULF toilet once per week.

Double flushing more often than once per week was reported by eleven households (30 percent). Another 10 households (27 percent) said they double flushed a few times a year. Sixteen households (43 percent) indicated that they never need to double flush their toilets.

Homeowners were asked to rate their non-ULF toilets and any ULF toilets in the following areas on a scale of 1 to 5 (1 = unsatisfied and 5 = completely satisfied): bowl cleaning, flushing performance, appearance, noise, leakage, and maintenance. The results of this rating are presented in Table 2.2. It can be seen from this analysis that the small number of existing ULF toilets scored higher in every category except bowl cleaning. The overall score for the ULF toilets was higher than for the non-conserving toilet.

Using the same rating system (1 = unsatisfied and 5 = completely satisfied), homeowners were asked to rate their current non-conserving clothes washer in the following areas: cleaning of clothes, maintenance/reliability, noise, moisture content of clothes, cycle selection, and capacity. The results of this rating are presented in Table 2.3. Homeowners appear to be satisfied for the most part with their existing clothes washers. Respondents were particularly pleased with the reliability of the machines, the capacity and the selection of wash cycles available. They were less satisfied with the noise the machines make and the moisture content of the clothes after washing.

Table 2.2 Pre-retrofit toilet rating, ULF and Non-ULF toilets

Rating Category	**Non-ULF Toilets** (n=37)	**ULF Toilets** (n=8)
Bowl Cleaning	3.76	3.38
Flushing performance	3.54	3.63
Appearance	3.70	3.75
Noise	3.32	3.63
Leakage	3.70	4.25
Maintenance	3.89	4.25
Overall Average	3.65	3.81

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

The participants in this study had the following selection of clothes washer brands: 15 Kenmore (41 percent), 7 Maytag (19 percent), 5 Whirlpool (14 percent), 4 General Electric (11 percent), 3 Hot Point (8 percent), 1 Frigidaire (3 percent), 1 Kitchen Aid (3 percent), and 1 Montgomery Wards (3 percent). The average age of the machines was 13 years old (purchased in 1987). The oldest machine was purchased in 1965 and the newest in 1998.

Table 2.3 Pre-retrofit rating of non-conserving clothes washers

Rating Category	**Non-Conserving Clothes Washer** (n=37)
Cleaning of clothes	3.86
Reliability	4.44
Noise	3.32
Moisture content of clothes	3.50
Cycle selection	4.06
Capacity	4.30
Overall Average	3.91

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

END USE DATA

The water use data collected and analyzed using the flow recorders and Trace Wizard software contains specific information on the use of water in each study home over the two week data collection period. These data were analyzed in a variety of ways so that the impacts of the retrofit can be measured by comparing water use after the retrofit with the baseline demand patterns. The baseline water use analyses included daily use, daily per capita use, per capita use for different fixtures, the frequency and intensity of use of various fixtures, and the variability of water use. Where useful, these baseline results are compared to the findings from the AWWARF Residential End Uses of Water study for Seattle and the national sample.

Daily Household Use

A total of 531 complete days of end use data were recorded from the 37 study homes in Seattle for an average of 14.4 days of data per household. A minimum of 14 days of data were collected from each house, and more than 14 days of data were obtained from a few houses. Baseline end use data were recorded from October 26th through December 4th, 1999, and the majority was obtained between November 3rd and 17th, 1999.

The total daily use (including indoor and outdoor uses) from each logged day is plotted as a scatter diagram in Figure 2.4. The average daily use for all houses was 151.9 gallons per day (gpd) and the standard deviation was 98.9 gpd. The median daily use was 131.2 gpd. The maximum observed daily use during the logging period was 777.4 gpd, which is actually fairly low when considering that the maximum *average* daily use from the REUWS was more than 9000 gpd. These results suggest that there was very little outdoor use during the logging period.

These same daily use data were used to develop a frequency distribution (histogram), Figure 2.5. Figure 2.5 shows that nearly 50 percent of daily water use was less than 125 gallons per day and 90 percent of daily use was less than 275 gallons per household per day.

INDOOR PER CAPITA USE

Per capita water use was calculated daily for each individual study home using the daily water use obtained from the flow trace analysis data and the day by day reported number of residents in each house. Averages of per capita use were made from the individual daily per capita use values calculated for each identified end use.

Toilet flushing was the largest component of baseline indoor per capita water use among the 37 study homes, accounting for 29.5 percent of indoor demand. Clothes washers were the second largest component of indoor use at 23.3 percent followed by faucets at 14.4 percent, showers at 14.2 percent, leaks at 10.3 percent, baths at 5.8 percent, dishwashers at 2.2 percent, and other/misc. use at 0.3 percent. Figure 2.6 shows the percentage breakdown of all indoor water uses collected form the 37 study homes.

For comparison, the REUWS results from the sample of 100 homes in the Seattle area found similar mean per capita per day consumption. In the Seattle REUWS homes, toilets accounted of 29.9 percent of indoor per capita use, clothes washers 21.0 percent, showers 19.9 percent, faucets 15.2 percent, leaks 10.3 percent, baths 1.9 percent, and dishwashers 1.7 percent.

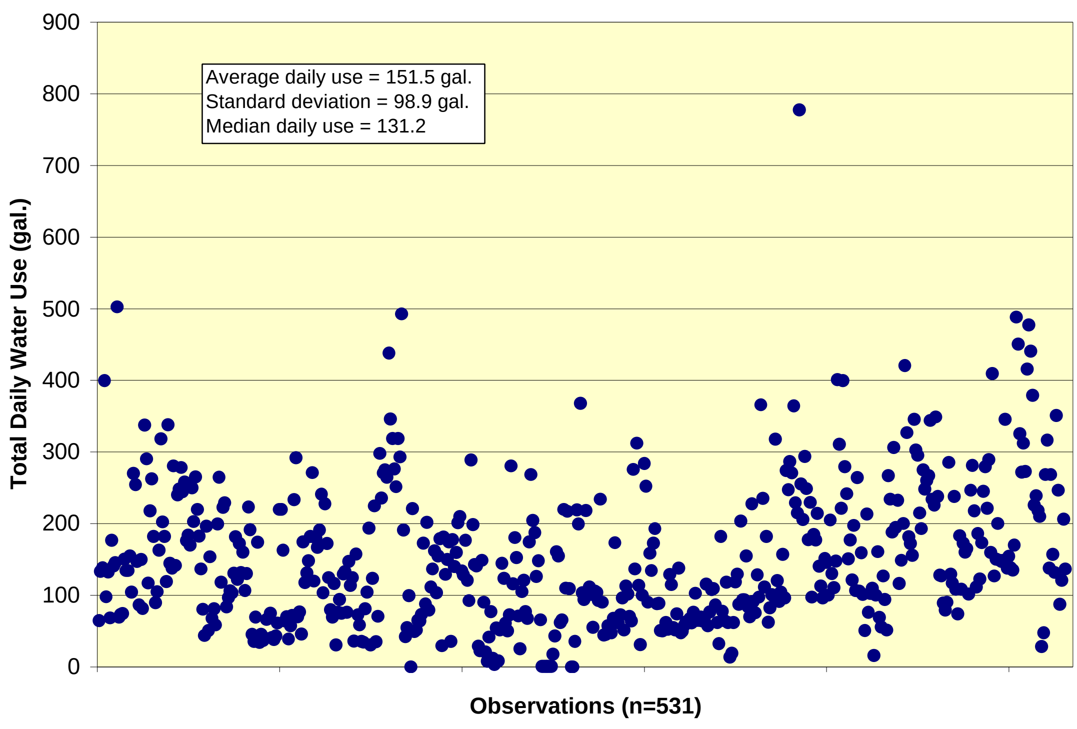


Figure 2.4 Scatter diagram of daily household water use, Seattle retrofit group

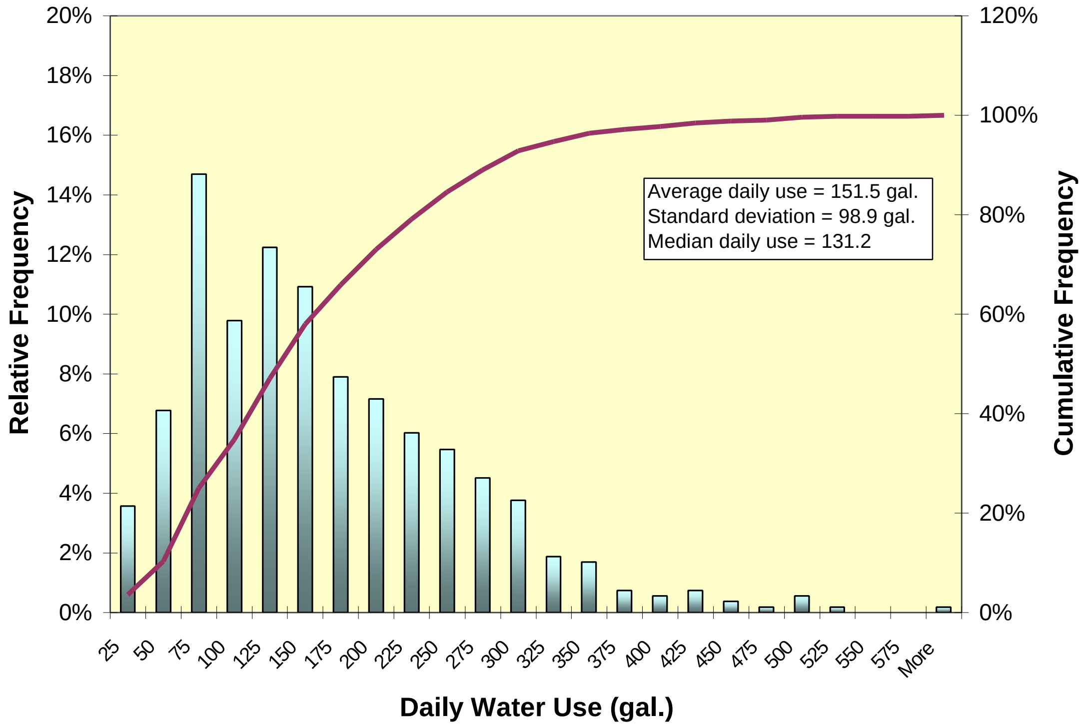


Figure 2.5 Frequency distribution of total daily household water use, Seattle retrofit group

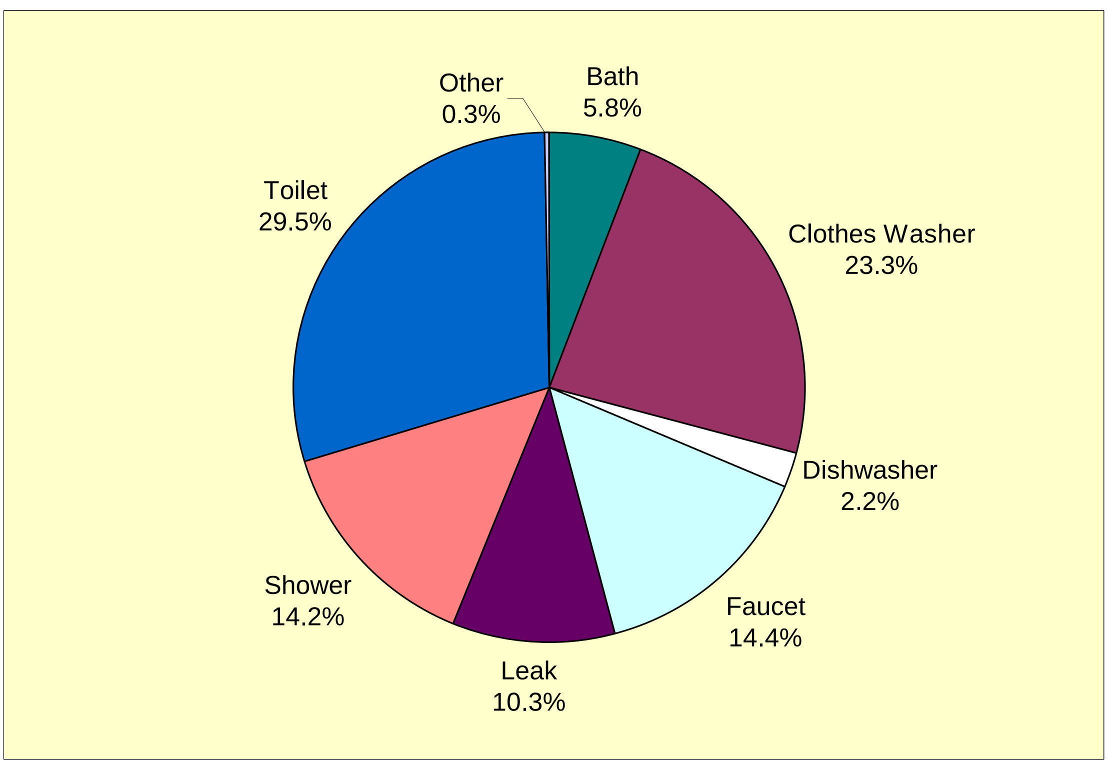


Figure 2.6 Baseline indoor per capita water use percentage including leakage

Mean Per Capita Indoor Use

The baseline average per capita indoor water use in the Seattle study homes was 63.6 gallons per capita per day (gpcd) and the median was 59.1 gpcd. The average for the retrofit group was about six gallons more than was found in the REUWS where the mean per capita water use in Seattle was found to be 57.2 gpcd.[6] Table 2.4 presents the average per capita water use values from the Seattle retrofit study, the Seattle homes in the REUWS, and the REUWS national sample.

The indoor water use in the group of 37 homes in the retrofit study falls squarely in-between indoor use in the Seattle REUWS sample and the REUWS national sample.

Table 2.4 Indoor Per Capita Water Use Comparison

	Seattle Retrofit Baseline		**Seattle REUWS**		**All REUWS**	
	Average gpcd	**Percent**	**Average gpcd**	**Percent**	**Average gpcd**	**Percent**
Bath	3.7	5.8%	1.1	1.9%	1.2	1.7%
Clothes Washer	14.8	23.3%	12.0	21.0%	15.0	21.6%
Dishwasher	1.4	2.2%	1.0	1.7%	1.0	1.4%
Faucet	9.2	14.4%	8.7	15.2%	10.9	15.7%
Leak	6.5	10.3%	5.9	10.3%	9.5	13.7%
Shower	9.0	14.2%	11.4	19.9%	11.6	16.7%
Toilet	18.8	29.5%	17.1	29.9%	18.5	26.7%
Other	0.2	0.3%	0.0	0.0%	1.6	2.3%
Indoor Total	63.6	100.0%	57.2	100.0%	69.3	100.0%
Sample size	*37*		*99*		*1188*	
Avg. # of residents	*2.54**		*2.8*		*2.8*	

*Number of residents during logging period

Combined shower and bath usage was quite similar between the retrofit study group (12.7 gpcd), the Seattle REUWS group (12.5 gpcd), and the entire REUWS study group (12.8 gpcd). Toilet and faucet usages were also quite similar between the groups. Differences were more apparent when comparing clothes washer usage and leakage. Dishwasher usage was higher in the retrofit study group than in both the Seattle REUWS group and entire REUWS study group (1.4 vs.1.0 gpcd). The average number of residents per household in the retrofit group was

[6] It should be noted that the number of people per household information from the REUWS is much less reliable than the data collected for the Seattle retrofit study.

smaller (2.4 vs. 2.8). Overall, the per capita usage in the retrofit group appears quite typical of the demand patterns observed in the earlier REUWS research, suggesting the group is fairly typical of single family homes in Seattle and in other cities across the country.

Baseline Hot Water Usage

An innovative aspect of this study was the logging of both hot and cold water on a portion of the study group. Water meters were installed on the hot water heaters of 10 of the 37 study homes and flow recorders were attached to these meters so that hot water usage could be monitored alongside overall household usage. The hot water flow traces were disaggregated into end uses using Trace Wizard and the data were stored in the Seattle database.

There was an average of 2.6 residents in the 10 so-called "hot water" homes during the baseline data collection period, and the average daily per capita use in them was 62.2 gpcd compared with 63.6 for the larger 37 home retrofit group. Surprisingly, over 25 gpcd or 40 percent of the total indoor use was made up of hot water in these homes. This strengthens the linkage between water and energy conservation.

Overall per capita indoor use in the 10 hot water homes was very similar to the study group as a whole differing by only 1.4 gpcd. A *t-test* test performed on the two data sets found no statistical difference at the 95 percent confidence level.

Toilet flushing was the only indoor use that had no hot water component. Over one quarter of the total leaks were composed of hot water. These results and a comparison with the average gpcd found in the entire 37 home study group are presented in Table 2.5.

Not surprisingly, 100 percent of dishwasher use is made up of hot water – this is the only indoor use that is entire made up of hot water. Only 27.8 percent of clothes washer usage was hot water while 78.2 percent of baths and 73.1 percent of showers were hot water.

These results suggest that on an annual basis each person in the hot water homes is using approximately 9,160 gallons of hot water. It is calculated that the annual cost in gas and electricity charges of heating 9,160 gallons of water is approximately $34.[7] The calculated cost

[7] Assumptions: 80 percent of the homes heat water with gas and 20 percent heat with electricity; the water starts out at a temperature of 55 °F and is heated to 105 °F; gas costs $0.44 per Them and electricity costs $0.06 per kWh.

of heating 1000 gallons of water with gas is $2.82 and the cost of heating 1000 gallons of water with electricity is $7.32.

Table 2.5 Baseline per capita hot water use

	Baseline Hot Water Use		Total Use in Hot Water Homes	Seattle Retrofit Group
	Average gpcd	Percent of Indoor Use that is Hot Water	Average gpcd	Average gpcd
Bath	4.2	78.2%	5.3	3.7
Clothes Washer	3.9	27.8%	14.1	14.8
Dishwasher	0.9	100.0%	0.9	1.4
Faucet	8.6	72.7%	11.9	9.2
Leak	1.2	26.8%	4.4	6.5
Shower	6.3	73.1%	8.7	9.0
Toilet	0.0	0.0%	16.9	18.8
Other	0.01	35.1%	0.02	0.2
Indoor Total	25.1	39.6%	62.2	63.6
Sample size	*10*	*10*	*10*	*37*
Avg. # of residents	*2.6**	*2.6*	*2.6*	*2.4*

*Residents in homes with hot water monitoring during logging period

Leaks

The leakage rate in the Seattle retrofit group was below the average found in the REUWS, but leaks still constituted over 10 percent of indoor water use. The leakage data showed a strong positive skew. That is, the mean value is greater than the median, and consequently, there are more values less than the mean than greater. In this case, the mean per capita leakage rate was 6.5 gpcd and the median leakage rate was only 2.9 gpcd. It was found that 8 houses (22 percent) in the study were responsible for more than 70 percent of the total per capita leakage during the baseline period. The top two leaking homes by themselves were responsible for nearly 20 percent of the total leakage. These homes each leaked approximately 45 gpcd. While leakage is clearly a problem in this group of homes as a whole, it is really only significant problem in a small number of homes. This result is quite similar to the findings from all other study sites in the REUWS – a small number of houses are responsible for most of the leakage.

The first high leakage homes had a persistent, but not completely continuous, low flow leak (less than one gpm) probably caused by a faucet that could not be shut off. The second home had a less continuous leak that typically ran around 0.3 gpm. This is also consistent with a faucet or showerhead that cannot be effectively closed, but could also be caused by a toilet, an outdoor leak, or a leak in the water system. A distribution of daily per household leakage is shown in Figure 2.7.

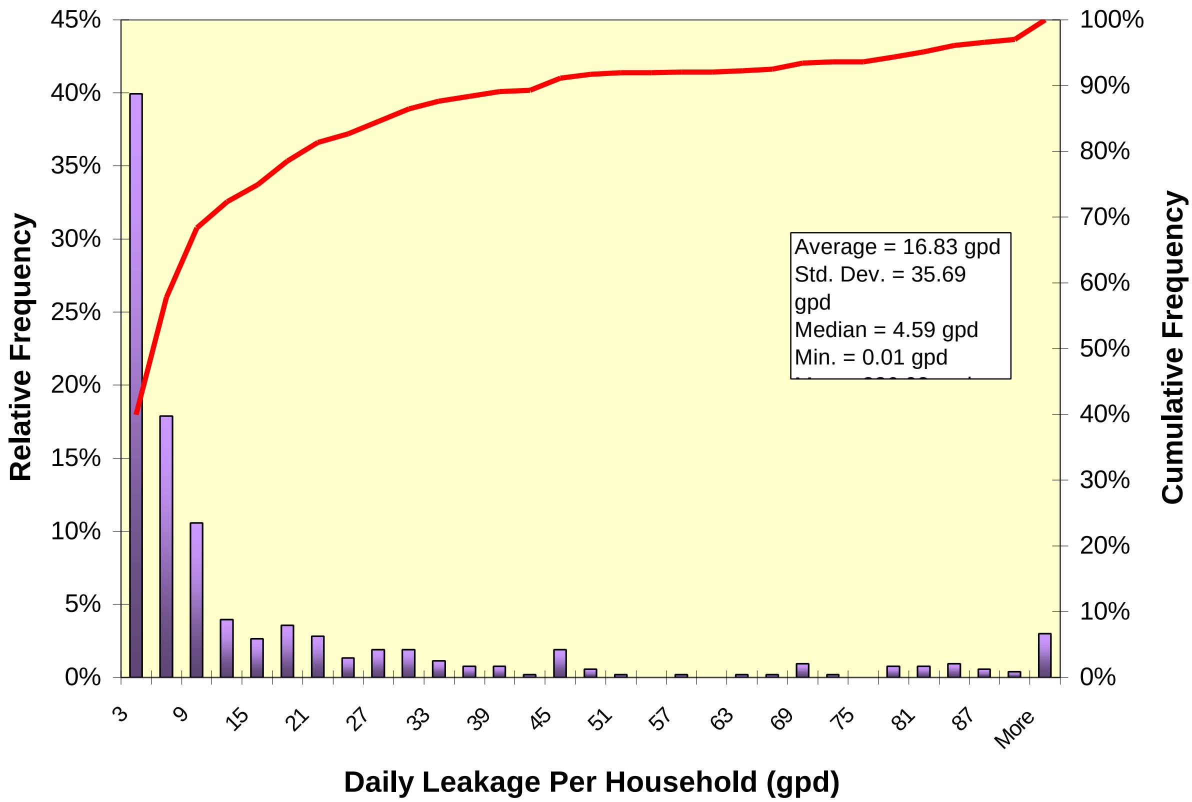


Figure 2.7 Daily per household leakage distribution.

FIXTURE USAGE

Toilets

The data set developed for this study made it possible to calculate the number of times per day each fixture was used and the volume of use per fixture. It is important to compare these results against the fixture utilization measured after the retrofit to ensure that increased utilization is not diminishing efficiency savings.

During the baseline data collection period a total of 5,846 individual toilet flushes were recorded from the 37 study homes on 519 days for an average of 11.0 flushes per household per day and 5.17 flushes per capita per day.[8] The average flush volume across the 37 study sites was 3.61 gallons per flush (gpf) with a standard deviation of 1.27 gpf. The distribution of toilet flushing volume of all recorded flushes is shown in Figure 2.8. This distribution shows the range of flushing volumes found during the baseline data collection period. Only 10 percent of the baseline recorded flush volumes were in the low flow range (below 2 gpf). About 50 percent of the flush volumes were above 3.5 gpf and 12 percent were above 5 gpf.

Residents in the Seattle retrofit study group flushed the toilet an average of 5.17 times per person day during the baseline data collection period. The median value of flushes per capita per day (fpcd) was 4.50. A daily per capita flushing distribution for all 519 days on which toilet flushes occurred is presented in Figure 2.9. This distribution shows that 80 percent of the study homes flushed an average of seven times per person per day or less.

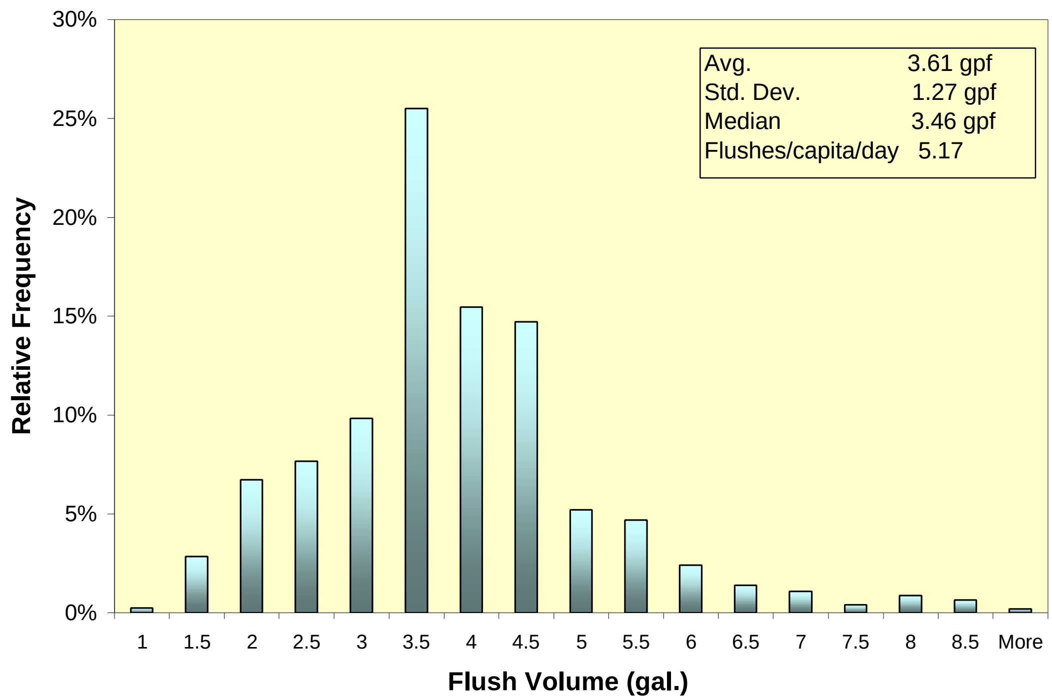


Figure 2.8 Baseline toilet flush volume distribution

[8] The value of 5.17 flushes per capita per day was derived by averaging the flushes per person per day determined for each home on each day of the study. This is not the same as dividing the 5846 total flushes by the 531 days of observation and 2.4 persons per home (which gives 4.59 flushes per person per day).

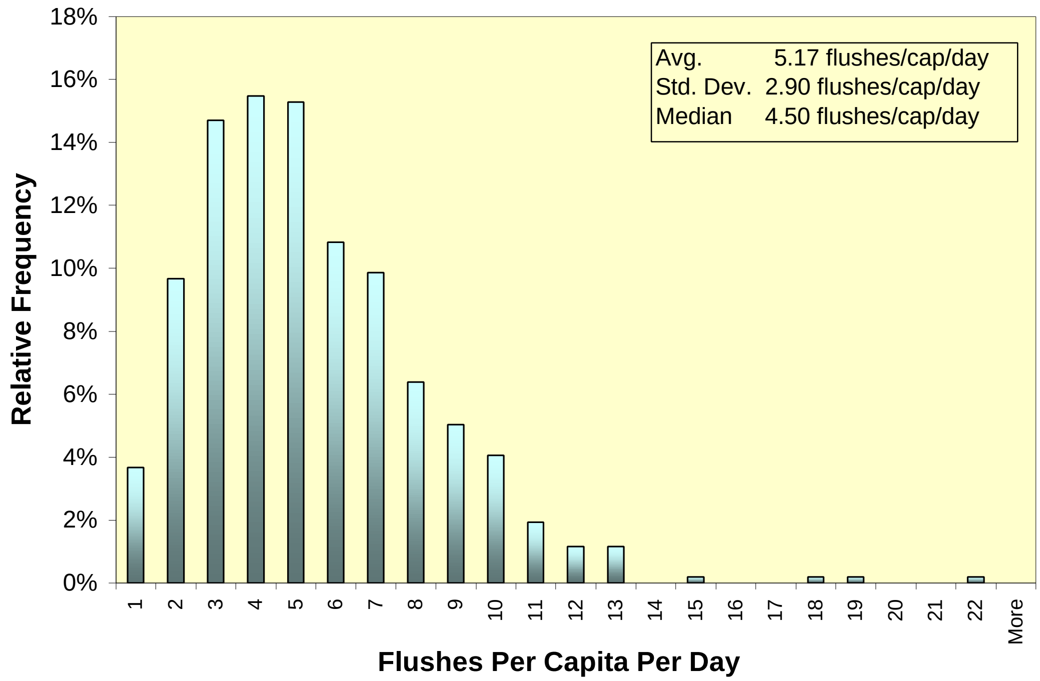


Figure 2.9 Baseline toilet flush frequency distribution

Showers

Showering accounted for 14.2 percent of the average per capita indoor water use during the baseline period. A total of 648 individual shower events were recorded during the baseline period for an average of 0.51 showers per person per day. The average shower used 18.1 gallons, lasted for 7.9 minutes, and was taken at an average flow rate of 2.24 gallons per minute (gpm). This indicates that on average, the people in the study group already shower at a flow rate below the national plumbing code standard of 2.5 gpm. A similar result was found in the REUWS. This suggests that the actual water savings achievable through a showerhead retrofit may be less than has been traditionally estimated using standard engineering techniques.

The distribution of showering volumes is shown in Figure 2.10. This distribution shows that most showers (83 percent) used between 7.5 and 27.5 gallons. These results are quite similar to the showering volume calculated in the REUWS. In that study the average shower volume was 17.2 gallons and the average duration was 8.2 minutes.

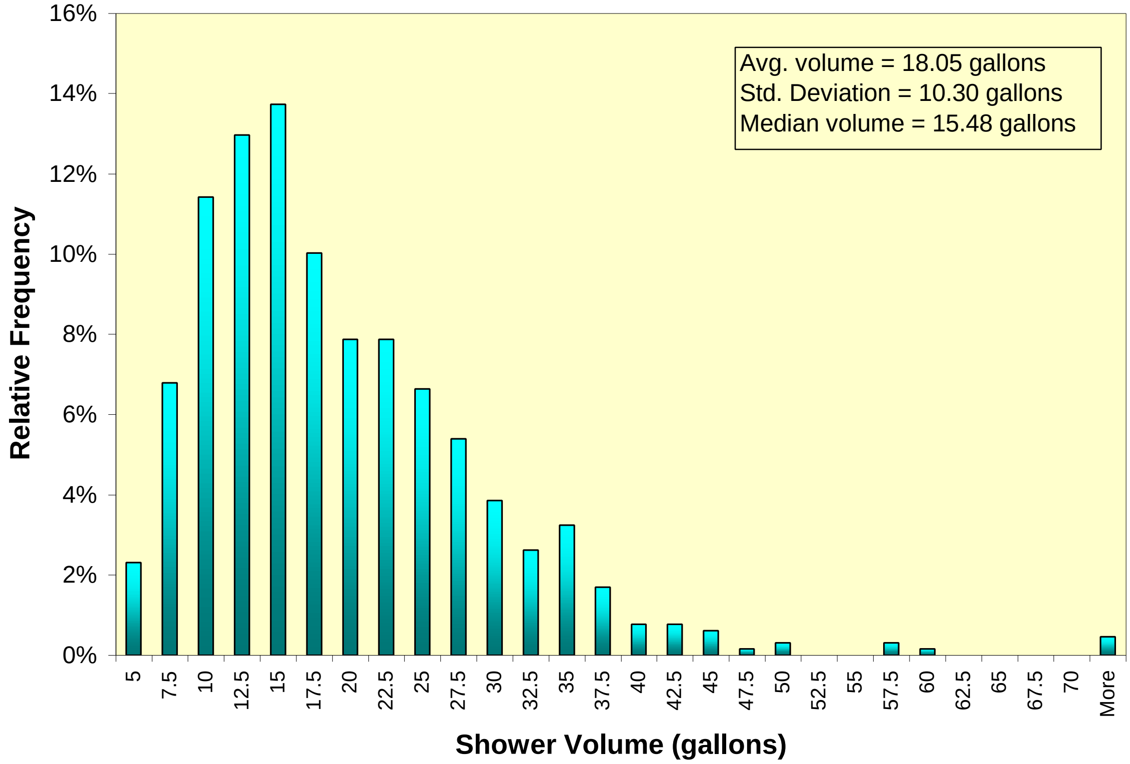


Figure 2.10 Baseline shower volume distribution

The distribution of shower durations for al recorded shower events during the baseline period is shown in Figure 2.11. In this figure, 77.5 percent of all showers were between 4 and 11 minutes in length with a mean of 7.9 minutes and a standard deviation of 4.0 minutes. Less than 5 percent of all showers were longer than 15 minutes in duration.

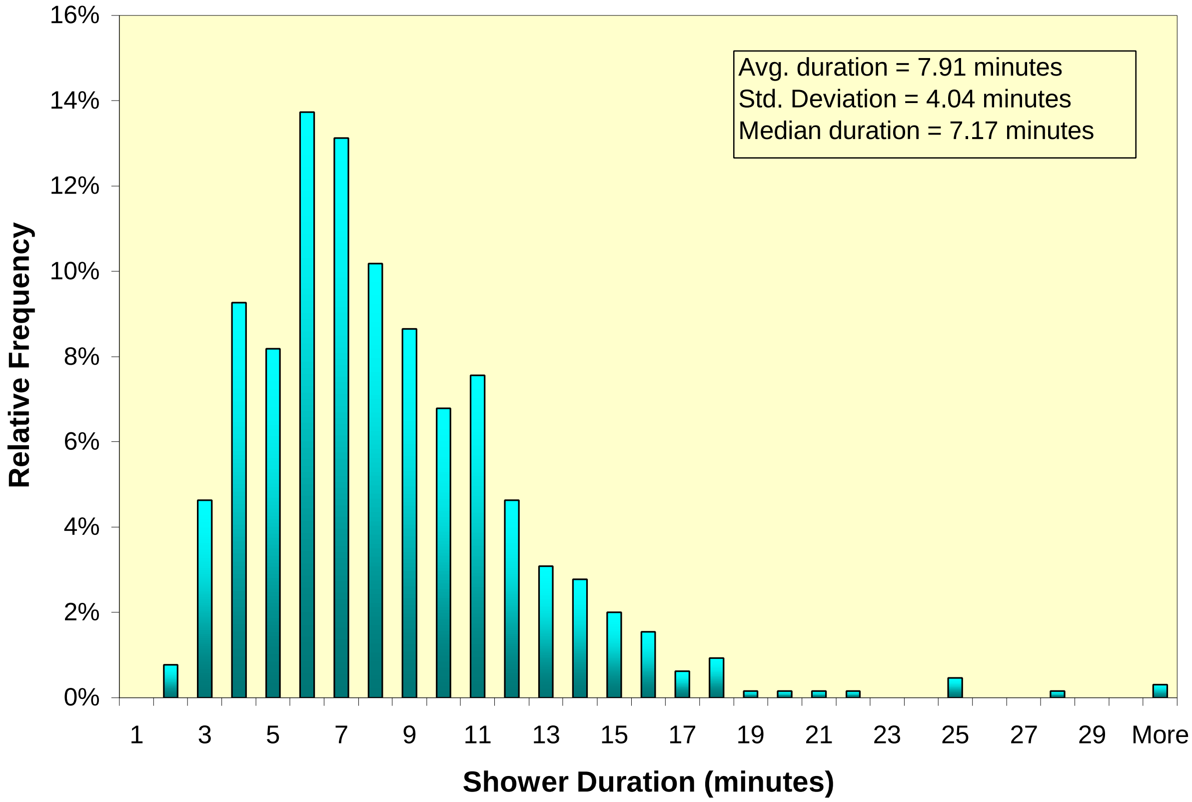


Figure 2.11 Baseline shower duration distribution

The distribution of shower flow rates for all recorded showers during the baseline period is shown in Figure 2.12. For this chart the mode flow rate statistic generated by Trace Wizard during flow trace analysis was taken as the actual shower flow rate because it best represents the flow during the shower itself. An average flow rate might over estimate shower flows because many showers start at a high flow rate is water is run through the bathtub spigot and the temperature adjusted then the flow is restricted when the shower diverter valve is used and flow is constricted through the shower head.

The mean shower flow rate during the baseline period was 2.24 gpm with a median of 2.19 gpm and a standard deviation of 0.74 gpm. The distribution of shower flow rates appears less regular than either the distribution of shower volumes or the distribution of shower durations. More than 60 percent of the showers recorded during the baseline period were taken at a flow rate blow 2.5 gpm, which suggests that flow rate reductions may only be accomplished on roughly 40 percent of the showers as a result of the showerhead retrofit. All of the shower distributions shown in this section are compared against post retrofit distributions later in this report.

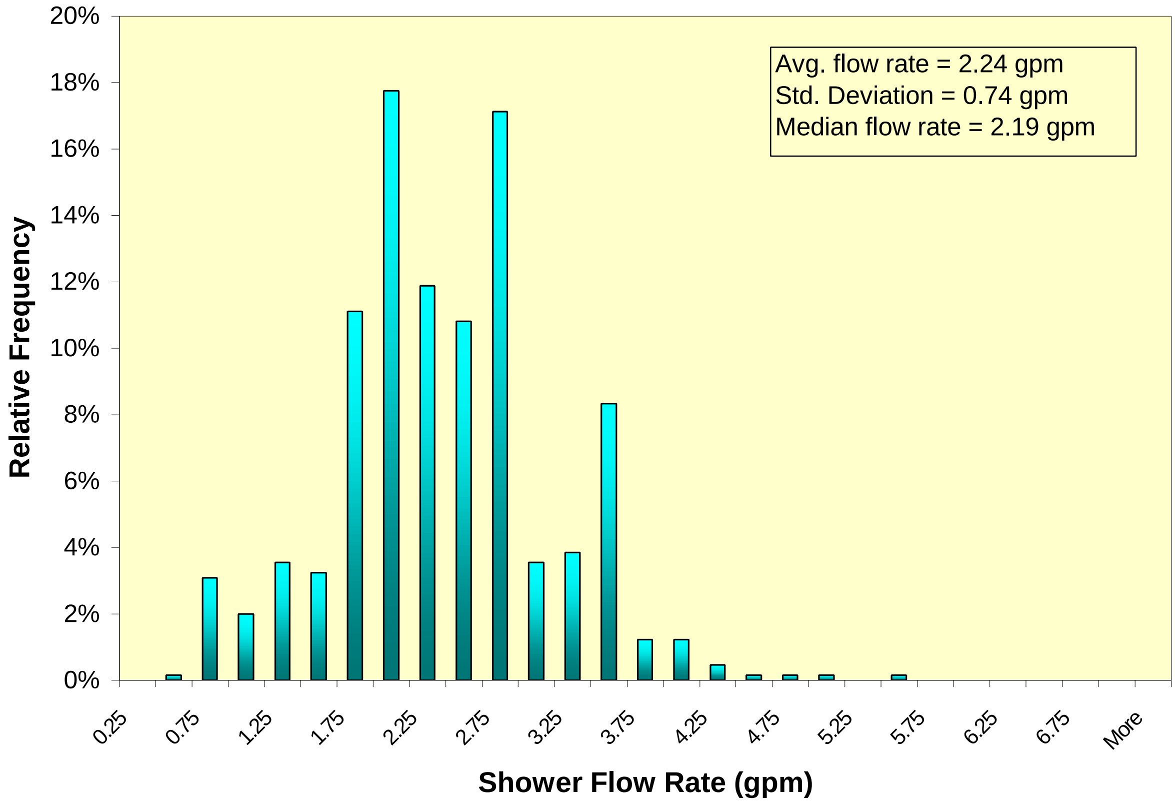


Figure 2.12 Baseline shower flow rate distribution

Clothes Washers

All of the homes in this study had to have a washing machine as a requirement of participation. A total of 454 loads of laundry were washed in the 37 study homes during the baseline period for an average of 0.36 loads of laundry per person per day.

The average volume used to wash a load of clothes was 40.9 gallons with a standard deviation of 11.9 gallons. Nearly 88 percent of the washer loads used 50 gallons of water or less and 97 percent of the washer loads used less than 70 gallons of water. In the few loads that used more than 70 gallons it appeared that one or more extra rinse cycles were used. The largest individual cycle (wash or rinse) observed was approximately 38 gallons.

A few sample clothes washer flow traces from Trace Wizard are presented below. Figure 2.13 shows a 1989 Kenmore HD 80 washer. The total volume for this load of clothes was 36.2 gallons. The five cycles shown include the wash cycle, two rise cycles, and two spin cycles.

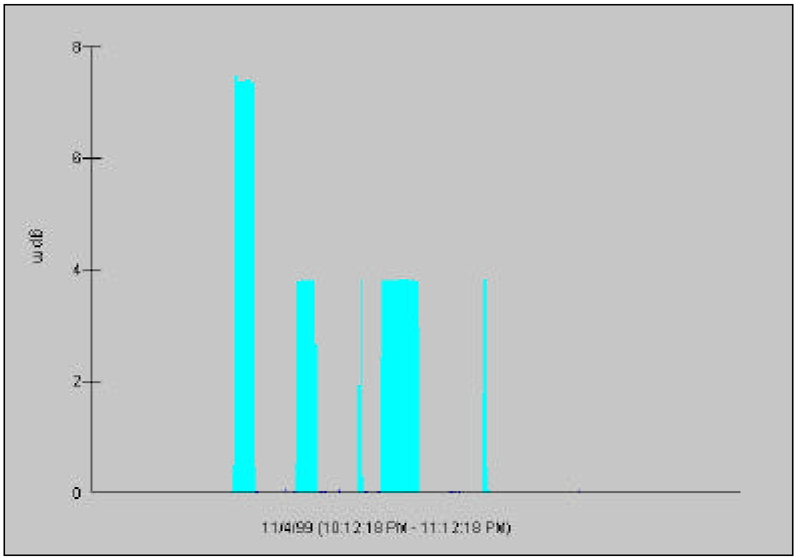


Figure 2.13 Sample clothes washer flow trace, 1989 Kenmore HD 80

Figure 2.14 shows a 1998 Maytag Performa model clothes washer. The total volume for washing this load of clothes was 40.7 gallons. The large wash and rinse cycles were each almost exactly 20 gallons.

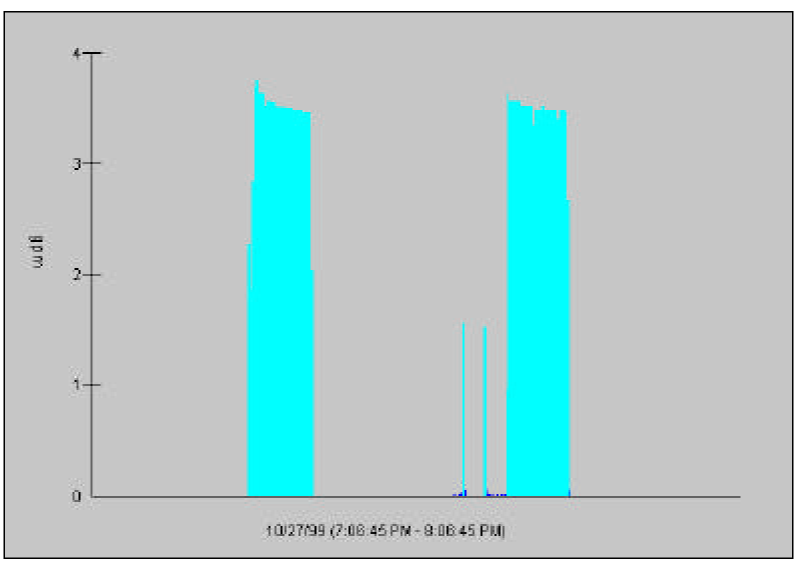


Figure 2.14 Sample clothes washer flow trace, 1998 Maytag Performa

Results from the hot water homes show that 27.8 percent of the water used for clothes washing is hot water. From the 10 hot water flow traces, it appears that the first cycle (the wash cycle) is typically the only cycle to contain any hot water. Subsequent cycles (rinse and spin cycles) are almost exclusively cold water with a few exceptions.

Given the average volume per load of clothes found during the baseline period there appears to be considerable opportunity for conservation savings with the new conserving machines if they actually meet their advertised usage of no more than 30 gallons per load.

Dishwashers

A total of 187 loads of dishes were washed during the baseline study period. On average, dishwashers were used 0.15 times per person per day – almost exactly once per week per person. The average load of dishes used 9.3 gallons of water. The maximum amount of water used by any dishwasher was 19.4 gallons. More than 77 percent of the dishwashers in the study homes used between 6 and 12 gallons per load.

All of the water used in the dishwashers was hot water. So, while the volume of their use is relatively small they are significant energy users.

Faucets

Faucet use accounted for 14.4 percent of the total indoor water use during the baseline study period and 72.7 percent of faucet use was made up of hot water. A useful means of evaluating faucet utilization is to calculate the duration faucets are utilized per capita per day. During the baseline period it was found that faucets were used an average of 8.4 minutes per person per day. In the REUWS, faucet use averaged 8.1 minutes per person per day.

The typical baseline faucet flow rate was 1.2 gpm, based on an analysis of the mode faucet flow rates calculated using Trace Wizard. Typical peak baseline faucet flow rate was 2.9 gpm. Similar to the situation with showers, it appears that many of the homes in this study either already have faucet flow restrictors or simply throttle their faucets below the 2.2 gpm federally establish low flow rate.

Baths

Because baths require a fixed amount of water, this conservation retrofit program is not expected to reduce bath water usage. With the increasing popularity of larger Jacuzzi tubs in the past decade, it seems likely that there could be an increase in per capita bath water usage.

During the baseline period, the average bath used 24.0 gallons of water. The maximum bath usage was 55.7 gallons. Baths in the hot water homes were 78.2 percent hot water and 17.8 percent cold water. Study residents took an average of 0.14 baths per person per day or 0.98 baths per person per week. There did not appear to be a distinctively higher number of baths in the eight households with children. Average per capita bath usage in households without any children under the age of 13 was 3.7 gpcd; in households with one child the bath average was 3.0 gpcd; and in households with two children the bath average was 3.92 gpcd.

Twenty-three of the 37 study homes (62 percent) took at least one bath during the baseline data collection period. Information on bathing habits (time and frequency) was collected during the audit portion of the study and this information proved useful during the flow trace analysis process enabling baths to be identified with greater confidence. The hot water traces were also helpful in accurately identifying baths.

MAXIMUM DAY DEMANDS

Maximum demands are often the driving factor for facility expansions and facility design. While interior retrofits are not designed with the intention of reducing peak instantaneous and peak day demand they may achieve this goal anyway.

The maximum day water use for each household in the study was calculated and plotted from the highest to lowest in Figure 2.15. The average maximum day during the baseline data collection period was only 297 gallons. The largest maximum day household was 777 gallons. Because the baseline data collection period was during the winter, there was little outdoor water use. Typically it is outdoor demand that drives peak day usage in the single-family sector.

The peak instantaneous demand distribution of all 531 baseline logged days is shown in Figure 2.16. The average peak instantaneous demand was only 5.4 gpm and the maximum peak demand was 13.5 gpm. In the REUWS, the average peak instantaneous demand was 8.2 gpm and the maximum peak was 64.6 gpm. The flows in the Seattle retrofit study group were considerably smaller primarily because demand during the baseline period was almost exclusively indoors. High peak flows are typically observed during automatic irrigation.

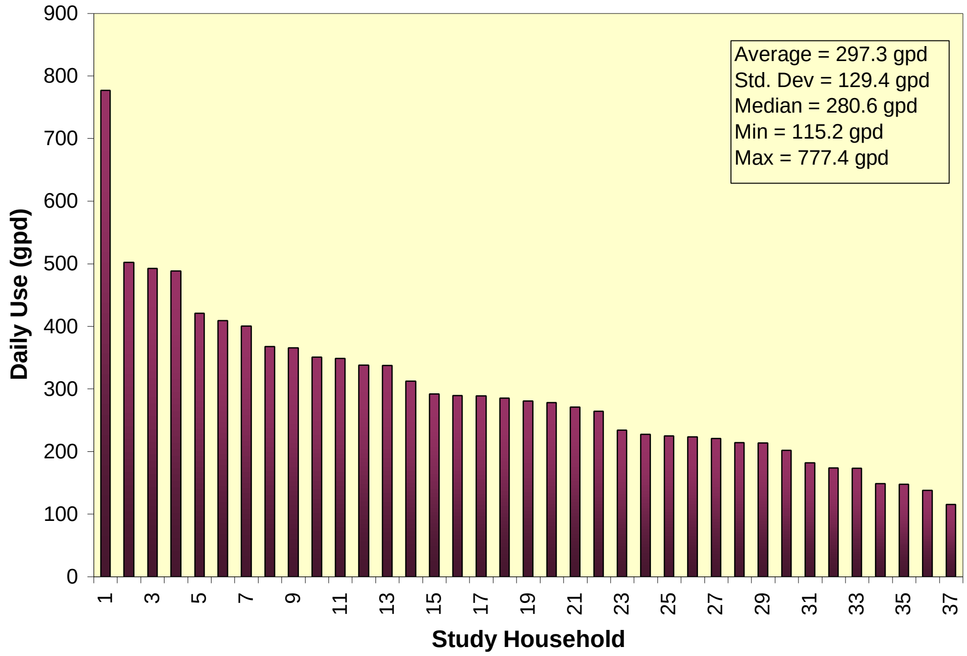


Figure 2.15 Baseline peak day demand for each study house

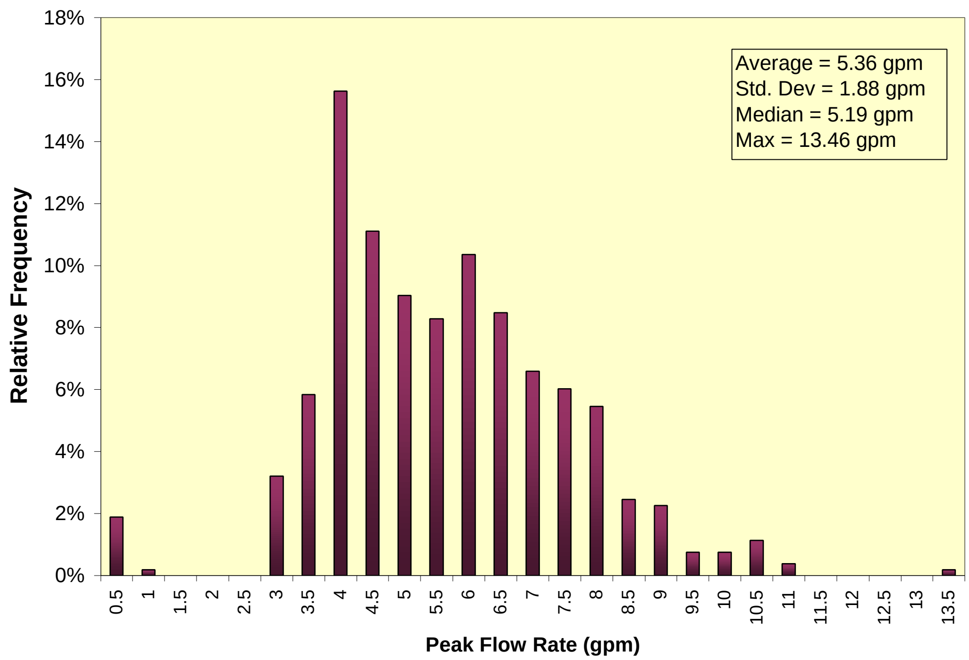


Figure 2.16 Baseline peak daily instantaneous demand distribution

CHAPTER 3 POST-RETROFIT WATER USE

The installation of conserving fixtures in all 37 participating study homes was begun in December, 1999 and completed by the end of January, 2000 and the first set of post-retrofit end use data was collected during the period from March 23 to May 4, 2000. In July the participants completed a detailed opinion survey about their experience with the conserving fixtures and the second and final set of post-retrofit data was collected from July 22 to September 1, 2000. Additionally, billing data from the entire sample of 248 homes were obtained through the September,2000 billing period. Aquacraft analyzed all of these data and the results are presented below.

COMPARISON OF WATER USE DURING LOGGING PERIODS

It was clear that the data analysis would be greatly simplified if the data from the two post-retrofit logging periods could be combined into a single group. Consequently, one for the key analyses involved a comparison of the two post-retrofit logging sessions against each other. If the results of this showed that the two were similar statistically, then it would possible to combine them for the comparison against the baseline use upon which the assessment of the retrofits would then be performed.

Table 3.1 shows a comparison of the mean daily indoor per capita water use during the three logging periods. After the installation of the conserving fixtures, the mean daily indoor per capita water use dropped from 63.6 gcd to approximately 40 gcd, which represents a 37 percent reduction. This is based on one baseline and two post-retrofit logging periods in which end use data were obtained from all 37 participating households for a total of 1459 days. It should be noted that the per capita water use was determined for each home based on the number of people in the home each day of the study. Days in which no one was home, i.e. days with 0 occupants, had to be excluded from the data set to avoid the mathematical impossibility of dividing by zero. This explains why the second post-retrofit logging period contains fewer days.

In order to test whether the observed variation in means is significant, the per capita daily use from the three data collection periods were compared through a series of paired *t-tests* at a 99 percent confidence level. The null hypothesis in each test was that the mean daily per capita indoor use in the compared logging periods were equal; the alternate hypothesis was that they were not equal. The t-test results are shown in Table 3.2.

The difference between the baseline and post-retrofit water use was found to be significant at the 99 percent confidence level. This result indicates the observed reductions in per capita demand were not due simply to random chance. On the other hand, the difference between the two post-retrofit logging periods was found to be *not significant* at this confidence level. This result indicates that there was no statistical difference between the water use during the two post-retrofit logging periods, and allowed the data sets to be combined into a single data set, which was used to compare pre and post-retrofit water use.

Table 3.1 Mean daily indoor per capita use comparison – 3 logging periods

	n (logged days)	Mean daily indoor per capita use (gcd)	Variance	Standard Deviation	Standard Error
Baseline	520	63.6	1465.7	38.3	1.7
Post-Retrofit 1	501	40.4	580.9	24.1	1.1
Post-Retrofit 2	438	39.4	809.8	28.6	1.4

Table 3.2 Comparison tests of baseline and post-retrofit indoor per capita water use

	Mean difference in indoor daily per capita use (gcd)	Degrees of Freedom	t-Value	P-Value	99% Lower Limit	99% Higher Limit	Statistically significant difference?
Baseline vs. Post-Ret. 1	23.2	1019	11.525	<.0001	17.99	28.36	Yes
Baseline vs. Post-Ret. 2	24.2	956	10.919	<.0001	18.47	28.90	Yes
Post-Ret. 1 vs. Post-Ret. 2	1.0	937	0.587	0.5573	-3.421	5.44	No

Demographic Information

In order to improve the accuracy of the per capita measurements each household was asked to report the number of people in residence during each logging day. The average number of people per household during the baseline logging period was 2.54, which is slightly higher than the 2.51 full time residents reported during audits. During the post-retrofit logging periods the average number of people per household was 2.51 – exactly the number reported during the audit.

DAILY HOUSEHOLD USE

When the post-retrofit data were used to compare water use before and after the retrofits a clear pattern of reduction was noted. Figure 3.1 shows a scatter diagram of total indoor water use before and after the retrofit for each logging day. The figure shows that there were many more high demand days during the baseline period despite the fact that the baseline data were collected during November and the post-retrofit data were collected during April and August. The mean daily indoor demand, which was 150.7 gpd per household during the baseline period, dropped 39% to 92.1 gpd after the installation of the new devices. On an annual basis this equates to an indoor use of 55.0 kgal for baseline conditions and 33.6 kgal with the retrofit.

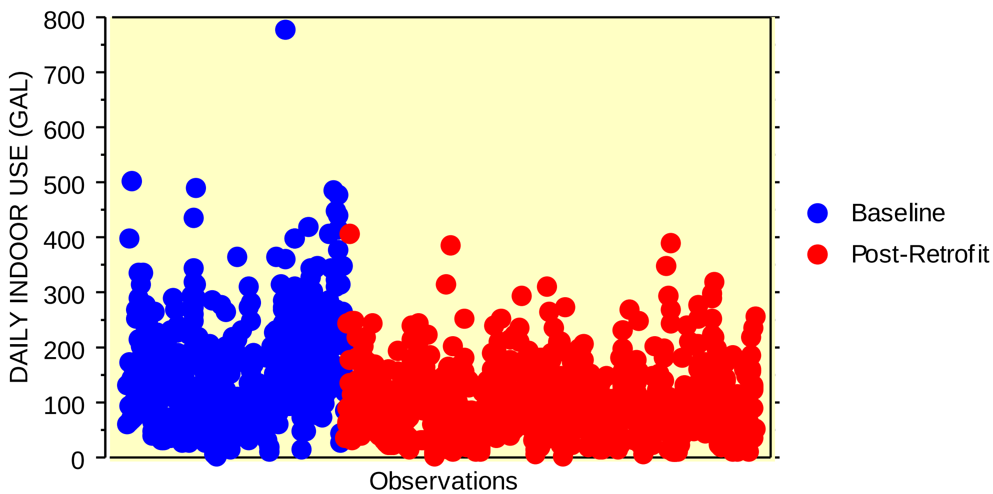


Figure 3.1 Scatter diagram of daily indoor per household use, pre and post-retrofit

These data are plotted as a histogram (frequency diagram) in Figure 3.2. Here the change in demand brought about by the retrofit can be seen in the shift of the demand distribution to the left. The effectiveness of the retrofits in reducing daily demand can be seen from the fact that while during the baseline period indoor use fell below 175 gallons 66 percent of the time, in the post-retrofit period it fell below this level 90 percent of the time.

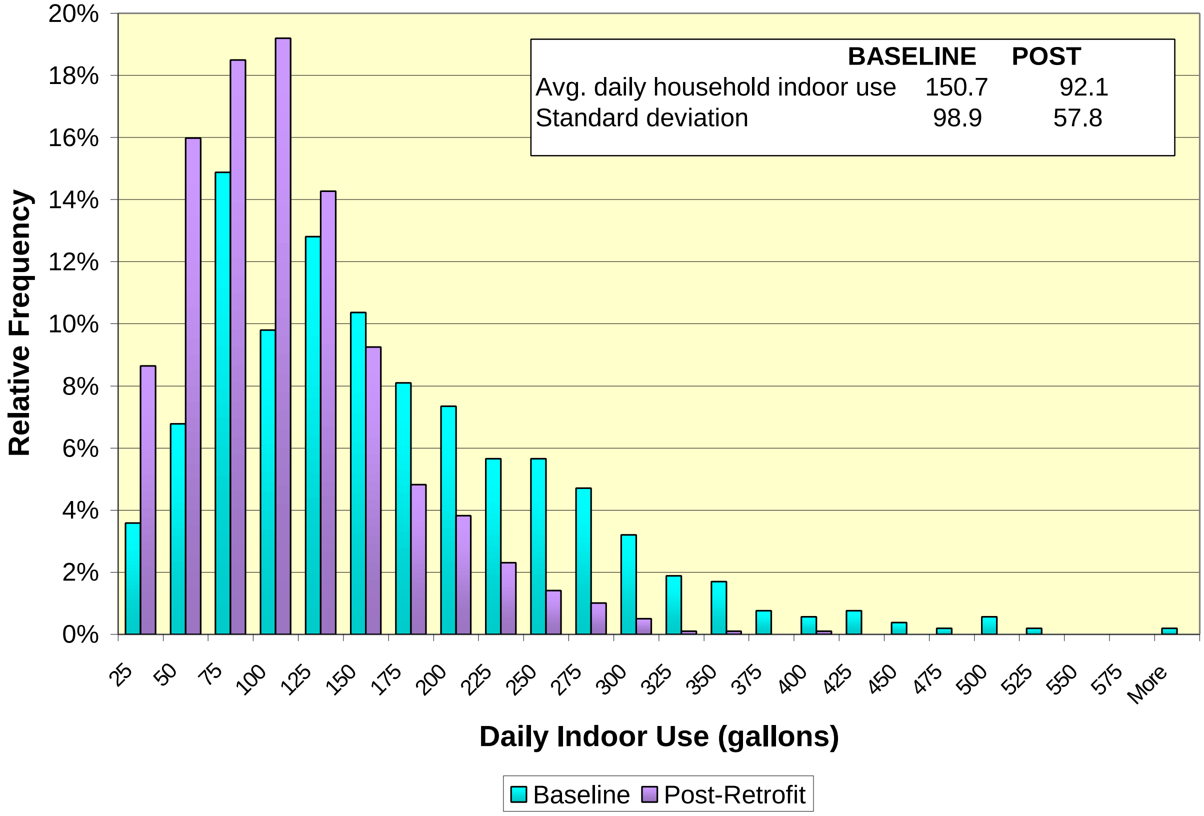


Figure 3.2 Daily per household indoor water use distributions, pre and post-retrofit

INDOOR PER CAPITA USE

Indoor water use patterns changed dramatically after the conservation retrofit. Average daily per capita use decreased in 35 on the 37 study homes. A comparison of the baseline and post-retrofit average per capita daily use is shown in Figure 3.3. In this figure the data are sorted from highest to lowest baseline per capita use.

After the retrofit, toilet usage, which had previously been the largest component of indoor use dropped below faucets into fourth place. Clothes washers became the largest indoor water use followed by showers, and faucets. A pie chart showing the relative importance of each per capita end use is shown in Figure 3.4. The combination of showers and baths actually form the largest block of indoor use in the post-retrofit era at 28.4 percent.

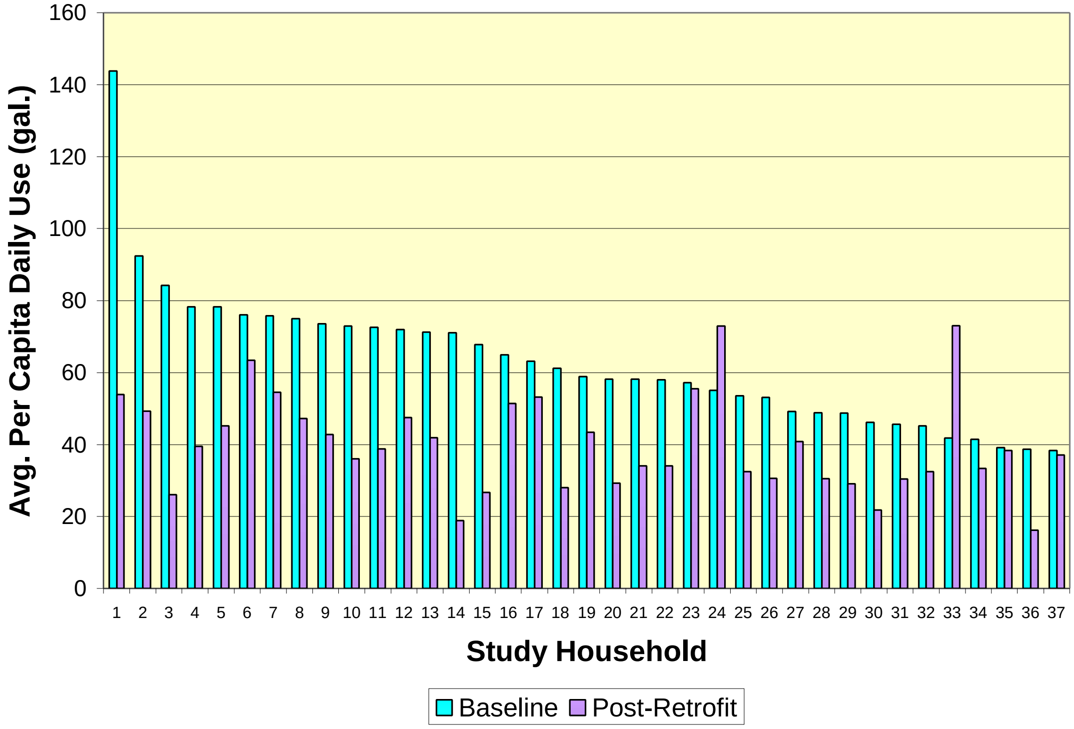


Figure 3.3 House by house average per capita daily use comparison, baseline and post-retrofit

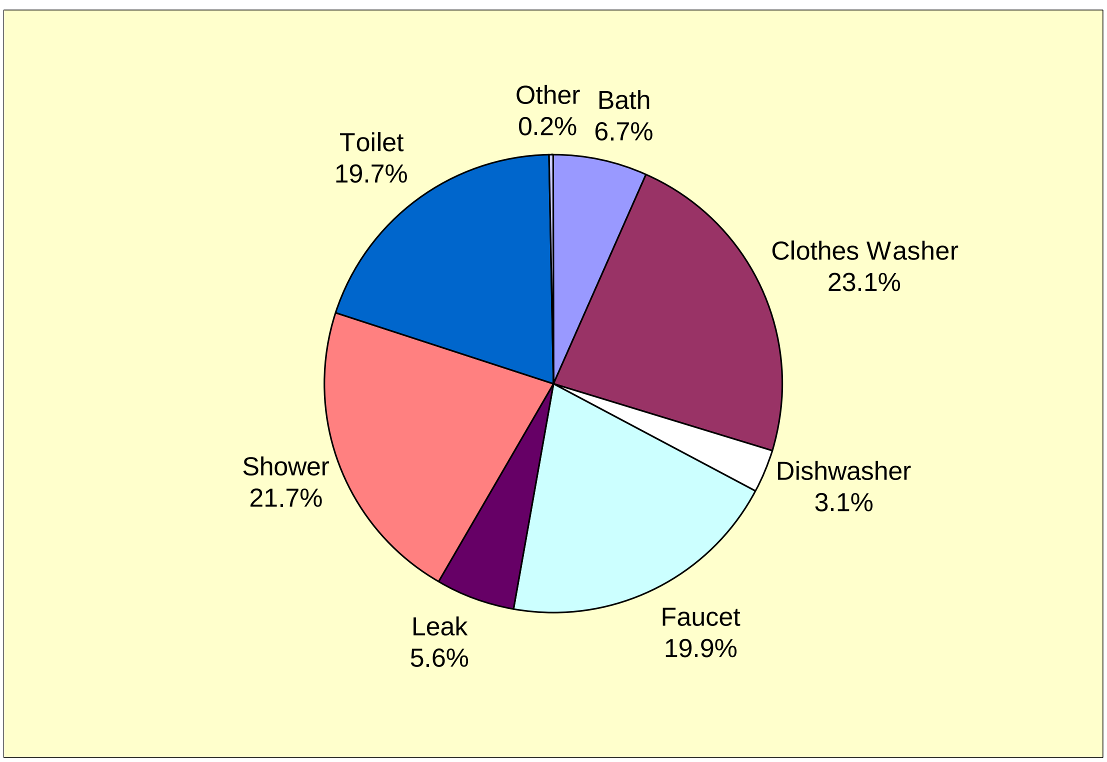


Figure 3.4 Post-retrofit indoor per capita water use percentage including leakage

Table 3.3 presents a comparison of the mean indoor per capita water use from the baseline and post-retrofit data collection periods. Overall, indoor water use decreased by 23.6 gcd – a 37.2 percent drop. A series of unpaired *t-tests* were performed on each end use in these two data sets to determine which changes in water use are statistically significant at the 99 percent confidence level. The results of this analysis are also presented in Table 3.3 as the t-Value and P-Value from the t-test. In order for a difference in means to qualify as statistically significant, the P-Value must be less than the alpha level of 0.01, the 99 percent confidence level. Statistically significant changes in water use were detected for clothes washers, faucets, leaks, toilets, and total indoor use.

Table 3.3 Mean indoor per capita water use, baseline and post-retrofit

Category	Baseline (gcd)	Post-Retrofit (gcd)	Difference in Means (gcd)	% Change	t-Value	P-Value	Statistically significant difference?*
Bath	3.7	2.7	-1.0	-27.9%	2.443	0.0147	No
Clothes Washer	14.8	9.2	-5.6	-37.7%	5.157	<0.0001	Yes
Dishwasher	1.4	1.2	-0.2	-13.6%	1.460	0.1446	No
Faucet	9.2	8.0	-1.2	-13.1%	3.310	0.0010	Yes
Leak	6.5	2.2	-4.3	-66.0%	9.891	<0.0001	Yes
Shower	9.0	8.7	-0.3	-3.8%	0.740	0.4596	No
Toilet	18.8	7.9	-10.9	-58.1%	25.29	<0.0001	Yes
Indoor	63.4	39.8	-23.6	-37.2%	13.935	<0.0001	Yes
Other/Unknown	0.2	0.1	-0.1	-46.9%	1.570	0.1166	No
Total	63.6	39.9	-23.7	-37.2%	13.927	<0.0001	Yes
Avg. # of Residents per household	2.54	2.51					

*99 percent confidence level

More than 20 gallons of the 23.6 gcd average saved through the retrofit was the result of three end uses: toilets, clothes washers, and leaks. Installation of ULF toilets, including some dual flush models saved an average of 10.9 gcd. The new conserving clothes washers saved an average of 5.6 gcd. A reduction in leakage resulted in savings of 4.3 gcd. The leakage savings were almost certainly the result of the toilet retrofit. Toilet leaks, primarily flapper leaks, are the single largest contributor to household leakage. In this study, replacing old toilets through the retrofit eliminated almost all of these toilet leaks and resulted in substantial savings. None of the other measures implemented through this study (clothes washers, showerheads, or faucet aerators) should have had any impact on the leakage rate, although it is known that at least one study participant repaired a substantial faucet leak (44 gcd) about the time of the retrofit. A more detailed analysis of leakage is presented later in this report.

It is interesting to note that after the retrofit, statistically significant reductions in water use occurred in most of the end use categories impacted by the retrofits: toilets, faucets, leaks and clothes washers. Showers did not show any significant water use reduction, even though new showerheads were installed. The remaining categories not targeted by the retrofit (baths and dishwashers) also showed no change. Mean per capita faucet use was reduced by 1.2 gcd (13.1 percent) after the installation of faucet aerators. But mean per capita shower usage only decreased by 0.3 gcd (3.8 percent) in spite of the installation of LF showerheads in many of the study homes. These end uses are examined in more detail in the next section.

Post-Retrofit Hot Water Usage

Water meters were installed on the hot water heaters of 10 of the 37 study homes and flow recorders were attached to these meters so that hot water usage could be monitored alongside overall household usage. The hot water flow traces were disaggregated into end uses using Trace Wizard and the data were stored in the Seattle database.

There were an average of 2.79 residents in the 10 so-called “hot water” homes during the post-retrofit data collection period, and the average daily indoor per capita use in these homes was 41.7 gcd compared with 39.9 for the larger 37 home retrofit group.

Overall per capita indoor use in the 10 hot water homes was very similar to the study group as a whole, differing by only 1.8 gcd. A *t-test* test performed on the two data sets found no statistical difference between the means at the 95 percent confidence level.

Toilet flushing was the only indoor use that had no hot water component. Over one quarter of the total leaks were composed of hot water. These results and a comparison with the average gcd found in the entire 37 home study group are presented in Table 3.4. In the post-retrofit period, nearly half of all water used indoors, 20.5 gcd, was hot water. On a daily basis, the most hot water (71.7 percent) was used for faucets and showers. Interestingly, a substantial portion of the water lost to leakage (62.1 percent) in the post-retrofit period was hot water. This is probably the result of the elimination of toilet leaks brought about by the retrofit. The remaining leaks are running or dripping faucets (and possibly showers or baths) and much of this water is hot water.

A comparison of hot water usage during the baseline and post-retrofit periods is shown in Table 3.4. Here it can be seen that in the post-retrofit period, the study participants used an average of 4.6 gcd less hot water than during the baseline period. A series of unpaired *t-tests* assuming unequal variances were performed to compare the baseline and post-retrofit hot water end uses. The results of these tests are presented in Table 3.5. These tests showed that a statistically significant difference in mean water use before and after the retrofit was detected for the following categories: baths, clothes washers, leaks, and total indoor use.

The total hot water use dropped by 4.6 gcd after the retrofits, but not all of this can be attributed to this intervention. The decreases in hot water used for baths is probably unrelated to the retrofits. If we look just at those categories where an action was taken we see reductions of 2.4 gcd for clothes washers, and 0.9 gcd for faucets. This implies that the total hot water savings attributable to the retrofit is approximately 3.3 gcd.

Table 3.4 Post-retrofit per capita hot water use

	Post-Retrofit Hot Water Use		**Total Use in Hot Water Homes**	**Seattle Retrofit Group**
	Average gcd	**Percent of Indoor Use that is Hot Water**	**Post-Retrofit Average gcd**	**Post-Retrofit Average gcd**
Bath	2.5	80.5%	3.1	2.7
Clothes Washer	1.5	15.1%	9.6	9.2
Dishwasher	1.0	100.0%	1.0	1.2
Faucet	7.7	79.5%	9.7	8.0
Leak	0.8	62.1%	1.3	2.2
Shower	7.0	75.5%	9.3	8.7
Toilet	0.0	0.0%	7.6	7.9
Other	0.01	9.1%	0.1	0.1
Indoor Total	20.5	49.2%	41.7	39.9
Sample size	10	10	10	37
Avg. # of residents	2.8	2.8	2.8	2.5

Table 3.5 Comparison of baseline and post-retrofit per capita hot water use

Category	Baseline Hot Water Use (gcd)	Post-Retrofit Hot Water Use (gcd)	Difference (gcd)	% change	t-Value	P-Value	Statistically significant difference?*
Bath	4.2	2.5	-1.7	-41.0%	2.625	0.0090	Yes
Clothes Washer	3.9	1.5	-2.4	-62.8%	5.001	<0.0001	Yes
Dishwasher	0.9	1.0	0.1	12.2%	-0.324	0.7458	No
Faucet	8.6	7.7	-0.9	-10.6%	1.424	0.1551	No
Leak	1.2	0.8	-0.4	-32.8%	4.464	<0.0001	Yes
Shower	6.3	7.0	0.7	11.6%	-1.090	0.2764	No
Toilet	0.0	0.0	0.0	0.0%	na	na	na
Other/Unknown	0.01	0.01	0.0	0.0%	-0.360	0.7194	No
Indoor Total	25.1	20.5	-4.6	-18.4%	3.302	0.0010	Yes
Avg. # of Residents per household	2.8	2.8					

*99 percent confidence level

FIXTURE USAGE

Toilets

During the post-retrofit data collection period a total of 12,928 individual toilet flushes were recorded from the 37 study homes over 975 days; for an average of 13.3 flushes per household per day and 5.46 flushes per capita per day[9]. After the ULF fixtures were installed, the average flush volume across the 37 study sites was 1.38 gallons per flush (gpf) with a standard deviation of 0.44 gpf. During the baseline period the average flush volume was 3.61 gpf, so the new fixtures reduced the average flush volume by 2.23 gpf, a 62 percent reduction.

The distributions of the volumes of all recorded toilet flushes in the baseline and post-retrofit periods are shown in Figure 3.5. These distributions shows the range of flushing volumes found during the baseline and post-retrofit data collection periods. Two households in the study group each kept one of their old non-conserving toilets and these higher volume flushes can be seen in the 3 – 4 gpf range of the post-retrofit distribution.

[9] The value of 5.46 flushes per capita per day was derived by averaging the flushes per person per day determined for each home on each day of the study. This is not the same as dividing the 12,928 total flushes by the 975 days of observation and 2.51 persons per home (which gives 5.28 flushes per person per day).

During the baseline period, only 10 percent of the recorded flush volumes were in the low flow range (below 2 gpf), about 50 percent of the flush volumes were above 3.5 gpf, and 12 percent were above 5 gpf. During the post-retrofit period 95 percent of the toilet flushes were in the low flow range. A *t-test* (two tail) assuming unequal variances was conducted at the 99 percent confidence level to determine with there was a significant difference between the mean flush volume during the baseline period and the post-retrofit period. The t-Value in this test was –130.055 and the P-Value was <0.00001, clearly indicating a statistically significant difference between the two mean flush volumes at the 99 percent confidence level. Thus the conclusion can be made that the installation of the ULF toilets in the study homes resulted in substantial reduction in toilet water usage in these study homes.

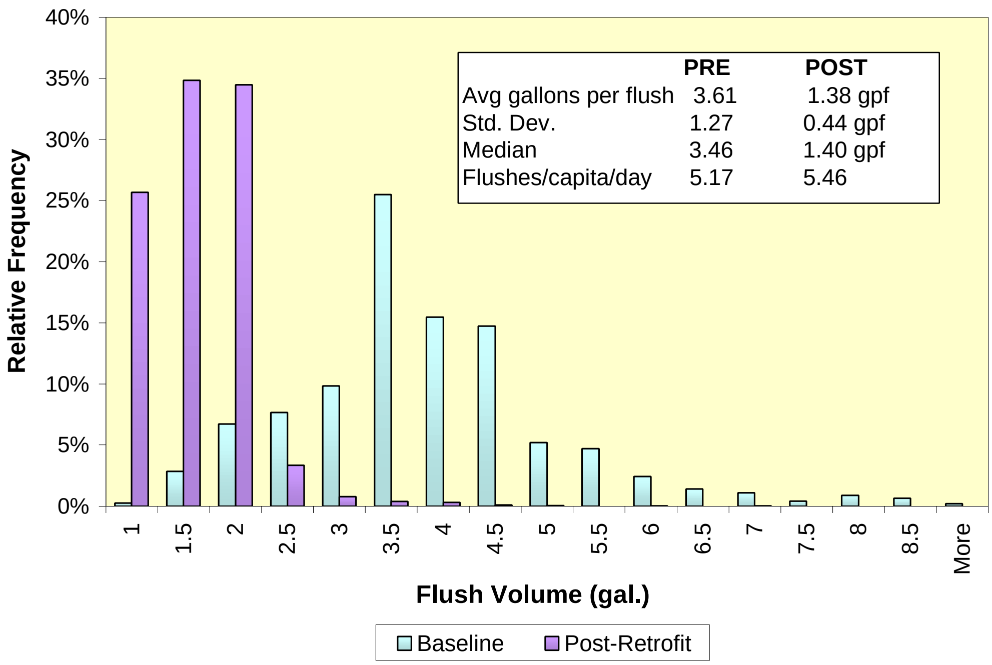


Figure 3.5 Toilet flush volume distribution, baseline and post-retrofit

Flushes per capita per day

Double-flushing has been a concern about ULF toilets ever since they were introduced. Critics have charged that it takes two flushes of a ULF toilet to do the job. The data collected in this study provided another opportunity to test if flushing frequency increases with the installation of ULF toilets[10].

During the baseline period, residents in the Seattle retrofit study group flushed the toilet an average of 5.17 times per capita per day (fpcd). During the post-retrofit period the average number of flushes per person per day increased to 5.46 fpcd. The daily per capita flushing frequency distributions for the baseline and post-retrofit periods is shown in Figure 3.6.

Although the flushing frequency increased by an average of 0.29 fpcd after the ULF toilets were installed, the flushing frequency distributions are remarkable similar. A *t-test* (two tail) assuming unequal variances was conducted at the 99 percent confidence level to determine of the difference between the baseline and post-retrofit mean flushes per capita per day was significant. This test returned a t-Value of 1.78 and a P-Value of 0.075. Given that the t-value was less than the critical value of 2.58 and the P-value was greater than 0.01 it was concluded that there was *not* a statistically significant difference between the mean baseline and post-retrofit flushing frequency at the 99 percent confidence level. The small increase in average flushing frequency was not enough to diminish the water savings accomplished through the installation of the ULF toilets.

[10] See Mayer and DeOreo (1999), pg. 131, which discusses the lack of evidence for significant double flushing in the 1188 homes of the REUWS study.

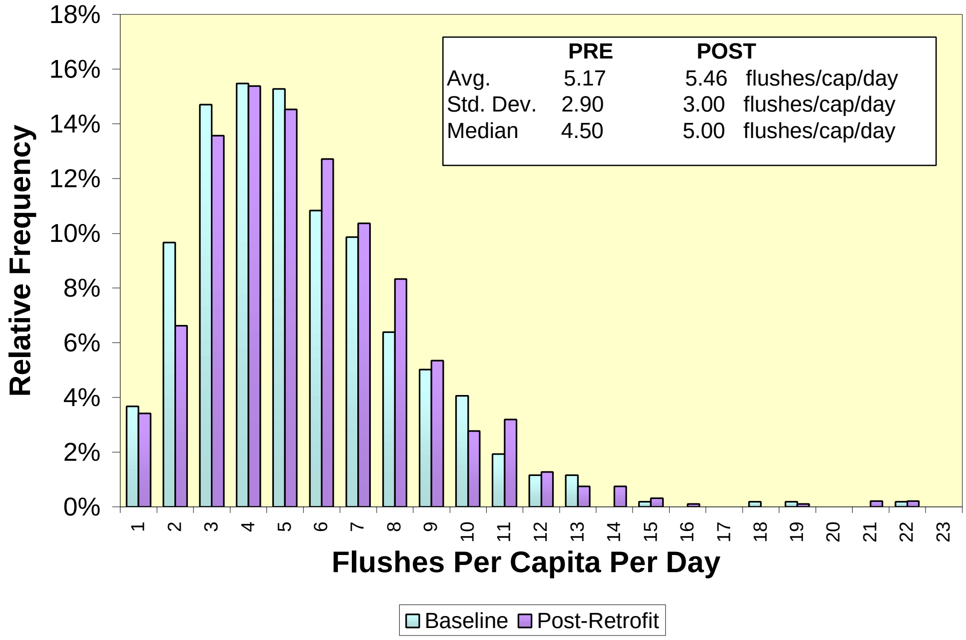


Figure 3.6 Toilet flushing frequency distribution, baseline and post-retrofit

Impact of Toilet Make and Model

Two types of ULF toilets were installed as part of this study: the Toto Drake and Caroma Caravelle. The data collected in this study made it possible to evaluate the impacts of both models of toilet to compare water use, flush volume, and flushing frequency. These results are presented in Table 3.6.

The Toto Drake is a traditional gravity flush toilet with a 3-inch flush valve. This is substantially larger than the traditional 2-inch valve. The tank is designed to hold up to 3 gallons of water, but only 1.5 gallons are used in the flush. The extra water in the tank provides more pressure and during the flush water is rapidly expelled through the 3-inch flush valve into the bowl.

The Caroma Caravelle is a dual flush gravity toilet designed and manufactured in Australia. The unique feature of this toilet is that it offers two different flush options – a full 1.6 gallon (6 liter) flush and a half flush of 0.8 gallon (3 liter). There are two buttons on the top of the toilet tank allowing the user to select the size of flush required. Some dual flush devices have been available in the US, but none offers the reliability and convenience of the Caroma design.

In order to test the water using characteristics of these two devices, daily per capita water use for toilets was compared for the homes equipped with the Toto and the Caroma toilets. A total of 40 Caroma toilets were installed in 20 homes while 34 Toto toilets were installed in 17 homes. (To avoid confusion, no homes were equipped with both types.) Results are shown in Table 3.6. The homes equipped with Caroma toilets used 6.9 gcd while the homes equipped with Toto toilets used 9.1 gcd, a difference of 2.2 gallons per capita per day. The difference in means was found to be significant at the 99 percent confidence level.

Table 3.6 Caroma vs. Toto toilet water use

	Toto Homes Avg.	**Caroma Homes Avg.**	**Difference**	**% Difference**	**t-Value**	**P-Value**	**Statistically significant difference?***
Per capita use (gcd)	9.1	6.9	2.2	24.2%	-7.537	0.00	Yes
Flush volume (gallons)	1.54	1.25	0.29	18.8%	-41.70	0.00	Yes
Flushing frequency (fpcd)	5.5	5.4	0.1	1.8%	-0.476	0.6345	No
Sample size (homes)	17	20					

*99 percent confidence level

As shown in Table 3.6, the average flush volume of the Caroma toilets was 1.25 gallons while the Toto toilets used 1.54 gpf - a difference of 0.29 gpf. This difference in means was found to be statistically significant at the 99 percent confidence level. The lower average flush volume for the Caroma was due to study participants using the 0.8 gpf flush option available on those fixtures.

Residents equipped with the Caroma toilets flushed an average of 5.4 times per person per day while residents equipped with Toto toilets flushed an average of 5.5 times per person per day. This small difference in flushing frequency was found to be not significant at the 99 percent confidence level.

The Caroma dual flush toilets appear to offer increased savings over ordinary 1.6 gpf models. The Toto Drake is an excellent toilet, manufactured to exceed many of the industry standards, however, because of the half flush option, the Caromas saved more than two gallons per person per day more than the Toto.

ULF Toilet Savings from Other Studies

A number of studies have measured water savings achievable from installing ULF toilets. These studies include the REUWS (Mayer and DeOreo, et. al. 1999), the Stevens Institute of Technology micro-metering studies for East Bay MUD and Tampa, Florida (Aher et. al. 1991; Anderson et. al. 1993), A&N Technical Service's statistical models developed for MWD (Chesnutt et. al. 1992a, 1992b; 1994), and Aquacraft's small scale retrofit study in Boulder, Colorado (DeOreo et. al. 1996). The per capita per day toilet savings found in these studies is compared with the SHWCS results in Table 3.7.

Table 3.7 Comparison of ULF savings from other studies

Research project	**Per capita savings from ULF toilets** (gcd)	**Saturation rate of ULF toilets in study homes**
Seattle Home Water Conservation Study (2000)	10.9	84%
REUWS (1999)	10.5	100%
MWD (1992 – 1994)	11.4	73%
Tampa, Florida (1993)	6.1	100%
East Bay MUD (1991)	5.3	100%
Boulder Heatherwood (1996)	2.6	50%

The savings found in the Seattle study were higher than found in all the other studies except for the statistical models developed for Southern California. It should be noted that the REUWS was not retrofit study and no conserving hardware was installed as part of this research. Rather, the ULF savings estimates were calculated as the difference between the mean per capita toilet usage in homes that exclusively used ULF toilets and homes in the study which did not use a ULF. However, from the similarity of the results in the Seattle study, the REUWS, and the MWD studies a more accurate picture of the per capita savings achievable from ULF toilet retrofits emerges. These research efforts each approached the task of calculating savings differently yet their results are quite similar.

Showers

During the baseline period, the study participants showered an average of 0.51 times per day. The average shower consumed 18.06 gallons of water, lasted for 7.91 minutes, and was taken at a flow rate of 2.24 gpm. All but two of the 37 study homes received one or more Brasscraft LF showerheads as part of the conservation retrofit. In the post-retrofit period, study residents showered an average of 0.59 times per day. The average post-retrofit shower used 14.93 gallons, lasted for 7.84 minutes, and was taken at flow rate of 1.88 gpm. The frequency distributions of baseline and post-retrofit shower volumes are presented in Figure 3.7, Figure 3.8 shows the frequency distributions of baseline and post-retrofit shower durations, and Figure 3.9 presents the frequency distributions of baseline and post-retrofit shower flow rates.

From these results, it appears that the LF showerheads installed during the retrofit did reduce the flow rate at which people shower and consequently reduced the volume of showers. However, because of an increase in showering frequency no statistically significant savings were observed in the comparison of baseline and post-retrofit per capita use shown in Table 3.3.

To determine if and how the installation of LF showerheads impacted demand, unpaired t-tests assuming unequal variance were performed on the baseline and post-retrofit shower usage data. The results of these analyses are presented in Table 3.8. The mean shower volume decreased by 3.13 gallons after the retrofit. The change in means in shower volume was found to be statistically significant at the 99 percent confidence level.

It has been hypothesized that the introduction of LF showerheads and the subsequent reduction in shower flow rate could cause people to increase the length of time spent in the shower. Results from this study show that the introduction of LF showerheads does not affect the length of time people spend in the shower. The average shower duration changed by just 4.2 seconds (less than 1 percent) after the retrofit. Not surprisingly this change was found to be not statistically significant at the 99 percent confidence level.

LF showerheads are expected to reduce the water flow rate during the shower. These new fixtures are designed to restrict the flow of water to 2.5 gpm or less. While this may seem like a low flow rate, results from this study show that most residents showered at a flow rate below 2.5 gpm prior to the installation of the LF fixtures. Many of the participants already had LF showerheads installed in their homes. Others simply chose to throttle their showerheads down, finding that flow rate more comfortable for showering. In a few homes low water pressure limited the shower flow rates, independent of the type of head in place.

After the retrofit, the average flow rate for showers decreased by 0.36 gpm, from 2.24 gpm to 1.88 gpm. The results of the *t-test* conducted on these data show that this change in mean showering flow rate is statistically significant at the 99 percent confidence level. This indicates that the new showerheads successfully reduced shower flow rates in the study homes.

Table 3.8 Shower usage comparison, baseline and post-retrofit

Comparison Category	**Baseline avg.**	**Post-Retrofit avg.**	**Difference**	**% change**	**t-Value**	**P-Value**	**Statistically significant difference?***
Shower Volume (gal.)	18.06	14.93	-3.13	-17.34%	6.958	<0.0001	Yes
Shower Duration (min.)	7.91	7.84	-0.07	-0.94%	0.391	0.6959	No
Shower Flow Rate (gpm)	2.24	1.88	-0.36	-16.11%	11.570	<0.0001	Yes
Showers per capita per day	0.51	0.59	0.08	16.74%	-3.525	0.000	Yes
Baths per capita per day	0.142	0.106	-0.04	-25.32%	2.174	0.030	Yes**

*99 percent confidence level
**95 percent confidence level

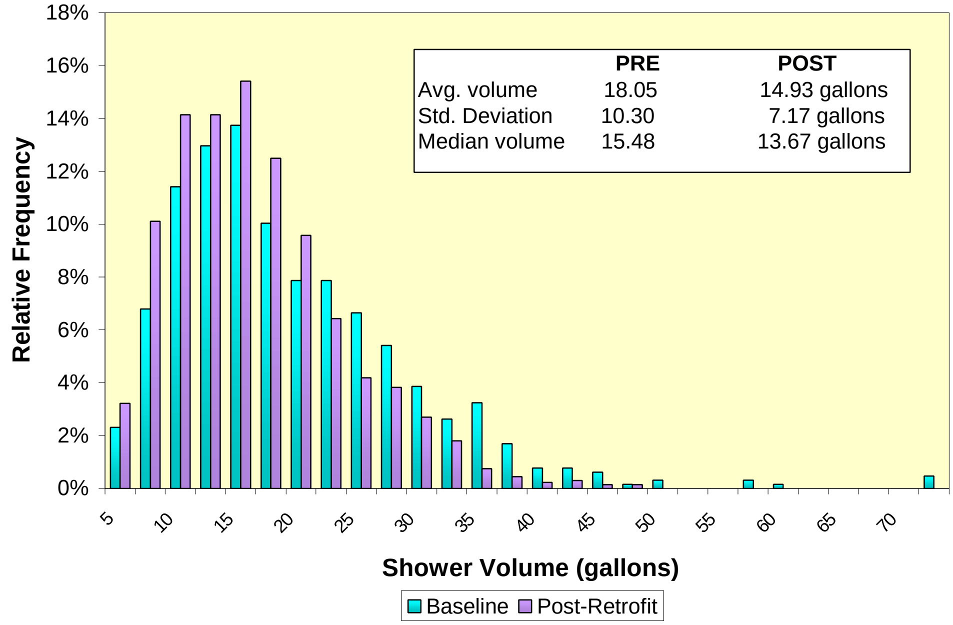


Figure 3.7 Shower volume frequency distributions, baseline and post-retrofit

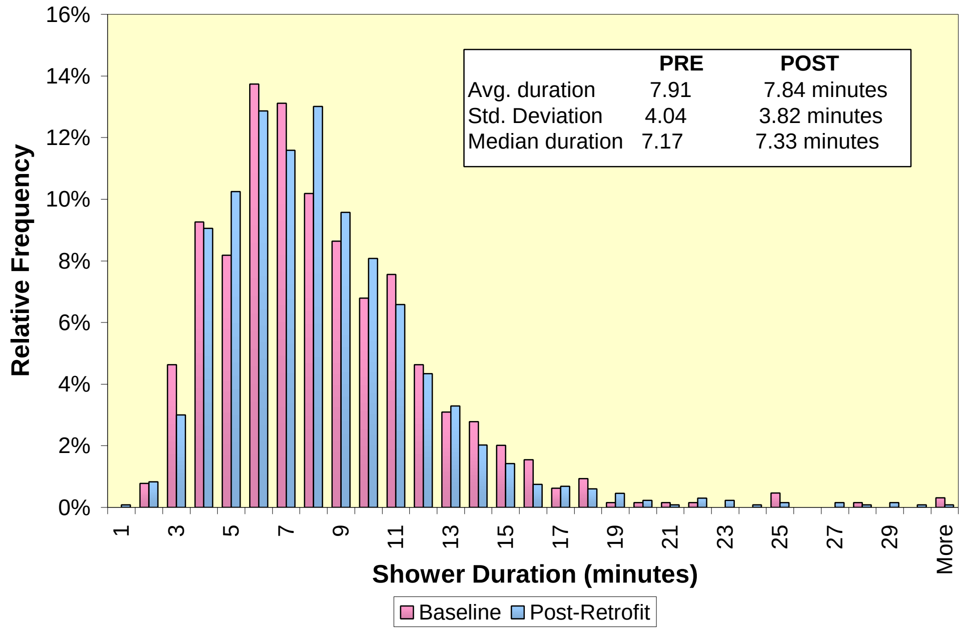


Figure 3.8 Shower duration frequency distributions, baseline and post-retrofit

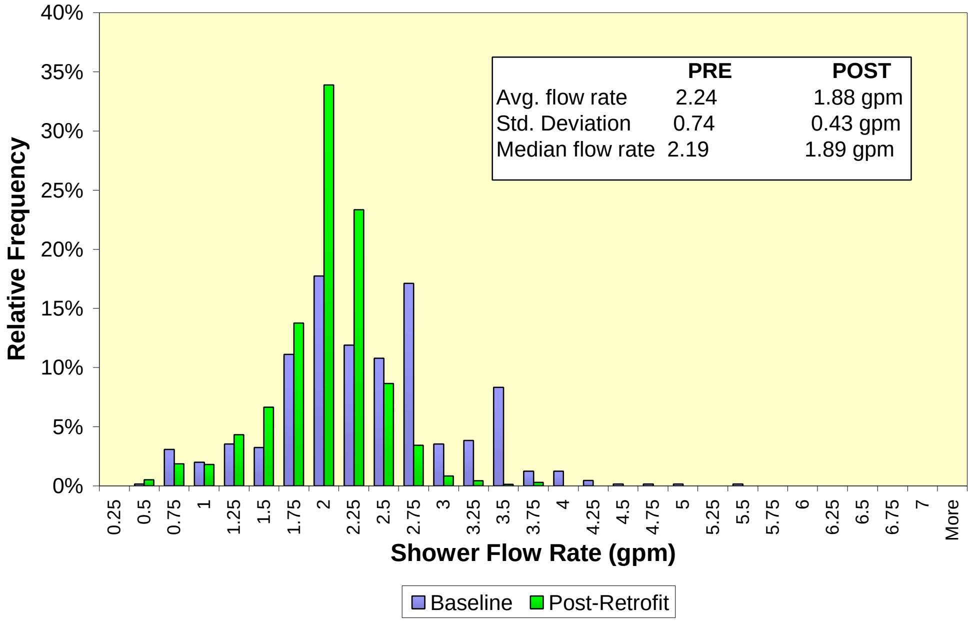


Figure 3.9 Shower flow rate frequency distributions, baseline and post-retrofit

Although these results indicate the LF showerheads accomplished the task of reducing shower flows and volumes, the actual per capita usage for showers decreased by only 0.3 gcd and this changes was found to be not statistically significant. These somewhat contradictory results are explained by the fact that the frequency of showering by study participants increased in the post-retrofit period. During the baseline period, study participants averaged 0.51 showers per person per day, but during the post retrofit period this increased to 0.59. At the same time, the frequency of baths decreased during the post-retrofit period from 0.14 baths per person per day to 0.10. As shown in Table 3.8 both of these changes in use were found to be statistically significant.

One possible explanation for the change in showering habits is the change in seasons from the baseline to the post-retrofit period. Baseline data were obtained during November 1999. November is typically one of the cooler rainiest months, which may have encouraged more study participants to take baths rather than showers. The post-retrofit data were obtained during April and August 2000 and weather records indicate that these were relatively warm and dry months. This may have encouraged the switch towards increased showering and decreased bathing. The impact of seasonal changes on showering and bathing is an area for further research. It would be a simple matter to test this hypothesis by re-logging the homes in November and comparing the results to the other data.

Regardless of the reason, the increase in showering frequency did substantially reduce the per capita water savings for showering that would have been observed had the number of showers remained constant. If the number of showers per person per day is held constant at 0.55, it is anticipated that the introduction of low flow showerheads would save approximately 1.7 gallons of water per person per day or about 630 gallons per person per year.

LF Shower Savings from Other Studies

A number of studies have measured water savings achievable from installing low-flow shower heads. These studies include the REUWS, the Stevens Institute of Technology micro-metering studies for East Bay MUD and Tampa, Florida (Aher et. al. 1991; Anderson et. al. 1993) and the 1984 HUD study (Brown & Caldwell 1994). The per capita per day shower savings found in these studies is compared with the Seattle retrofit study results in Table 3.9.

Table 3.9 Comparison of LF showerhead savings from other studies

Research project	**Per capita savings from LF showerheads** (gcd)	**Saturation rate of LF showerheads in study homes**
Seattle Home Water Conservation Study (2000)	0.3	94%
REUWS (1999)	4.5	100%
HUD (1984)	7.2	NA
Tampa, Florida (1993)	3.6	100%
East Bay MUD (1991)	1.7	100%

The Seattle study found the lowest level of showerhead savings. The savings found in the REUWS were higher than found in all the other studies except for the HUD study. It should be noted that the REUWS was not retrofit study and no conserving hardware was installed as part of this research. Rather, the LF showerhead savings estimates were calculated as the difference between the mean daily per capita shower usage in homes in which the residents showered exclusively at or below the 2.5 gpm flow rate and homes in which the residents showered exclusively above the 2.5 gpm flow rate.

The disparate results for showerheads suggest that the savings achieved by the devices are uncertain at best. Since showerheads are not expensive it probably makes sense to continue to distribute them broadly, but water planners should be cautious when projecting savings from faucet retrofit programs. Many homes are already equipped with LF showerheads through natural retrofit and many other people simply throttle their showers down below 2.5 gpm for comfort.

Clothes Washers

As part of the retrofit program, the clothes washer in each of the 37 study homes was replaced with a new water conserving model. There are now several different water conserving clothes washers available in the U.S. In this study, three different models were installed and evaluated: the Frigidaire Gallery, the Maytag Neptune, and the Whirlpool Super Capacity Plus. The Frigidaire Gallery and Maytag Neptune are both front loading horizontal axis machines. The Whirlpool Super Capacity Plus is a traditional top loading washer with a redesigned rinse cycle that uses less water. In this study 23 Frigidaire, 12 Maytag, and 2 Whirlpool machines were installed.

To depict how these machines differ in operation several sample flow traces from Trace Wizard were captured and are presented in Figure 3.10 - Figure 3.14. These figures show the different wash and rinse cycles typical of each machine.

The Frigidaire Gallery used an average of 23.7 gallons per load of clothes with a standard deviation of 4.5 gallons. As shown in Figure 3.10 and Figure 3.11, the Gallery starts with a wash/fill cycle that is a higher flow rate than subsequent wash and rinse cycles. Sometimes the first fill is briefly interrupted and then resumed as shown in Figure 3.10. Usually only the first fill cycle of the Gallery uses any hot water (because most people set the machines to rinse with cold water). There are typically five wash and rinse cycles that complete the load. These cycles may be of different volumes and durations based upon the washer settings. It is also possible to add additional rinse cycles if desired. A single run of the Gallery takes less than one hour.

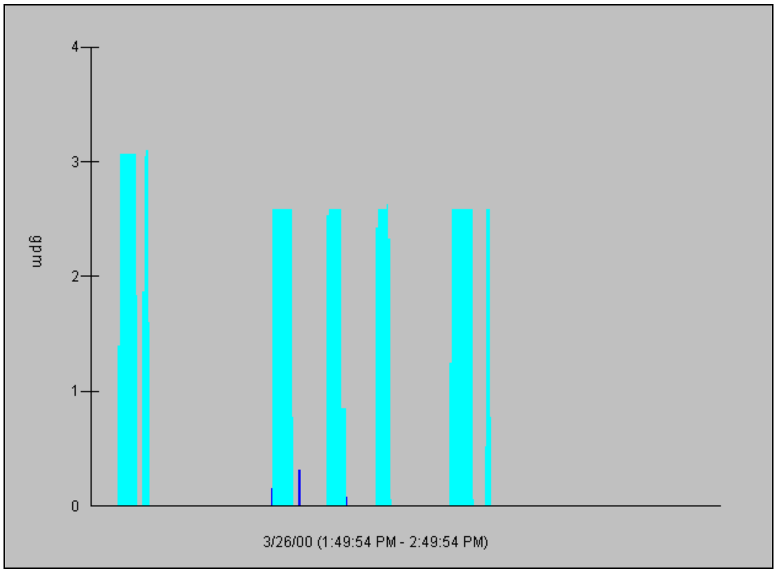


Figure 3.10 Frigidaire Gallery sample flow trace

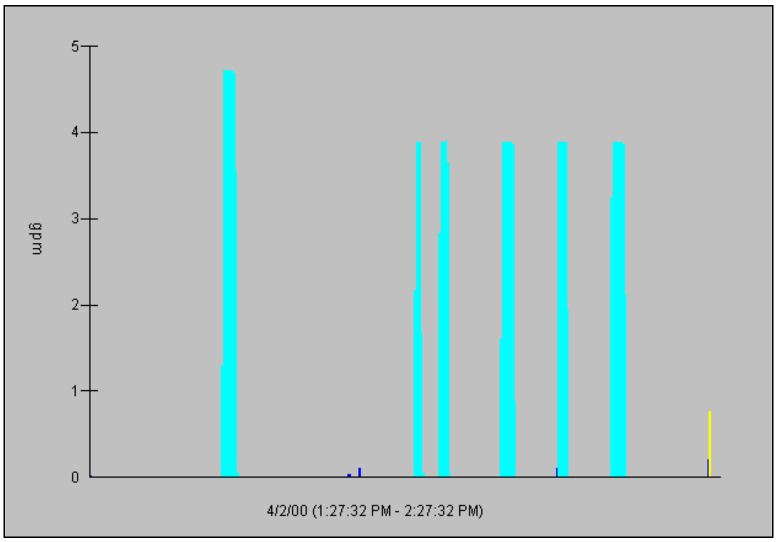


Figure 3.11 Frigidaire Gallery sample flow trace

The Maytag Neptune used an average of 24.7 gallons per load of laundry with a standard deviation of 4.6 gallons. An examples of the standard water use pattern for this machine is shown in Figure 3.12, and Figure 3.13 shows the water use pattern with an extra rinse cycle. The extra rinse adds between 5 and 6 gallons to the wash volume. Like the Gallery, the initial fill/wash cycle of the Neptune is separated from the four subsequent wash/rinse cycles by about 15 minutes. The first fill cycle typically includes some hot water and subsequent cycles are almost exclusively cold water. The fill rate of the final four cycles alternates between 3 and 4 gpm while the first fill cycle is usually about 3 gpm. A single run of the Neptune takes less than one hour.

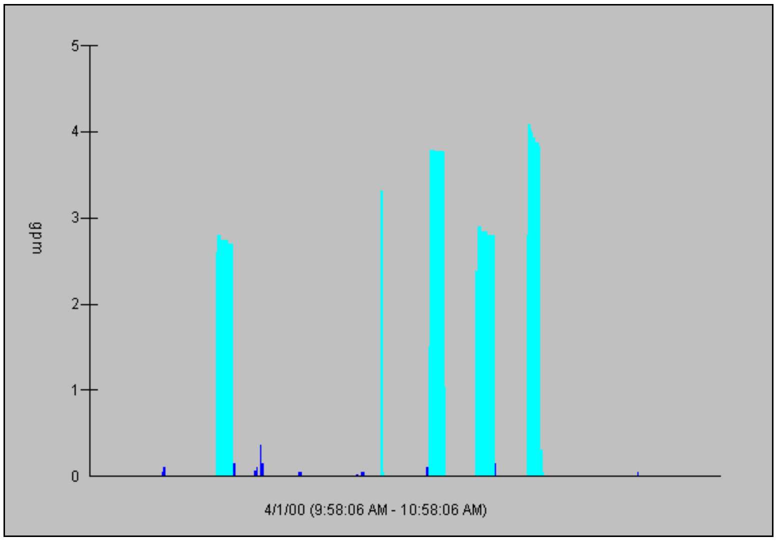


Figure 3.12 Maytag Neptune regular wash cycle sample flow trace

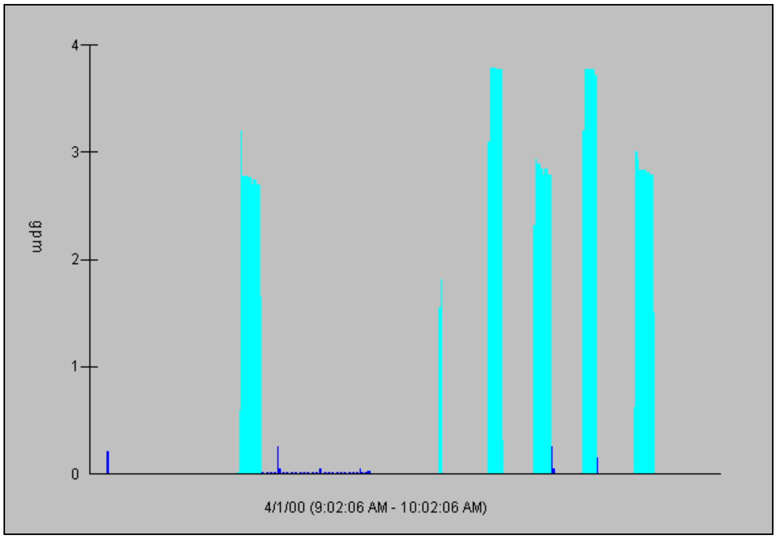


Figure 3.13 Maytag Neptune with extra rinse sample flow trace

The Whirlpool Super Capacity Plus clothes washer used an average of 27.2 gallons per load of laundry. This machine has a traditional top loading design, but utilizes only one large fill cycle and a series of six short rinse cycles to wash the clothes. A sample for trace from a Super

Capacity Plus is shown in Figure 3.14. There is a 15 minute period between the end of the first fill cycle and the first rinse cycle. The first fill cycle typically used about 20 gallons and the subsequent rinse cycles used 1.5 – 2 gallons each. Typically only the first fill cycle included hot water, but there were examples when the rinse cycles also had a hot water component. An analysis of the hot water consumption of each machine is presented later in this section. A single run of the Super Capacity Plus takes less than one hour.

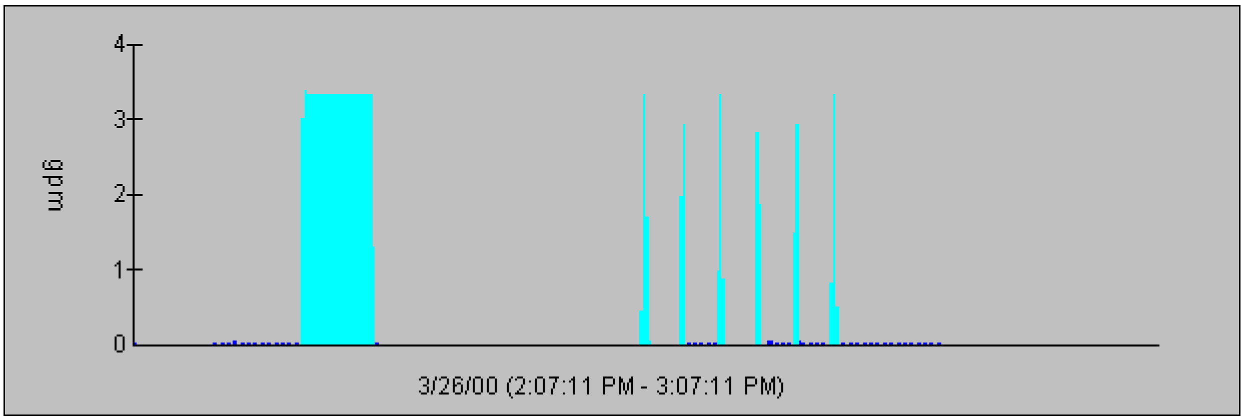


Figure 3.14 Whirlpool Super Capacity Plus sample flow trace

Prior to the retrofit the washing machines in the study homes used an average of 40.9 gallons per load of clothes with a standard deviation of 11.9 gallons. Data from the baseline period indicated that 27.8 percent (11.4 gallons per load) of the water used for clothes washing was hot water. During this period, participants ran an average of 0.36 loads of laundry per person per day. From the analysis shown in Table 3.3 it is known that a statistically significant change in per capita water usage was achieved through the installation of the new conserving clothes washers. Table 3.10 shows the relevant usage statistics for each make and model of washing machine installed for this study.

The clothes washers installed for this study used between 23.8 and 27.2 gallons per load of wash on average. The Frigidaire Gallery averaged 23.75 gallons per load, the Maytag Neptune averaged 24.73 gallons per load, and the Whirlpool Super Capacity Plus averaged 27.18

gallons per load.[11] The differences in average load volume were not statistically significant at the 95 percent confidence level.

Hot water usage for clothes washing decreased substantially in the post-retrofit period. The Frigidaire used only 2.72 gallons of hot water per load (11.5 percent), the Maytag used 4.55 gallons of hot water per load (18.4 percent), and the Whirlpool averaged 7.43 gallons of hot water per load (27.3 percent).

Table 3.10 Clothes washer usage comparison

		Frigidaire Gallery	Maytag Neptune	Whirlpool Super Capacity Plus	Entire Study Group (post-retrofit)	Entire Study Group (baseline)
Volume Per Load (gal.)	Average	23.75	24.73	27.18	24.3	40.9
	Std. Dev.	4.53	4.55	6.88	4.8	11.9
Hot Water Volume Per Load	Average	2.72	4.45	7.43	4.2	11.4
Loads Per Capita Per Day	Average	0.37	0.42	0.33	0.38	0.36
	Std. Dev.	0.54	0.42	0.33	0.65	0.61
Per Capita Daily Use (gal.)	Average	8.77	10.11	8.71	9.2	14.8
	Std. Dev.	13.28	19.87	10.73	15.7	25.6
Number of machines in study		23	12	2	37	37

The frequency of washing machine use did not change significantly from the baseline period. The study households ran their new clothes washers an average of 0.38 times per person per day and during the baseline period they ran their washers 0.36 time per person per day. The brand of clothes washer present in the home had no effect on the washing frequency. This result suggests that the capacity of the new machines was quite comparable to old machines removed for this study, and that no additional loads of laundry were required as a result of the retrofit.

The mean per capita daily water use for clothes washing was 8.77 gcd for the Frigidaire homes, 10.11 gcd for the Maytag homes, and 8.71 gcd for the Whirlpool homes. None of these differences was significant at the 95 percent confidence level. The overall average per capita

[11] Only 2 Whirlpool Super Capacity Plus clothes washers were installed for this study. Because the sample size is so small, water use statistics for this machine should not be considered conclusive.

usage for clothes washers was 9.2 gcd with a standard deviation of 15.7 gcd. As shown in Table 3.3, the difference in mean per capita clothes washer usage from the baseline to the post-retrofit period was statistically significant at the 99 percent confidence level.

Clothes washer Savings Found in Other Studies

A few other studies have measured water savings achievable from installing conserving clothes washers. These studies include Aquacraft's 1999 study of water wise homes in Westminster, Colorado (Mayer et. al. 2000), the Bern Kansas study (Tomlinson and Rizy, 1998), and the small scale Heatherwood retrofit study. The per capita per day clothes washer savings found in these studies is compared with the Seattle results in Table 3.11.

Table 3.11 Comparison of clothes washer savings from other studies

Research project	**Per capita savings from conserving clothes washers** (gcd)
Seattle Home Water Conservation Study (2000)	5.6
Westminster water wise homes (1999)	4.6
Bern Kansas (1998)	7.2
Boulder Heatherwood (1996)	10.9

The measurements of per capita savings varies substantially in these four studies. The 1996 Heatherwood study only included four homes and two of those homes received the water efficient Asko washer. The Bern Kansas study exclusively used Maytag Neptune washers. Both Heatherwood and Bern were true intervention studies (like Seattle), which measured demand before and after the installation of conserving washers. The Westminster study compared clothes washer use in a sample of standard new homes and sample of "water wise" new homes equipped with high efficiency fixtures including clothes washers. The variability in these results points out the need for additional research into the impact of these products.

Faucets

A total of 60 bathroom faucet aerators and 27 kitchen faucet aerators were installed as part of the retrofit program in Seattle. These aerators were manufactured by the New Resources Group and were designed to limit flows to less than 2.2 gpm in the kitchens and less than 1.5

gpm in the bathrooms. These aerators have a pressure compensating feature so that flow rates can be maintained under a variety of different water pressures.

Mean per capita faucet usage decreased from 9.2 gcd to 8.0 gcd after the retrofit. As shown in Table 3.3, this change in mean use was significant at the 99 percent confidence level. During the baseline period, faucet usage accounted for 14.4 percent of all indoor use. After the retrofit it accounted for 19.9 percent of total indoor use because of the larger decrease in toilet and clothes washer usage.

In the 10 hot water study homes, mean per capita hot water faucet use went from 8.6 gcd in the baseline period to 7.7 gcd in the post retrofit period, but this change was found not to be statistically significant. During the baseline period 72.7 percent of all faucet usage was hot water and after the retrofit the hot water component increased to 79.5 percent. A summary of results for faucet usage is presented in Table 3.12.

Table 3.12 Faucet use comparisons, baseline and post-retrofit

	Per Capita Daily Use		Typical Flow Rates	
	Volume (gal)	Duration (minutes)	Average (gpm)	Peak (gpm)
Baseline	9.2	8.4	1.2	2.9
Post-Retrofit	8.0	8.9	1.0	2.6**
t-Value	3.310	-1.284	13.454	4.782
P-Value	0.001	0.199	<0.0001	<0.0001
Statistically significant difference?*	Yes	No	Yes	Yes

*99 percent confidence level
**Not all faucet aerators could be replaced.

Figure 3.15 shows the baseline and post-retrofit frequency distributions of per capita faucet use durations. The change in the duration of faucet usage was the only comparison shown in Table 3.12 that was not statistically significant at the 99 percent confidence level. This result is important because reducing the flow rate of faucets could logically cause an increase in the duration of faucet usage. Many faucet uses such as filling a glass or a sink should be independent of faucet flow rate, meaning that the volume of water used for these purposes is fixed and that volume will be used regardless of the delivery flow rate of the water. Reducing the flow rate should result in water users spending more time to fill specific volumes. Results from this study show that although the faucet flow rate did decrease as a result of the retrofit, the change in the daily duration of faucet use was not statistically significant.

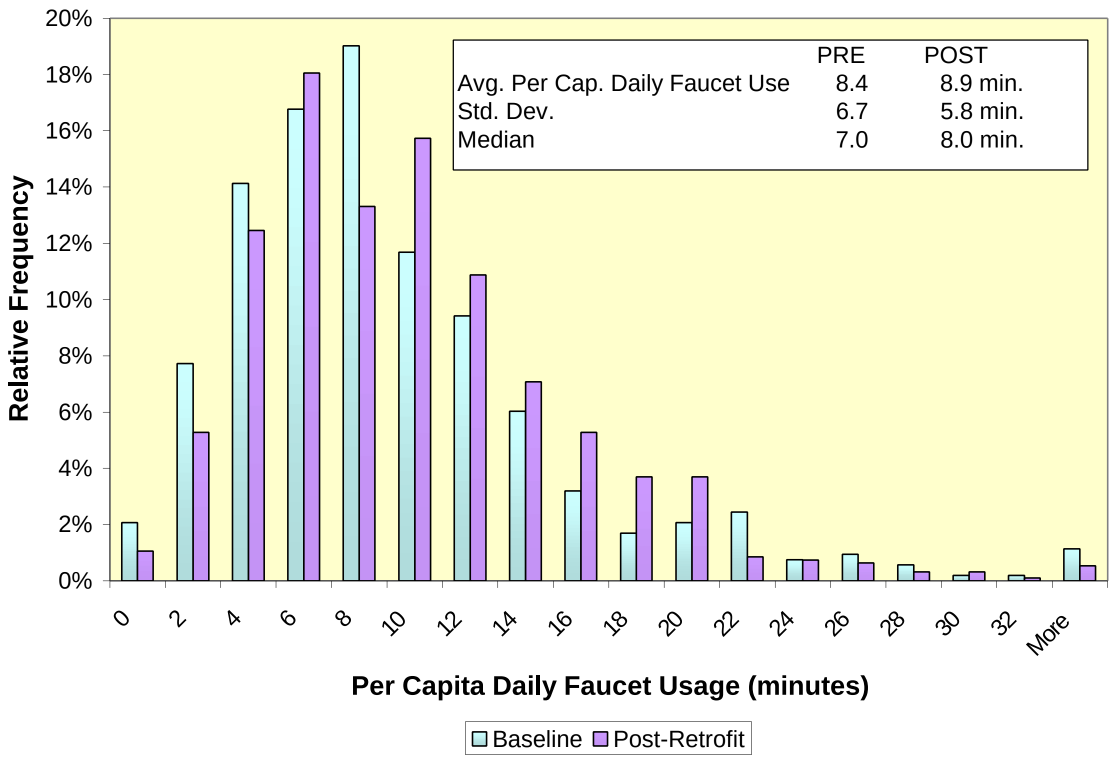


Figure 3.15 Faucet usage comparison, baseline and post-retrofit

Baths

Because baths require a fixed amount of water, this conservation retrofit program was not expected to reduce bath water usage. During the baseline period, the average bath used 24.0 gallons of water and during the post-retrofit period the average bath used 24.3 gallons. This difference was found not to be statistically significant. The maximum baseline bath usage was 55.7 gallons and the maximum post-retrofit bath usage was 53.4 gallons.

During the baseline period, baths taken in the hot water homes were 78.2 percent hot water and 17.8 percent cold water. During the post-retrofit period, baths were measured as using 78.3 percent hot water and 17.7 percent cold water.

Study residents took an average of 0.14 baths per person per day or 0.98 baths per person per week during the baseline and 0.104 baths per person per day or 0.73 baths per person per week during the post-retrofit period. Comparisons of baseline and post retrofit bath data are shown in Table 3.13.

Table 3.13 Bath usage comparisons, baseline and post-retrofit

	Avg. Bath Volume (gal.)	Max. Bath Volume (gal.)	Hot Water Component %	Avg. Baths per Capita Per Day
Baseline	24.0	55.7	78.2%	0.14
Post-Retrofit	24.3	53.4	78.3%	0.10
Statistically Significant Difference?*	No	na	No	Yes**

*99 percent confidence level
**95 percent confidence level

Leaks

The reduction and elimination of leaks appears to be one important results of the retrofit program. Mean daily per capita leakage was reduced by 66 percent from 6.5 gcd to 2.2 gcd after the retrofit as shown in Table 3.3. Most of the leaks eliminated during the retrofit were the result of leaky flapper valves. The new toilets installed during the retrofit replaced a number of older leaking fixtures.

During the baseline period it was discovered that two of the households were responsible for roughly 20 percent of the total leakage in the entire study group. In the intervening months, both of these homes repaired these leaks (and reported this information to Aquacraft), hence the reduction in leakage observed was not entirely due to the new toilets. However, it is evident that the toilet retrofit was responsible for at least saving 2 gcd of leakage. These savings should be attributed to the toilet retrofit effort.

As was the case during the baseline period and in the results of the REUWS, a few houses accounted for most of the leakage during the post-retrofit period. Two houses accounted for 23 percent of the total leakage during the two post-retrofit data collection periods and five houses accounted for more than 40 percent of the total. Leaks in the top two leaking homes were re-examined using Trace Wizard and the leaks appeared as intermittent water uses with very low flow rates (<0.5 gpm). While it is impossible to determine the exact cause of these leaks, they looked to be caused by leaking faucets or hose bibs. These events did not appear to be toilet leaks, which are almost always associated with toilet flushes, nor did they appear to be irrigation leaks, typically caused by broken heads or stuck valves in automatic irrigation systems.

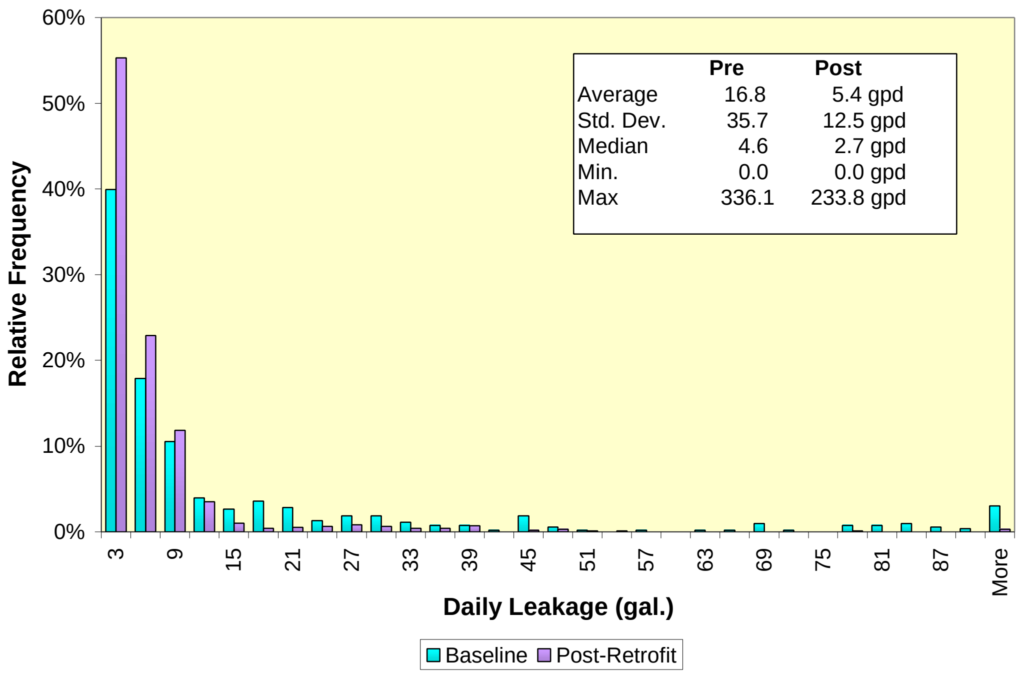


Figure 3.16 Daily per household leakage distributions, baseline and post-retrofit

Figure 3.16 shows the baseline and post-retrofit distributions of daily household leakage. The general shape of these distributions is the same, but in the post-retrofit period there were many more low leakage days. The difference in mean per household leakage (11.4 gpd) was found to be significant at the 99 percent confidence level. It is interesting to note that the median leakage rate in both distributions is substantially lower than the mean, belying the positive skew of the distributions.

MAXIMUM DAY DEMANDS

Peak day demands measured for each study house during the post-retrofit period were typically higher than the peak demands measured during the baseline period. This is not surprising since the post-retrofit data collection periods were during the spring and summer and most of the study participants were irrigating several times per week. Since the retrofit targeted indoor use exclusively it was decided to compare indoor peak day demands before and after the retrofit.

Figure 3.17 shows the maximum daily indoor demands for each study home during the baseline and post-retrofit period. Even though twice as much daily use data were available from the post-retrofit period, peak indoor use during the baseline period exceeded peak use during the post-retrofit period in each and every study home. Overall, indoor peak demand decreased by 32 percent after the retrofit. This reduction was found to be statistically significant at the 99 percent confidence level.

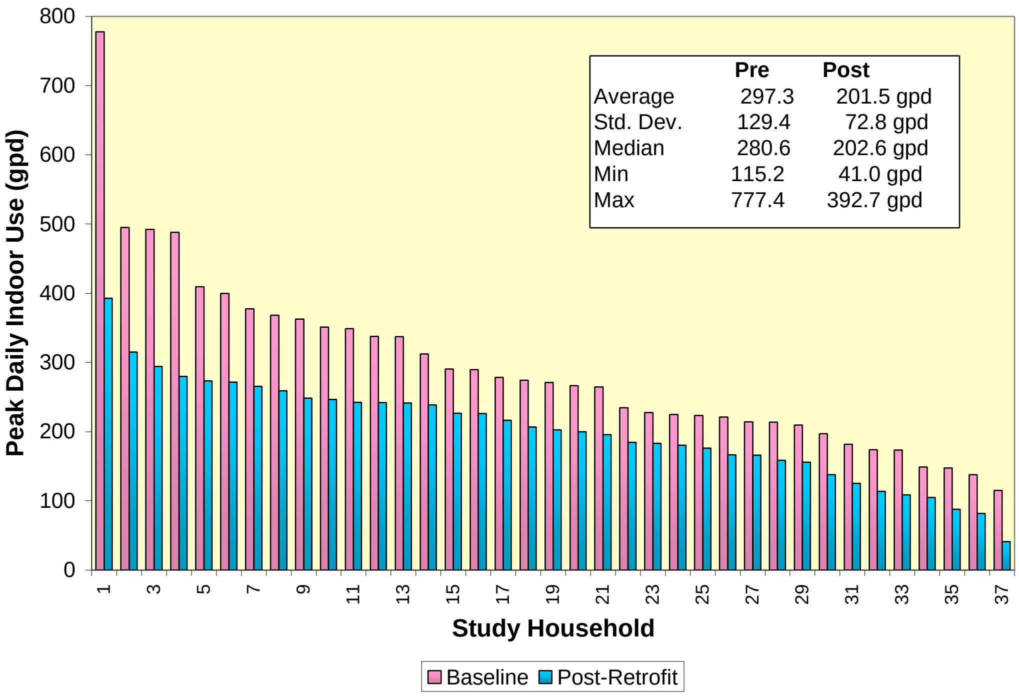


Figure 3.17 Peak daily indoor use comparison, baseline and post-retrofit

For most systems, peak demand during the summer due to outdoor use is the driving factor in sizing treatment plants and distribution lines. Reductions in indoor peak demands are not likely to profoundly impact these design criteria. Nevertheless, a 32 percent reduction in indoor peak demand will be reflected in a lower demand on the peak day, and will create a benefit from the perspective of peak reduction as well as volumetric demand reduction.

BILLING DATA ANALYSIS

Billing data from the post-retrofit period were obtained from SPU staff as one of the final data items for the study. It was hoped that billing data could be used to confirm the savings detected through the flow trace analysis techniques. Ideally such an analysis should be performed with at least one full year to post-retrofit billing data to use to compare against the pre-retrofit billing data described earlier in this report. Because of the project time schedule this was not possible and instead only about seven months of post-retrofit billing data, from February – August 2000, could be obtained. Billing data were obtained for all 248 homes in the original AWWARF study group, which includes 35 of the 37 homes in the retrofit study and a 213 home control group.

The retrofits in the 37 study homes were begun on December 14, 1999 and completed on January 24, 2000. Seattle Public Utilities reads customers' water meters on a bi-monthly schedule and different areas of the City are read at different times of the month. SPU keeps good records of the date each meter is read so it was possible to screen the billing data from each household to ensure that billing periods that included both pre and post-retrofit data were excluded.

There are problems inherent in using billing data to evaluate the effectiveness of conservation measures such as those tested in this study. These problems have been well documented and include: unequal billing periods, estimated meter readings, unusual usage levels, meter read errors, rounding of meter reads, changes in customer occupancy, etc. (Dziegielewski 1993a). However, billing data remains a reliable, cheap, and easy way to measure customers' water use and it should be examined in spite of the inherent shortcomings.

In this study, the limited amount of post-retrofit billing data available made a comparison of pre and post-retrofit water use more difficult. Much of the available post-retrofit data included a substantial component of irrigation demand which can easily mask the sought after effect. To minimize the potential impact of unequal billing periods, the average daily consumption for each billing period was calculated for the pre and post-retrofit periods, and the data were organized so that the meter read dates corresponded. A total of three post-retrofit billing periods were available for use in the analysis these were as follows:

- Period 1. Read dates from March 1 – April 30, consumption from January 1 – April 30.
- Period 2. Read dates from May 1 – June 30, consumption from March 1 – June 30.
- Period 3. Read dates from July 1 – August 31, consumption from May 1 – August 31.

Each period contained consumption data from a four-month period, but the data for any given account only covered a period of roughly 60 days. Because of the consistency in meter reading schedules, most customers' meters were read at roughly the same time in 1999 and 2000. This improved the accuracy of paired comparison tests that evaluated water use in 1999 before the retrofit and data from 2000 after the retrofit. Results of the billing data comparison for the study group is shown in Table 3.14 and for the control group is shown in Table 3.15.

Table 3.14 Pre and post-retrofit billing data comparison, study group (n=35)

	Avg. Daily Per Household Water Use (gallons)		**Mean Difference** (gal/day)	**t-Value**	**P-Value**	**Statistically Significant Difference?***
	1999 Pre-Retrofit	**2000 Post-Retrofit**				
Period 1 – Jan - April	140.9	88.9	-52.0	7.919	<.0001	Yes
Period 2 – Mar –June	151.1	110.2	-40.9	5.037	<.0001	Yes
Period 3 – May - Aug	207.0	162.8	-44.2	2.568	0.0148	Yes
ALL – Jan - Aug	166.3	120.6	-45.7	6.263	<.0001	Yes

*95% confidence level

For the study group, a statistically significant reduction in water use was observed in each of the three billing periods and in the six-month average. The billing data indicates that water use went down by an average of 45.7 gallons per household per day after the retrofit. This equates to a reduction of 1,389 gallons per month and 16,670 gallons per year.

Table 3.15 Pre and post-retrofit billing data comparison, control group (n=213)

	Avg. Daily Per Household Water Use (gallons)		**Mean Difference** (gal/day)	**t-Value**	**P-Value**	**Statistically Significant Difference?***
	1999 Pre-Retrofit	**2000 Post-Retrofit**				
Period 1 – Jan - April	144.4	137.7	-6.7	1.173	0.2421	No
Period 2 – Mar –June	170.2	158.6	-11.6	1.485	0.1391	No
Period 3 – May - Aug	218.9	251.7	32.8	3.026	0.0028	Yes
ALL – Jan - Aug	177.8	182.6	4.8	0.806	0.4210	No

*95% confidence level

For the control group, the only statistically significant change in water use was an *increase* in average daily use that occurred during Period 3. On average water use in the control group barely changed at all from 1999 to 2000. Billing data indicate an average daily per household increase of 4.8 gallons per household per day and this was not statistically significant.

These results suggest that the impacts of the retrofit can be detected through the bi-monthly billing data collected by SPU. It would be valuable to continue to track demand in this study group over the next several years to evaluate the on-going impacts of the retrofit. It should be noted that the average savings detected via the billing data were not as large as the average savings measured from the flow trace analysis effort. As described earlier in this chapter, the flow trace analysis found an average savings of 58.6 gallons per household per day or 21,400 gallons per household per year. Flow trace results provides an analysis of water use uncluttered by outdoor use, rounded or estimated meter reads. These and other factors could easily explain the different findings from the two methods. In particular outdoor use, which can vary tremendously depending on weather patterns, can easily disguise or enlarge savings from interior retrofit programs measured with billing data.

Despite the limited amount of post-retrofit billing data available at the time this report was written, the results provide strong evidence of water savings achieved as a result of the retrofit. Water use in the control group held constant from 1999 to 2000 while the study group reduced their demand by more than 27 percent.

CHAPTER 4 NEW FIXTURE SATISFACTION RATINGS

About seven months after installation of the new fixtures and appliances the study participants were asked to rate their performance. Each participating household was asked to complete a nine page, 44 question "New Product Information and Satisfaction Survey" that sought information about customer satisfaction with each of the products installed and with participation in the study. A copy of the survey instrument can be found in Appendix A and complete summaries of responses to each question along with any written comments can be found in Appendix B. Many of the questions were intentionally made identical to questions asked on the initial Audit Survey so that responses could be compared. Out of 37 participating households, 36 completed the survey, a 97 percent response rate. Numerous attempts were made to survey the final household, but the residents were uncooperative.

RESULTS

All of the equipment installed during the retrofit was kept in place during the study period with the exception of 3 faucet aerators (1 kitchen, 2 bathroom) and 3 toilet seats. Participants that removed aerators commented that the aerators installed simply restricted flow too much. The overwhelming majority of the fixtures installed were kept in place and used for the duration of the study period.

Toilets

Overall, customers were quite pleased with their new ULF toilets. Eighty-six percent of the respondents said they would recommend the fixtures to a friend and generally people preferred their new toilets over their old non-conserving models. At the same time, the participants had many recommendations for improving the toilets – particularly the toilet seats. Thirteen households (36 percent) reported a flushing or performance problem with their new toilet. Ten of these problems were related to the mechanical performance of the toilet and three were related to the toilet seat. Repairs successfully fixed flushing problems in five toilets. Of the 13 households reporting problems, 7 were equipped with Toto toilets and 6 were equipped with Caroma toilets.

Eighty percent of the households reported that their new ULF toilets never needed to be plunged during the study period. Seventeen percent said their toilet needed to be plunged less than once per month and 3 percent indicated that their toilet required plunging once per month. This suggests that the new ULF toilets required *less frequent* plunging than the old toilets removed during the retrofit. Prior to the retrofit, thirty-eight percent of the households reported that their toilets never required plunging. Forty-six percent reported infrequent plunging ranging from every other month to every other year and sixteen percent of the households reported that more frequent plunging was required for their toilet(s).

Participants reported that the level of frequent double flushing (more than once per week) decreased after the retrofit from 30 percent to 22 percent. However, occasional double flushing (a few times per year) increased from 27 percent to 47 percent. After the retrofit, 31 percent of the respondents said they never double flush their new toilets while prior to the retrofit 43 percent of the respondents indicated that they never needed to double flush.

Table 4.1 shows a comparison of the ratings of toilets before and after the retrofit in the following areas: bowl cleaning, flushing performance, appearance, noise, leakage, and maintenance. Participants rated their toilets on a scale of 1 to 5 (1 = unsatisfied and 5 = completely satisfied). There were existing ULF toilets in eight study homes prior to the retrofit that were also rated.

Table 4.1 Pre and post-retrofit toilet rating

	Pre-Retrofit		**Post-Retrofit**
Rating Category	**Non-ULF Toilets** (n=37)	**ULF Toilets** (n=8)	**ULF Toilets** (n=36)
Bowl Cleaning	3.76	3.38	4.03
Flushing performance	3.54	3.63	4.50
Appearance	3.70	3.75	4.67
Noise	3.32	3.63	4.69
Leakage	3.70	4.25	4.81
Maintenance	3.89	4.25	4.61
Overall Average	3.65	3.81	4.55

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

The new ULF toilets received substantially higher ratings in every category. The overall average was nearly one point higher for the new ULF toilets 4.55 vs. 4.65. Study participants were particularly pleased with the leakage and noise reduction associated with the new toilets. The new toilets received their lowest score for bowl cleaning, but the average rating of 4.03 equates to "somewhat satisfied". This score was higher than any score the old toilets received. It is important to remember that these ratings of the old fixtures were done while those fixtures were still in place during the audit.

The post-retrofit survey also asked participants to compare their new toilets to their old toilets in a number of ways. The results are shown in Table 4.2. Again the majority of respondents felt that the new toilets were an improvement in every way over their old fixture. Here it can be seen that 70 percent of the participants liked their new toilets more than the old ones and 14 percent liked them less. Sixty-four percent felt the new toilets clogged less frequently, 25 percent said the clogged the same amount, and 3 percent said the clogged more often.

Table 4.2 Comparison ratings of new and old toilets

Question: Compared to your old toilet…	**Response Percentages**			
	More	**Same**	**Less**	**Not Sure**
…do you like your new toilet(s)?	69.4%	11.1%	13.9%	5.6%
…do your new toilet(s) clog?	2.8%	25.0%	63.9%	8.3%
…do your new toilet(s) require double flushing?	22.2%	16.7%	61.1%	0.0%
…do your new toilet(s) require bowl cleaning?	27.8%	41.6%	27.8%	2.8%

Most people (61.1 percent) indicated that the new toilets required less frequency double flushing while 22.2 percent felt the new toilets were double flushed more. Respondents were evenly split on the subject of bowl cleaning with 27.8 percent indicating that more bowl cleaning was required and 27.8 percent indicating that less was required. Over forty percent felt that the new and old toilets performed the same in this area.

Toto vs. Caroma

Since two brands of ULF toilet were installed for this study it is possible to compare customer satisfaction ratings with both brands. These results are presented in Table 4.3. Both toilets received a favorable overall rating with the Toto edging out the Caroma 4.66 to 4.46. The Toto scored higher in two important categories – bowl cleaning and flushing performance. The

Caroma only received at rating of 3.58 for bowl cleaning. This toilet has a rather small water spot that may contribute to bowl cleaning difficulties.

Table 4.3 Customer ratings of Caroma and Toto Toilets

Rating Category	Caroma Toilets (n=19)	Toto Toilets (n=17)
Bowl cleaning	3.58	4.53
Flushing performance	4.21	4.82
Appearance	4.63	4.71
Noise	4.84	4.53
Leakage	4.89	4.71
Maintenance	4.58	4.65
Overall Average	4.46	4.66

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

In most categories the two brands were ranked similarly. The Caromas were praised for their noise level and low leakage rates. The Totos had a slight edge in appearance and maintenance. All 17 of the Toto-equipped households indicated that they would recommend the toilet to a friend. Thirteen of 19 Caroma-equipped homes said they would recommend the toilet, two respondents said they would not recommend the Caroma, and 3 respondents were unsure about making a recommendation. Overall, the Toto appeared to be the most popular toilet in the test homes, but the Caroma, which has a more experimental design and saved more water, also scored well and was popular with the majority of users.

Clothes Washers

Five of the 36 survey respondents (13.9 percent) indicated that they experienced a problem with their new clothes washer during the first six months. The problems included an improperly installed outflow hose, a broken door latch, an inability to reverse the hinges so the door could open in a convenient way, and a balance problem that turned out to be a problem with the customer's floor. Eighty-three percent of the households did not report any problems.

Most of the respondents (86 percent) liked their new clothes washer better than their old one and only 5.5 percent like it less. Eighty-nine percent said they would recommend the machine to a friend while 11 percent were unsure. None of the respondents indicated that they could not recommend their washer. An impressive 72 percent of the respondents agreed that if they were in the market for a washer they would be willing to pay a premium of $150 to get an equivalent quality conserving washer. Fourteen percent said they would not be willing to pay the extra money and another 14 percent were unsure.

Study participants rated the performance of their existing clothes washers during the initial audit interview. As part of the New Product Information and Satisfaction Survey they were asked to rate their new washer on exactly the same points. The responses to both surveys is shown in Table 4.4. Participants rated the new clothes washers higher in every single category. Of note were the substantially higher ratings of the new machines for cleaning of clothes, noise, moisture content of the clothes, and cycle selection. The new machines did not score below 4.5 in any category. The old machines did not score above 4.5 in any category. Respondents also expressed satisfaction with the wash cycle time and the detergent use of the machines. A number of respondents made comments and suggestions regarding the machines. These are presented in full in Appendix B.

Table 4.4 Comparison ratings of non-conserving and conserving clothes washers

Rating Category	**Non-Conserving Clothes Washer** (n=37)	**Conserving Clothes Washer** (n=36)
Cleaning of clothes	3.86	4.83
Reliability	4.44	4.92
Noise	3.32	4.81
Moisture content of clothes	3.50	4.64
Cycle selection	4.06	4.80
Capacity	4.30	4.56
Wash cycle time	NA	4.58
Detergent use	NA	4.61
Overall Average	3.91	4.72

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

Clothes washer ratings by brand

The same rating system shown in Table 4.4 can be used to compare the performance of the three models of clothes washer tested in this study: Frigidaire Gallery, Maytag Neptune, and Whirlpool Super Capacity Plus. These results are shown in Table 4.5. Readers are cautioned that only two Whirlpool washers were tested in this study it may not be possible to draw wider conclusions from this small sample.

Table 4.5 Comparison ratings of clothes washer by brand

Rating Category	Frigidaire Gallery (n=23)	Maytag Neptune (n=11)	Whirlpool Super Capacity Plus (n=2)
Cleaning of clothes	4.78	4.91	5.00
Reliability	4.87	5.00	5.00
Noise	4.83	4.82	4.50
Moisture content of clothes	4.48	4.91	5.00
Cycle selection	4.68	5.00	5.00
Capacity	4.43	4.73	5.00
Wash cycle time	4.57	4.55	5.00
Detergent use	4.61	4.55	5.00
Overall Average	4.66	4.81	4.94

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

All of the clothes washers received good ratings from the study participants. The Whirlpool machine was rated highest followed by the Maytag and Frigidaire. The Frigidaire Gallery received high ratings for reliability, noise, and cleaning of clothes. It's lowest scores were for capacity and moisture content of clothes. The Maytag Neptune, the most expensive washer tested, received a perfect score for reliability and high marks for cleaning of clothes, moisture content of clothes, and noise. The Whirlpool, the only top loading machine in the test, was rated highly in all categories except for noise.

Showerheads

New low-flow showerheads were installed in 34 of the 36 homes that responded to the satisfaction survey. Participants were generally satisfied with these showerheads and gave them an overall satisfaction rating of 4.58 as shown in Table 4.6. The shower heads received a favorable rating in each category and no specific problems emerged.

Seventy-five percent of the respondents said they would recommend the showerhead to a friend and only 3 percent said they would not recommend the fixture. More than 80 percent of the respondents said they liked the new showerhead the same or better than their old fixture. Fourteen percent like it less.

Table 4.6 Showerhead satisfaction ratings

Showerhead Rating Category	**Rating** (n=34)
Water flow	4.47
Flow pattern	4.47
Appearance	4.62
Clogging	4.76
Adjustability	4.56
Overall average	4.58

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

Faucet Aerators

The faucet aerators installed on most kitchen sinks and all bathroom faucets received satisfactory ratings from the study participants, but overall were the least popular product installed as part of this study. Fifty percent of the respondents would recommend the aerators to a friend, 17 percent said they would not recommend the devices, and 25 percent were not sure. Only 22 percent like the new aerators more than their old faucet fixtures and 36 percent felt they were the same. However, 28 percent liked the aerators less than their old ones.

Participants were asked to rate the performance of the aerators in a number of areas. Those results are presented in Table 4.7. All of the ratings were in the "somewhat satisfied" through "completely satisfied" range. People were most satisfied with the appearance of the aerators and least satisfied with the water flow and flow pattern. These results suggest that while these faucet aerators have a certain level of acceptability, there is plenty of room for improvement.

Table 4.7 Faucet aerator satisfaction rating

Faucet Aerator Rating Category	**Rating** (n=36)
Water flow	4.00
Flow pattern	4.12
Appearance	4.67
Clogging	4.41
Overall average	4.30

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

Study Participation

The final section of the New Product Information and Satisfaction Survey dealt with the experience of participating in the study and perceptions about behavioral changes that may have been brought about by participation. These responses can be used to improve implementation of conservation programs and similar future research efforts.

The majority of respondents (56 percent) did not feel that participating in the study had affected their water use behavior, but 28 percent did feel that their behavior had changed. Fourteen percent were not sure. Some of the comments about these changes included:

"More conscious of our water usage."

"I am more aware of wasting water."

"My showers are shorter."

"To be honest I don't think about the cost of water, as a Seattle native I have always felt we have an abundant supply. I don't bother to water lawn in the summer so it probably balances my lack of conservation in the home."

"Less multiple flushing, avoid leaving sink running, more conscious of general water use/outdoor watering. No more small washing loads."

"I am not doing as many loads of laundry because the washer capacity is greater."

"Do not do laundry unless we have a full load. We tried to take shorter showers, but we've become lax about it."

These comments suggest that for some participants, participating in the study and the water conservation educational materials that were provided had an impact upon water using habits. The water use data described earlier in this report showed that the water savings were maintained from the time the new fixtures were installed to a period about 7 months later.

Study participants were asked if they plan to remove or change any of the new products after the conclusion of the study. Sixty-seven percent said no, but 22 percent indicated that they did plan to make changes, and 11 percent were unsure. Some of the planned changes were described as follows:

"I will replace the washer back to my former top loader. It will be easier to load."

"Showerhead. Old head uses less water/ shower and has a better spray pattern."

“May put the old toilet back in. It was also a water-conserving toilet but the seat feels better. We will probably replace the kitchen aerator because of clogging.”

“One sink aerator back to old style.”

“May change some of the aerators because of spray that results from its use. May change basement toilet because of counter interference with lid.”

“I would like to put back the handheld shower in one bath. But wish it were a water-conserving model. Would trade the one I have for one that conserves water.”

“The toilet seats uncomfortable, and main floor bathroom flow rate too low, but I do not plan to change them.”

“I will only remove the aerator in our downstairs bathroom due to the problems with my children.”

Based on these comments the only substantial changes planned after the study are the removal of one conserving clothes washer and one toilet, and a number of participants plan to change out their aerators and showerheads.

An impressive 61 percent of the study participants said that they had a noticeable reduction in their water and sewer bill as a result of the fixture retrofit. Eleven percent felt there had not been a reduction and the remainder (28 percent) were unsure.

Participants were also asked to rate their experience in participating in the home water conservation study. These results are presented in Table 4.8. Most people felt completely satisfied in all aspects of participation in the study. The overall experience of participation was rated at 4.86 out of 5. Important areas for improvement include response to problems and fixture installation.

Table 4.8 Study participation satisfaction rating

Study Participation Rating Category	**Rating** (n=36)
Ease of participation	4.89
Response to problems	4.67
Scheduling convenience	4.89
Courtesy of study staff	5.00
Fixture installation	4.69
Overall experience	4.86

Rating scale from 1 – 5 where 1 = unsatisfied and 5 = completely satisfied

For complete satisfaction survey results please see Appendix B.

CHAPTER 5 ANALYSIS OF COSTS AND BENEFITS

This study was not specifically designed with cost-benefit analysis in mind, but it was possible to utilize the results to calculate cost of each conservation measure fixture and the value of the water saved. For this analysis three conservation measures were considered: toilets, clothes washers, and faucet aerators. A cost benefit analysis of showerheads was not performed because those devices did not effect a statistically significant difference in per capita use because of increased showering frequency during the post-retrofit period. For all three measures considered, the payback period calculated was less than six years. In many cases the payback period was less than three years. In addition, the cost-benefit analysis from the utility perspective indicates that for the most part all three measures would be cost-effective when compared to SPU's marginal cost of new water supply.

TOILETS

The costs and benefits of both toilets tested in this study, the Toto Drake and the Caroma Caravelle, were evaluated separately. In addition to considering the water saved by the toilet itself, the water saved through the reduction in leakage was also included because the elimination of leaks was judged to be a direct result of the toilet retrofit. The water saved and the value of that water are shown in Table 5.1.

As discussed earlier, although both models of ULF toilets tested in this study saved water, the Caroma Caravelle toilets saved more water than the Toto Drake. Water saved through the elimination of leaks in these houses was also added to the savings. The value of saved was set at $6.48 per hundred cubic feet (ccf) or $4.85 per kgal, which is the sum of the Seattle Public Utilities water and wastewater charges. The savings attributed to the Caroma Caravelles were valued at $136.29 per year while the savings from the Toto Drakes were valued at $102.46 per year.

Table 5.1 Water reduction and cost savings from ULF toilets

Toilet Brand	Toilet Model	Annual Per Capita Water Savings* (gal)	Annual per Household Savings (gal)	Annual per Household Savings (ccf)	Water & Sewer Cost per ccf**	Water and Sewer Savings per Year
Toto	Drake	4,712	11,827	15.8	$6.48	$102.46
Caroma	Caravelle	6,268	15,733	21.0	$6.48	$136.29

*Includes water saved from toilet retrofits and reduction in leakage
*$6.48 = $2.16 per ccf for water and $4.32 per ccf for wastewater

The toilets tested in this study were priced in the middle range of toilet products that can run from $80 -$800 per toilet. The Toto Drake retails for approximately $280 and the Caroma Caravelle for about $150. Installation costs vary, but for the cost-benefit analysis it was assumed that a professional plumber performed the work at a cost of $120 per toilet. Results of the cost-benefit analysis for toilets are shown in Table 5.2. The incremental cost for toilets was assumed to be 50 percent on the total installed cost. This is based on the assumption that each new toilet replaces a fixture that has one-half of its economic life remaining.

Table 5.2 Costs and payback period of ULF toilets

Toilet Brand	Toilet Model	Cost per Toilet	Cost of Installation per Toilet	Toilets Installed per House	Incremental Cost*	Annual Water & Sewer Savings	Payback period (years)
Toto	Drake	$ 280	$ 120	2	$ 400	$102.46	3.9
Caroma	Caravelle	$ 150	$ 120	2	$ 230	$136.29	2.0

*Set at 50 percent of the total installed cost

Given the annual water and sewer savings shown in Table 5.1, the payback period for installing two Toto Drake toilets (the average installed in this study) is just under four years and for the 1.7 Caroma Caravelle toilets installed for this study is only 2.0 years. The payback period for these toilets is quite short given the expected product life of 20 years. From the customer's perspective installing either of these toilet models makes sound economic sense.

Utility Cost Savings

To measure utility water conservation savings benefits, SPU calculates its marginal cost of water supply at $1.67 per ccf. For the utility rate-payer cost-effectiveness perspective, SPU calculates the "levelized" cost of the conservation measure and compares it to its marginal cost of water supply. The levelized cost is calculated as the economic cost of the measure divided by the measure's lifetime savings. Based on the savings and costs above, and assuming a 20 year life for the new toilets, the average levelized cost for the two toilet models installed is $1.22/ccf, which compares favorably to SPU's marginal cost of water of $1.67/ccf.

Table 5.3 shows the annual utility cost savings associated with the installation of ULF toilets. SPU saves between $17 and $23 per year per ULF toilet in various water and treatment costs. These savings can provide justification for incentive programs such as toilet rebates that encourage installation of high efficiency products.

Table 5.3 Utility cost savings from ULF toilets

Toilet Brand	**Toilet Model**	**Annual Water Savings per household** (ccf)	**Utility Cost Savings per ccf**	**Annual Savings**
Toto	Drake	15.8	$1.22	$19.28
Caroma	Caravelle	21.0	$1.22	$25.62

CLOTHES WASHERS

High efficiency clothes washers like those evaluated in this study typically cost more than traditional washers because they utilize the latest technology, offer more settings and options, and have spin speeds that are often twice as fast as older models. The three washer models tested in this study included two front loading horizontal axis washers – the Frigidaire Gallery and the Maytag Neptune; and one top loading machine the Whirlpool Super Capacity Plus. Because costs differed widely and each machine offered different options, the costs and benefits of each machine was evaluated individually.

Table 5.4 shows the annual water savings for each clothes washer based on an average of 2.51 residents per household. The Whirlpool and Frigidaire machines each reduced demand by about 7.5 ccf per year while the Maytag saved 5.7 ccf per year. The dollar savings for water and sewer charges are also shown in this table as well as an estimate of the annual energy savings from reduced hot water demand and reduced clothes drying time.

Energy savings were estimated using the EPA Energy Star clothes washer savings calculator and a very conservative assumed energy cost of $0.07 per kilowatt-hour (kWh). This calculator utilizes data about each machine provided by the manufacturer along with user inputs to calculate savings. The machines used in this study have faster spin speeds than conventional washers, resulting in less remaining moisture in the clothes, and shorter drying times. In Seattle, most homes use driers. As a result, the retrofit washers save energy both by using less hot water and by reducing drying time.

Table 5.4 Water reduction and cost savings from conserving clothes washers

Washer Brand	**Washer Model**	**Annual per Capita Water Savings** (gal)	**Annual per Household Savings*** (ccf)	**Water & Sewer cost per ccf**	**Water & Sewer Savings per Year**	**Energy Savings per Year****
Frigidaire	Gallery	2201	7.4	$6.48	$47.86	$34
Maytag	Neptune	1711	5.7	$6.48	$37.20	$51
Whirlpool	Super Capacity Plus	2223	7.5	$6.48	$48.34	$27

*Assumes 2.51 people per household.
**Calculated from the EPA Energy Star clothes washer savings calculator. Based on $0.07 per kWh

Washer costs were based upon an average per model cost using actual customer sales receipts from participants in Seattle's clothes washer rebate program. These data are shown in Table 5.5. Incremental costs were calculated as the price difference between the high efficiency washer and product of comparable quality from the same manufacturer. Clearly less expensive washing machines are available, but they do not offer nearly as many features or the same level of quality as the machines tested in this study. The Maytag Neptune was the most expensive machine with an average price of $1066 and a comparable Maytag top loading machine could be purchased for $550. The Frigidaire Gallery cost $702 and Frigidaire sells a comparable top loader for $495. The Whirlpool Super Capacity Plus cost $556 and similar non-conserving Whirlpool top loading machine can be purchased for $489.

The customer payback period for the clothes washers ranged from less than one year for the Whirlpool to just under six years for the Maytag. With an expected useful product life of 13 years[12], all of these washers effect a net cost savings. However, the Whirlpool and Frigidaire machines appear to offer much more rapid payback periods. Arguments can be made for the quality and features of the Maytag and many consumers have selected that machine in spite of the high price tag. As discussed in Chapter 4, all three machines received high satisfaction ratings from the participants in this study.

Table 5.5 Costs and payback period for conserving clothes washers

Brand	Cost	Comparable Washer Cost (same brand)	Incremental Cost	Annual Cost Savings*	Payback period (years)
Frigidaire	$ 702	$ 495	$ 207	$81.86	2.5
Maytag	$ 1,066	$ 550	$ 516	$88.20	5.9
Whirlpool	$ 556	$ 489	$ 67	$75.34	0.9

*Water and wastewater + energy savings

Utility Cost Savings

From the utility perspective, assuming a 13-year product life, the average levelized cost for the three models of washers installed is $1.10/ccf.[13] The levelized cost compares favorably to SPU's marginal water supply cost of $1.67/ccf. These results are shown in Table 5.6. The clothes washers provide less than half the annual benefit of ULF toilets because they don't save as much water.

Table 5.6 Utility cost savings from conserving clothes washers

Washer Brand	Washer Model	Annual Water Savings per household (ccf)	Utility Cost Savings per ccf	Annual Savings
Frigidaire	Gallery	7.4	$1.10	$8.12
Maytag	Neptune	5.7	$1.10	$6.32
Whirlpool	Super Capacity Plus	7.5	$1.10	$8.21

[12] Current national average (Department of Energy)
[13] The levelized cost calculation credits incremental washer costs to water and energy in proportion to their respective benefits.

FAUCET AERATORS

Faucet aerators are perhaps the most inexpensive conservation measure available. These devices can be purchased in bulk for just a few cents each or individually for dollar or two. While the water savings from the faucet aerators tested in this study were not overwhelming, the per capita savings was found to be statistically significant. The calculated annual water savings and cost benefits for these devices are shown in Table 5.7. On average the faucet aerators saved 1.5 ccf per household – a financial benefit of $9.52 per year.

Table 5.7 Water reduction and cost savings from faucet aerators

Brand	**Annual Per Capita Water Savings** (gal)	**Annual per household savings** (gal)	**Annual per household savings** (ccf)	**Water & Sewer cost per ccf**	**Water and Sewer Savings per Year**
New Resources	438	1099	1.5	$6.48	$9.52

Installation costs for faucet aerators can vary tremendously depending of the number of aerators installed and who performs the installation. For this analysis it was assumed that the homeowner would replace all aerators in a household. Total cost for the faucet retrofit was generously estimated at $15, $10 for the hardware and $5 for installation time. This results in a payback period of 1.6 years for the aerators, as shown in Table 5.8. Even if the aerators are given a useful product life of three years due to clogging, the benefits to the customer still substantially outweigh the costs. Given the above results, and assuming a life of 5 years, aerators have a levelized cost of $1.49/ccf, which compares favorably to SPU's marginal cost of $1.67/ccf.

Table 5.8 Cost and payback period for faucet aerators

Aerator Brand	**Hardware Cost**	**Installation**	**Annual Water & Sewer Savings**	**Payback period (years)**
New Resources	$ 10	$ 5	$9.52	1.6

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

RESEARCH FINDINGS

The Seattle Home Water Conservation Study found that significant, verifiable indoor water savings can be achieved through the installation of high efficiency plumbing fixtures and appliances. Not only did these high efficiency fixtures save water, participants reported that they worked better than their old non-conserving fixtures, and an analysis of benefits and costs showed that these products easily pay for themselves in water and sewer cost savings in just a few years.

In this study, 37 single-family homes were retrofit with new toilets, clothes washers, showerheads, and faucet aerators. Precise data on the quantify of water used for each end use was measured before and after the retrofit so that the savings effected by each device could be evaluated. The retrofit program implemented in this study resulted in an average reduction of 39 percent in per household water use from 150.7 gpd to 92.1 gpd. On an annual basis this equates to a savings of 21.4 kgal per household.

Per Capita Use

In most homes, indoor residential water demand can be reduced to a level at or below 40 gcd by retrofitting with high efficiency fixtures and appliances. Average daily per capita use decreased in 35 on the 37 study homes. After the retrofit, toilet usage, which had previously been the largest component of indoor use dropped below faucets into fourth place. Clothes washers became the largest indoor water use followed by showers, and faucets. The combination of showers and baths actually form the largest block of indoor use in the post-retrofit era at 28.4 percent. Overall, indoor water per capita use decreased to below 40 gcd – a 37.2 percent drop. Baseline per capita use was measured at 63.6 gcd and after the retrofit per capita use was only 39.9 gcd.

More than 20 gallons of the 23.6 gcd average saved through the retrofit was the result of three end uses: toilets, clothes washers, and leaks. Per capita use for toilet flushing was 2.2 gcd lower in homes with the dual flush toilets than with the standard 1.6 gpf toilets. If dual flush toilets were had been used exclusively in this study, per capita daily indoor use may have dropped below 38 gcd. The post retrofit per capita flushing rate increased by 0.29 flushes per person per day (from 5.14 to 5.46), but this was not statistically significant at the 99% confidence level. Even if it were significant, double flushing is a very minor factor, and does not impact the overall savings from ULF toilets. This study found that the installation of ULF toilets reduced water use by an average of 10.9 gcd.

The leakage savings were almost certainly the result of the toilet retrofit. Toilet leaks, primarily flapper leaks, are the single largest contributor to household leakage. In this study, replacing old toilets through the retrofit eliminated almost all of these toilet leaks and resulted in substantial savings. None of the other measures implemented through this study (clothes washers, showerheads, or faucet aerators) should have had any impact on the leakage rate, although it is known that at least one study participant repaired a substantial faucet leak (44 gcd) about the time of the retrofit. The new conserving clothes washers saved an average of 5.6 gcd. A reduction in leakage resulted in savings of 4.3 gcd.

Statistically significant reductions in water use occurred in most of the end use categories impacted by the retrofits: toilets, faucets, leaks and clothes washers. Showers did not show any significant water use reduction, even though new showerheads were installed. The remaining categories not targeted by the retrofit (baths and dishwashers) also showed no change. Mean per capita faucet use was reduced by 1.2 gcd (13.1 percent) after the installation of faucet aerators. But mean per capita shower usage only decreased by 0.3 gcd (3.8 percent) in spite of the installation of LF showerheads in many of the study homes.

Customer Satisfaction with New Products

About seven months after installation of the new fixtures and appliances the study participants were asked to rate their performance. Each participating household was asked to complete a “New Product Information and Satisfaction Survey” that sought information about customer satisfaction with each of the products installed and with participation in the study. Many of the questions were intentionally made identical to questions asked on the initial Audit Survey so that responses could be compared.

The results of the survey were extremely favorable to the new high efficiency fixtures and appliances particularly toilets and clothes washers. This is perhaps surprising given the often repeated assertions (often based on unscientific anecdotal evidence) that these devices are less satisfactory. The new ULF toilets were uniformly rated higher in performance than any of the old toilets and second, looking strictly at the old toilets, the customers preferred the ULF models to the standard toilets. With respect to the new ULF toilets used for this study, it should suffice to note that they were rated higher in every category.

Most of the respondents (86 percent) liked their new clothes washer better than their old one and only 5.5 percent like it less. Eighty-nine percent said they would recommend the machine to a friend while 11 percent were unsure. None of the respondents indicated that they could not recommend their washer. An impressive 72 percent of the respondents agreed that if they were in the market for a washer they would be willing to pay a premium of $150 to get an equivalent quality conserving washer. Fourteen percent said they would not be willing to pay the extra money and another 14 percent were unsure. Participants rated the new clothes washers higher in every single category. Of note were the substantially higher ratings of the new machines for cleaning of clothes, noise, moisture content of the clothes, and cycle selection.

Cost-Benefit Analysis

This study was not specifically designed with cost-benefit analysis in mind, but it was possible to utilize the results to calculate cost of each conservation measure fixture and the value of the water saved. For this analysis three conservation measures were considered: toilets, clothes washers, and faucet aerators. A cost benefit analysis of showerheads was not performed because those devices did not effect a statistically significant difference in per capita use because of increased showering frequency during the post-retrofit period. For all three measures considered, the payback period calculated was less than six years. In many cases the payback period was less than three years.

Toilets

The costs and benefits of both toilets tested in this study were evaluated separately. In addition to considering the water saved by the toilet itself, the water saved through the reduction in leakage was also included because the elimination of leaks was judged to be a direct result of the toilet retrofit. As discussed earlier, although both models of ULF toilets tested in this study saved water, the Caroma Caravelle toilets saved more water than the Toto Drake. Water saved through the elimination of leaks in these houses was also added to the savings. The value of saved was set at $6.48 per hundred cubic feet (ccf), which is the combination of the Seattle Public Utilities in-city charges for water and wastewater. The savings attributed to the Caroma Caravelles were valued at $136.29 per year while the savings from the Toto Drakes were valued at $102.46 per year.

The toilets tested in this study were priced in the middle range of toilet products that can run from $80 -$800 per toilet. The Toto Drake retails for approximately $280 and the Caroma Caravelle for about $150. Installation costs vary, but for the cost-benefit analysis it was assumed that a professional plumber performed the work at a cost of $120 per toilet. The incremental cost for toilets was assumed to be 50 percent on the total installed cost.

Given the annual water and sewer savings, the payback period for installing two Toto Drake toilets (the average installed in this study) is just under four years and for the 2 Caroma Caravelle toilets installed for this study is only 2.0 years. The payback period for these toilets is quite short given the expected product life of 20 years. From the customer's perspective installing either of these toilet models makes sound economic sense.

Clothes washers

High efficiency clothes washers like those evaluated in this study typically cost more than traditional washers because they utilize the latest technology, offer more settings and options, and have spin speeds that are often twice as fast as older models. The three washer models tested in this study included two front loading horizontal axis washers – the Frigidaire Gallery and the Maytag Neptune; and one top loading machine the Whirlpool Super Capacity Plus. Because costs differed widely and each machine offered different options, the costs and benefits of each machine was evaluated individually.

The Whirlpool and Frigidaire machines each reduced demand by about 5.61 kgal (28.4 kL) per year while the Maytag saved 5.7 ccf (21.6 kL) per year. The dollar savings for water and sewer charges are also shown in this table as well as an estimate of the annual energy savings from reduced hot water demand and reduced clothes drying time.

Energy savings were estimated using the EPA Energy Star clothes washer savings calculator and an assumed energy cost of $0.07 per kilowatt-hour (kWh). This calculator utilizes data about each machine provided by the manufacturer along with user inputs to calculate savings. The Maytag offers the most energy savings because it has the fastest spin speed (800-1000 rpm) which leaves clothes drier, thus substantially reducing drying time. The Frigidaire spin speed is 700 rpm and the Whirlpool spins at 600-650 rpm. A traditional top loading washer's spin speed is typically 400 rpm.

Washer costs were based upon the actual prices paid during the past year by customers in Seattle who participated in SPU's clothes washer rebate program. Al Dietemann of SPU maintains records of the installed retail price paid for each washer by make and model. Incremental costs were calculated as the price difference between the high efficiency washer and product of comparable quality from the same manufacturer. Clearly less expensive washing machines are available, but they do not offer nearly as many features or the same level of quality as the machines tested in this study. The Maytag Neptune was the most expensive machine with an average price of $1066 and a comparable Maytag top loading machine could be purchased for $550. The Frigidaire Gallery cost $702 and Frigidaire sells a comparable top loader for $495. The Whirlpool Super Capacity Plus cost $556 and similar non-conserving Whirlpool top loading machine can be purchased for $489.

The payback period for the clothes washers ranged from less than one year for the Whirlpool to just under six years for the Maytag. With an expected useful product life of 10 years, all of these washers effect a net cost savings. However, the Whirlpool and Frigidaire machines appear to offer much more rapid payback periods. Arguments can be made for the quality and features of the Maytag and many consumers have selected that machine in spite of its higher price. All three machines received high satisfaction ratings from the participants in this study.

Faucet aerators

Faucet aerators are perhaps the most inexpensive conservation measure available. These devices can be purchased in bulk for just a few cents each or individually for dollar or two. While the water savings from the faucet aerators tested in this study were not overwhelming, the per capita savings was found to be statistically significant. On average the faucet aerators saved 1.5 ccf per household – a financial benefit of $9.52 per year.

Installation costs for faucet aerators can vary tremendously depending of the number of aerators installed and who performs the installation. For this analysis it was assumed that the homeowner would replace all aerators in a household. Total cost for the faucet retrofit was generously estimated at $15, $10 for the hardware and $5 for installation time. This results in a payback period of 1.6 years for the aerators. Even if the aerators need to be replaced every three years, which is an unusually short life span, the benefits still substantially outweigh the costs.

RECOMMENDATIONS

The results from this study make it clear that residential retrofits are a cost-effective tool for saving water and that customers are quite satisfied with the performance of the new high efficiency toilets and clothes washers currently available. These results provide powerful evidence of the effectiveness of interior water conservation measures and justification for continued support of efficiency programs across the country.

The effects of conservation retrofits is an important area for future research. Clearly, the more sites that can be included in similar projects, the better and more reliable the results will be for generalizing to wider populations. Examination of the variability in the reductions in water use across several cities is an essential part of a determination the ability to make generalizations from the results. This should include studies at other sites using the same research approach. Two such studies are in the planning phases in Oakland, CA and Tampa, FL. Other sites, especially from the REUWS group would be useful.

In addition, tracking the consumption of the Seattle group via billing data, and collecting more end use data after 2 years or more time has elapsed is an important to confirm the stability of the savings.

Future studies should also include additional water saving technology such as instant hot water systems and hands free faucet controllers. While these may not be economically justified strictly on the basis of water savings, many customers or builders may wish to include them for their convenience, and their water savings should be evaluated.

APPENDIX A
AUDIT AND SURVEY FORMS

AUDIT FORM

CUSTOMER DATA

Customer Name____ Keycode __________

Service Address____

____

Date of Audit ____________________ Time of Audit ____________________

1. Total number of full-time residents __________________
   - Children (0-12 yrs) ____________
   - Teens (13-19 yrs) ____________
   - Adults (20+) ____________

2. Here during baseline logging period? __________________
   - Number absent ____________
   - Dates not present ____________

3. When did you move to this house? ____________

4. Year was the house built? ____________

5. Floor area of the house ____________

6. Number of stories ____________

7. Garage size *(1 car, 2 car, etc.)* ____________

8. Number of bedrooms ____________

9. Full baths ____________ 3/4 baths ___________ 1/2 baths _________

10. Irrigation system? ________________ # of zones _________________

SURVEY QUESTIONS

1. How many showers per week are taken outside the home? *(at school, work, swimming pool, health club, etc)* ____________________________

2. During a typical week day, (9am – 5pm) how many people are at home? ________________

3. Is there a home office in this home? _________________

If so, do people come into the house to work? ___________________

4. Are there any other business activities in the home? _________________________________

5. During the next two weeks how often do you expect to irrigate your yard?

0______ 1-2 times_______ 3-5 times ________ more than 5 times ________

6. Do you ever do laundry at a laundromat or laundry service? *(outside the home)* ___________

7. What times of day do most showers occur in your home? ____________________________

8. How often do people in the home take baths? *(instead of or in addition to showers)*

Daily_____ Weekly _______ Monthly _________ Yearly ________

9. When was the last time you had a problem with your existing toilet? ___________________

10. Please describe the nature of this problem? _______________________________________

11. How frequently do you have to use a plunger on your existing toilets?

Daily_____ Weekly _______ Monthly _________ Yearly ________

12. How frequently do you have to "double flush" your current toilets?

Daily_____ Weekly _______ Monthly _________ Yearly ________

13. How satisfied are you with your current toilets in the following areas? *(unsatisfied 1-5 completely satisfied)*

		"non-ULF"	ULF (if any)
a)	Bowl cleaning	____________	____________
b)	Flushing performance	____________	____________
c)	Appearance	____________	____________
d)	Noise	____________	____________
e)	Leakage	____________	____________
f)	Maintenance	____________	____________

14. How satisfied are you with your current clothes washer in the following areas? *(unsatisfied = 1 – 5=completely satisfied)*

a) Cleaning of clothes ____________

b) Maintenance/reliabilty ____________

c) Noise ____________

d) Moisture content of clothes ____________

e) Cycle selection ____________

f) Capacity ____________

15. What interested you in participating in this study? *(check all that apply)*

Free products _____ Water conservation ______ Help the environment _______

Civic duty ______ None of these ________ *Please describe* __________________________

16. Expected # of home car washes this month___________________
17. Expected # of sidewalk/driveway washes per month _________________

KITCHEN INFO

18. Dishwasher make ________________ Model _________________

Preferred wash setting _____________________________

19. Kitchen faucet make ______________ Time ___________ Leak_________

Aerator? *(Y/N/DK)* ______________ Hand sprayer? *(Y/N/DK)* ____________

20. Home water treatment? *(Y/N/DK)* ________ Make/model _________________

Point of Entry _________ Point of Use ________________ Regen? ______________

21. On demand hot water? *(Y/N/DK)* ________ Make/model _________________
(Recirculating hot water system)

Serving which fixtures? ____

22. Ice maker on fridge? ________________

23. Garbage disposal? ___________________

UTILITY/OTHER

24. Clothes washer make __________ Model ________Year *(if known)*___________

25. Utility sink? _____________Time ___________Leak_________

26. Swimming pool? _______ Length_______ Width_______ Avg. Depth _______

Fill method _______________________ Fill timing ________________________

27. Hot tub *(not in bathroom)*? _______Length______ Width______ Avg. Depth _______

Fill method _______________________ Fill timing ________________________

28. Other water using fixtures or items of note:
Hot water meter installed?

BATHROOM INFORMATION

		1	2	3	4	5
29	Description (master, guest, kids)					
30	Size (full, ¾, 1/2)					
31	LEAKS					
32	TOILET Make					
33	Toilet model					
34	Year of manufacture					
35	Time of flushes					
36	ULF or dual flush?					
37	BATH?					
38	Size of tub (length, width, depth)					
39	Time of bath					
40	SHOWER?					
41	Type of showerhead					
42	Time of shower					
43	SINK?					
44	Aerator?					
45	Time of sink					
46	Other?					
47	Other?					

OUTDOORS

48. Number of hose bibs _________________ Times 1 ______________2____________

Leaks____________

49. Front yard landscape description ____

50. Quality score *(poor = 1, excellent = 5)* _____________

51. Back yard landscape description ____

52. Quality score *(poor = 1, excellent = 5)* _____________

NEW PRODUCT INFORMATION AND SATISFACTION SURVEY

Please take a few minutes to complete this survey about your new conserving fixtures. Your answers will help us select the best products for water conservation programs in our area. When you have completed the survey, simply fold it in half and place it in the addressed and stamped envelope provided. Thank you very much for your assistance.

CUSTOMER DATA

Customer Name: Keycode:

Address:

Please review the following information about the new products installed in your home and correct any errors.

Number of new toilets? Correct information: ___________________

New faucet aerators? Correct information: ___________________

New showerheads? Correct information: ___________________

Kitchen aerator installed? Correct information: ___________________

Toilet brand? Correct information: ___________________

Clothes washer brand? Correct information: ___________________

1. Have any of the above products installed for this study been removed or changed?

   ❑ Yes ❑ No ❑ Not sure

2. If yes, please list those removed or changed and explain why. ______________________

____

____

TOILETS

3. Have you experienced any flushing or performance problems with your new toilet(s)?

❑ Yes ❑ No ❑ Not sure

4. If yes, please describe the nature of these problems. ________________________________

____

5. If you had problems, did you request a repair?

❑ Yes ❑ No ❑ Not sure

6. If you requested a repair, was the repair completed to your satisfaction?

❑ Yes ❑ No ❑ Not sure

7. How frequently do you have to use a plunger on your new toilet(s)?

❑ Daily ❑ Weekly ❑ Monthly ❑ Less than monthly ❑ Never

8. How frequently do you have to "double flush" your new toilet(s)?

❑ Daily ❑ Weekly ❑ Monthly ❑ Less than monthly ❑ Never

9. On a scale of 1 – 5, how satisfied are you with your new toilets in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

g) Bowl cleaning	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
h) Flushing performance	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
i) Appearance	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
j) Noise	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
k) Leakage	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
l) Maintenance	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5

10. Compared to your old toilets, do you like your new toilet(s)?

❑ More ❑ Same ❑ Less ❑ Not sure

11. Compared to your old toilets, do your new toilet(s)?

a) Clog…	❑ More	❑ Same	❑ Less	❑ Not sure
b) Require double flushing…	❑ More	❑ Same	❑ Less	❑ Not sure
c) Require bowl cleaning…	❑ More	❑ Same	❑ Less	❑ Not sure

12. Would you recommend your new toilet to others?

❑ Yes ❑ No ❑ Not Sure

13. If your new toilet(s) have a dual flush feature (two flush buttons), how often do you use the "half flush" button?

❑ Don't have dual flush ❑ Never ❑ Less than half the time

❑ About half the time ❑ More than half the time ❑ Always

14. If there were one thing you would want the manufacturer of your toilets to change, what would it be?____

____

____

15. Other comments about your new toilet(s):____

____

____

CLOTHES WASHER

16. Have you experienced any problems with your new clothes washer?

❑ Yes ❑ No ❑ Not sure

17. If yes, please describe any problems with your new clothes washer. ____________________

____

____

18. On a scale of 1 – 5, how satisfied are you with your new clothes washer in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

a) Cleaning of clothes	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
b) Maintenance/reliability	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
c) Noise	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
d) Moisture content of clothes	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
e) Cycle selection	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
f) Capacity	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
g) Wash cycle time	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
h) Detergent use	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5

19. Does your new clothes washer have an extra rinse option?

❑ Yes ❑ No ❑ Not sure

20. If your clothes washer has an extra rinse option, how often do you use it?

❑ Always ❑ Sometimes ❑ Never ❑ Not sure

21. Compared to your old clothes washer, do you like the new clothes washer?

❑ More ❑ Same ❑ Less ❑ Not sure

22. Would you recommend your new clothes washer to others?

❑ Yes ❑ No ❑ Not sure

23. You received your new washer free as part of this study. But, if you were *buying* a washer, would you pay $150 more for your new washer than for an equivalent quality, conventional (i.e., top-loading, non-water saving) model?

❑ Yes ❑ No ❑ Not sure

24. If there were one thing you would want the manufacturer of your new clothes washer to change, what would it be? ____

____

____

25. Other comments about your new clothes washer:_______________________________

____

____

SHOWERHEADS

Only answer the following questions if you received new showerhead(s).

26. On a scale of 1 – 5, how satisfied are you with the performance of your new showerhead in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

a) Water flow	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
b) Flow pattern	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
c) Appearance	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
d) Clogging	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
e) Adjustability	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5

27. Would you recommend your new showerhead(s) to others?

❑ Yes ❑ No ❑ Not Sure

28. Compared to your old showerhead(s), do you like your new showerhead(s)?

❑ More ❑ Same ❑ Less ❑ Not sure

29. Compared with your old showerhead(s), is your showering time with your new showerhead(s)?

❑ Shorter ❑ About the same ❑ Longer ❑ Not sure

30. Other comments about your new showerhead(s):______________________________________

____

____

FAUCET AERATORS

Only answer the following questions if you received new faucet aerators.

31. On a scale of 1 – 5, how satisfied are you with the performance of the new aerator(s) installed on your faucets in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

a) Water flow	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
b) Flow pattern	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
c) Appearance	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
d) Clogging	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5

32. Would you recommend your new faucet aerators to others?

❑ Yes ❑ No ❑ Not Sure

33. Compared to your old aerators, do you like the new aerators?

❑ More ❑ Same ❑ Less ❑ Not sure

34. Other comments about your new aerators: ____

____

____

STUDY PARTICIPATION

35. Have you changed any of your water use behaviors as a result of participating in this study?

❑ Yes ❑ No ❑ Not sure

36. If yes, please describe the changes in your water use behaviors. ________________________

____

____

37. Do you plan on removing or changing any of the new products after the conclusion of this study *(fall 2000)*?

❑ Yes ❑ No ❑ Not sure

38. If yes, please list those you plan to remove or change and explain why. __________________

____

____

39. Have you noticed any reduction in your water and sewer bill as a result of participating in this study?

❑ Yes ❑ No ❑ Not sure

40. If yes, by about how much do you think your bill has gone down?

❑ Less than 5% ❑ 5-10% ❑ 11-20% ❑ 21-30% ❑ More than 30%

41. On a scale of 1 – 5, rank your experience participating in the home water conservation study in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

a) Ease of participation	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
b) Response to problems	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
c) Scheduling convenience	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
d) Courtesy of study staff	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
e) Fixture installation	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5
f) Overall experience	❑ 1	❑ 2	❑ 3	❑ 4	❑ 5

42. Please respond to the following statement: "I feel my home has been improved by the installation of the water conserving products in this study".

❑ Strongly agree ❑ Agree ❑ Neutral ❑ Disagree ❑ Strongly Disagree

43. If there were one thing you would change about the study, what would it be? ______________

____

____

44. Other comments: ____

____

____

Thank you for completing this survey. Please place the survey form in the pre-addressed and stamped envelope provided, and place it in the mail.

HOME WATER CONSERVATION STUDY
Participation Agreement

This Home Water Conservation Participation Agreement (“Agreement”) is made between The City of Seattle acting by and through Seattle Public Utilities (“SPU”) and ________________ ____________________________________, the owner(s) (“Participant”) of the home located at ____ (“Home”).
In consideration of the mutual promises contained herein, Participant and SPU agree as follows:

AGREEMENT

1. Purpose and Nature of Study

A. The Home Water Conservation Study (the “Study”) will measure impacts on water use resulting from the replacement of certain existing water using fixtures and appliances (“Existing Appliances”) with new fixtures and appliances that are designed to save water (“Study Appliances”). Study Appliances will include some or all of the following: washing machine, toilets, showerheads and faucet aerators. SPU or its assigned contractors will replace Existing Appliances with Study Appliances, connect the Study Appliances to Participant’s plumbing system, and install equipment that monitors water use. Details of the Study are included in the Project Description as Exhibit A.

B. SPU will be responsible for all Study costs, including the removal of Existing Appliances, the purchase, installation and connection of Study Appliances, and the purchase, installation and removal of water use monitoring equipment. At the conclusion of the Study, all Study Appliances will become the property of Participant, at no cost to Participant.

C. The Study will include up to five visits to Participant's home by SPU staff or that of its assigned contractors. The purpose of these visits includes initial inspection of Home for suitability (as described below), installation and removal of water use monitoring equipment; removal of Existing Appliances and installation of Study Appliances, and collection of data from the water monitoring equipment. Approximate dates and requirements for the visits are included in the Project Description as Exhibit A.

D. Participant and SPU agree that only homes with existing plumbing conditions which, in the opinion of SPU, are able to support the safe replacement of Existing Appliances with Study Appliances without significant repairs or modifications of the Home or its plumbing system will be included in the Study. The parties further agree that SPU staff or that of its assigned contractors shall make an initial inspection to determine suitability of the Home for the Study. Such inspection shall be limited to those portions of Participant’s plumbing system directly involved in the replacement of the Study Appliances (“Study Plumbing”), and not other portions of Participant’s plumbing system (“Other Plumbing”).

E. The Study will begin on the date this Agreement is signed by Participant and SPU, and will conclude October 1, 2000.

2. Installation of Fixtures and Appliances

A. SPU staff or that of its assigned contractors, at SPU's cost and expense, will replace Participant's Existing Appliances with Study Appliances selected by SPU from those described in the Project Description in Exhibit A. Selection of brands or models by Participant is not guaranteed or implied.

B. SPU makes no representation or warranty (1) that Participant will be satisfied with the performance of the Study Appliances or (2) that Study Appliances actually will use less water than Existing Appliances

C. SPU reserves the right to reclaim the Study Appliances if (1) Participant chooses to terminate this Agreement prior to the Study's conclusion, (2) Participant's home is sold or rented prior to September 1, 2000, or (3) Participant does not meet its obligations under this Agreement. If SPU chooses to reclaim the new fixtures upon early termination of this Agreement, it will restore Participant's Existing Appliances to pre-Study conditions.

3. Connections to Plumbing System.

SPU staff or its assigned contractors will make necessary connections to Participant's Study Plumbing. Such connections may include reasonable, inexpensive plumbing repairs required to ensure the proper functioning of the Study Appliances. SPU reserves the right to terminate this Agreement if, after the initial inspection, conditions are revealed which require repairs deemed by SPU to be unreasonable. In this case, SPU will restore Participant's Existing Appliances and Study Plumbing to pre-Study conditions. All work done on Participant's Study Plumbing will be done under the oversight of a licensed plumber under the general direction of SPU.

4. Limits of SPU's Responsibility

A. SPU will not be responsible for any cost or work that is not directly related to the removal of Existing Appliances, the installation of Study Appliances, their proper functioning, and the connection of the Study Appliances to Study Plumbing. Any modifications beyond those described in the previous sentence, including any remodeling or cosmetic changes that might be desired by Participant, must be pre-arranged and approved by SPU prior to being undertaken and must not interfere with the Study design or schedule. Participant shall conduct or contract for such modifications and be solely responsible for their cost.

B. SPU will assume no liability for any loss or damage related to the Other Plumbing.

C. Except as otherwise specified in this Agreement, SPU will not restore Existing Appliances.

5. Requirements for Participation

A. Participant agrees that if, upon initial inspection, SPU determines that the existing plumbing conditions are unsuitable for inclusion in the Study, SPU may terminate this Agreement, with no further obligation on the part of SPU or Participant. Participant agrees that

SPU also may terminate this Agreement pursuant to Section 3 and other provisions of this Agreement

B. Participant shall cooperate with scheduling, be available for visits as described in Section 1 and Exhibit A, provide information of the type described in this Agreement as requested by SPU, and permit reasonable access to the Home for Study purposes.

C. Participant shall not disturb, tamper with, or remove any of the water monitoring equipment installed for this Study. Participant will not replace, disconnect, modify or intentionally damage any of the Study Appliances prior to the conclusion of the Study.

D. Participant shall provide SPU with data on household characteristics, including number and ages of household members, water using fixtures and appliances, water use practices, and other information pertaining to the Study, as requested.

E. Participant voluntarily agrees to join in the Home Water Conservation Study.

6. Study Data.

All information obtained from this Study will be the sole property of SPU. The information will be used for statistical purposes only. Unless otherwise required by law, SPU will make no public disclosure of any information about Participant's person, family, Home, address, or water consumption.

7. Release.

Participant releases and agrees to hold harmless the City of Seattle, its officers, employees and contractors, from any and all claims, losses, harms, costs, liabilities, damages and expenses (collectively, "Losses") directly or indirectly resulting from or related to Participant's participation in the Study, except as such Losses directly result from the removal of Existing Appliances, the installation of Study Appliances, the connection of the Study Appliances to the Study Plumbing, or the installation, use or removal of the equipment to monitor water use.

8. Representations.

Participant represents that he/she/they has the authority to execute this Agreement and to authorize installation of the Study Appliances and water use monitoring equipment. Participant also represents that there are no other agreements between SPU and Participant, oral or written, concerning the Study. In witness whereof, the parties have executed this Agreement on the dates indicated below.

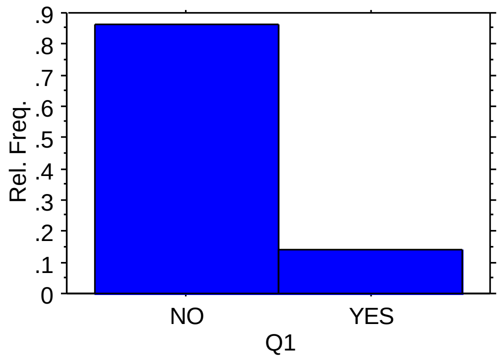
Seattle Public Utilities **By: ___________________________**	**Participant** (Home Owner(s)) **By: ______________________________**
Tim Skeel, Home Water Conservation Study Manager	Print Name: ______________________
Date: ___________________	By:______________________________

APPENDIX B
COMPLETE SURVEY RESPONSES

NEW PRODUCT INFORMATION AND SATISFACTION SURVEY

1. Have any of the above products installed for this study been removed or changed?

   14% Yes   86% No   0% Not sure



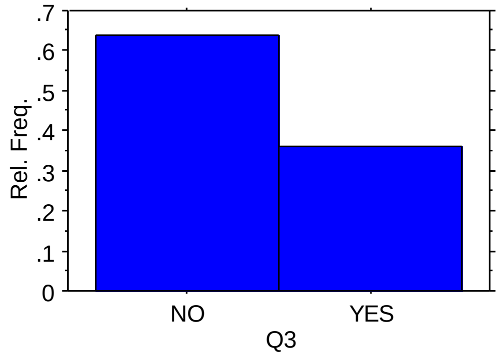
2. If yes, please list those removed or changed and explain why:

   1. Kitchen aerator removed. Flow rate too low to produce suds. Took too long to fill a medium size cooking pot.
   2. Bathroom sink faucet aerator was changed. Took too long to get hot water.
   3. All are the same except new toilet seat installed on Toto toilet
   4. Bathroom aerator changed to higher flow aerator because first was too low to get hot water.
   5. Wrong toilet originally installed.
   6. Lid/ seat assembly on toilets replaced because of failure of plastic parts in original assembly.
   7. Toto toilet seats replaced with newer model Toto brand.

TOILETS

3. Have you experienced any flushing or performance problems with your new toilet(s)?

   36% Yes   64% No   0% Not sure

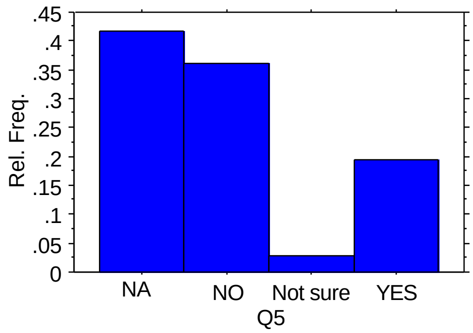


4. If yes, please describe the nature of these problems.

    1. Full flush does not always stop running until the half-flush button is pushed. Toilet seat slides to the right. There is not enough standing water in bowl.
    2. Bowl will never clean itself.
    3. Sometimes it does not remove all the waste even on a full flush. Installation- needed to be reattached to the floor.
    4. Both toilets have been plug up.
    5. Half flush on one of the toilets sticks open.
    6. Doesn't flush bowl clean. Need to use brush to clean sometimes. We assumed the low water flush was the cause.
    7. Toilet seat broke after about two weeks of use.
    8. It did not flush solids completely, improper fitting tank lid and cracked seat.
    9. Actually it works great, stays clean. I am concerned that there isn't enough flow to flush waste down the sewer line and that it will clog in the future. Yet there are no indications that this is happening.
    10. One toilet backed up two times due to offset range. Changed to pressure flush toilet and now works fine.
    11. The toilet seats move. The screws do not stay tight.
    12. Downstairs toilet not secured to floor.
    13. One temporary blocked, but used plunger to clear.
    14. One toilet flush value shut off needed simple cleaning. It was contaminated with rust in water pipes.
    15. No problems with flushing, but one toilet when it refills it makes an annoying clicking sound.
    16. The full flush button has stuck a few times, but this is easily fixed.

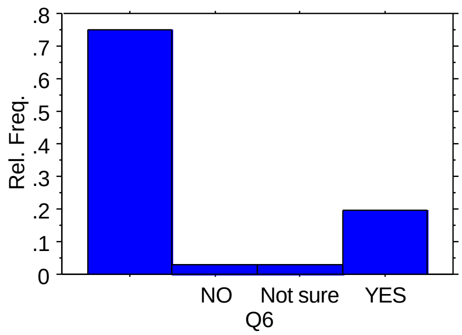
5. If you had problems, did you request a repair?

    42% No answer, 36% No, 3% Not sure, 19% Yes



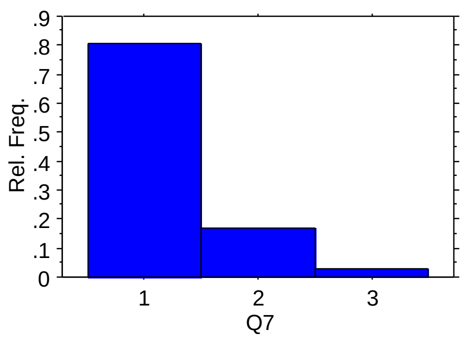
6. If you requested a repair, was the repair completed to your satisfaction?

   19% Yes   3% No   3 % Not sure   75% No answer



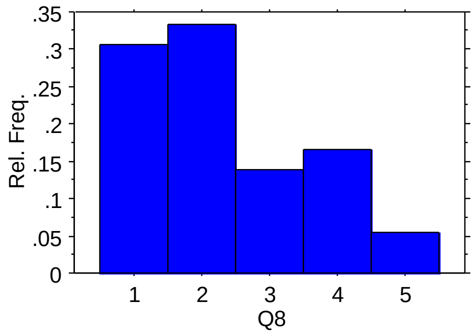
7. How frequently do you have to use a plunger on your new toilet(s)?

   81% Never (1), 17% Less than monthly (2), 3% Monthly (3), 0% Daily, 0% Weekly



8. How frequently do you have to "double flush" your new toilet(s)?

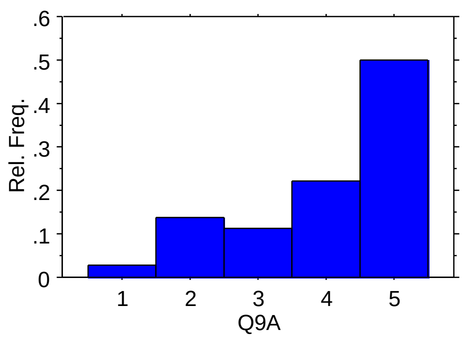
   31% Never (1), 33% Less than monthly (2), 14% Monthly (3), 17% Weekly (4), 5% Daily(5)



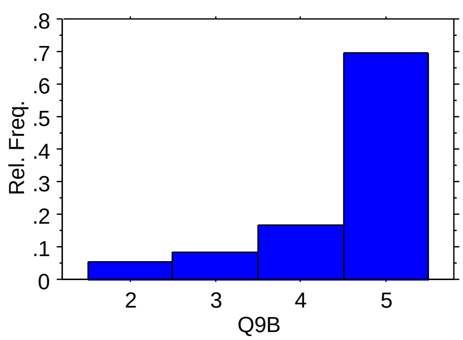
9. On a scale of 1 – 5, how satisfied are you with your new toilets in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

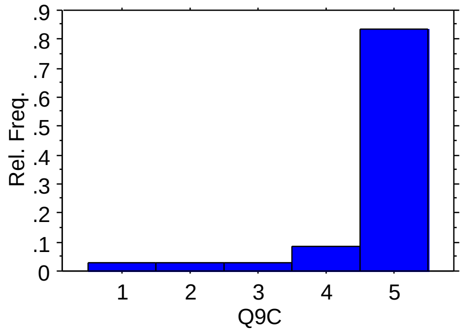
m) Bowl cleaning: 3% Dissatisfied (1), 14% Somewhat dissatisfied (2), 11%Neutral (3), 22% Somewhat satisfied (4), 50% completely satisfied (5)



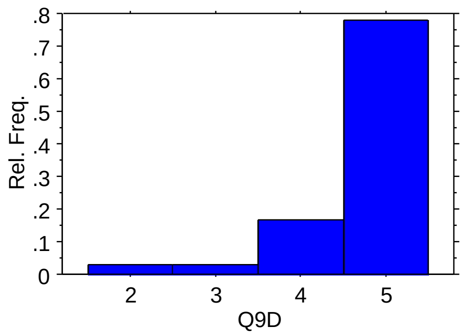
n) Flushing performance: 0% Dissatisfied (1), 6% Somewhat dissatisfied (2), 8%Neutral (3), 17% Somewhat satisfied (4), 69% completely satisfied (5)



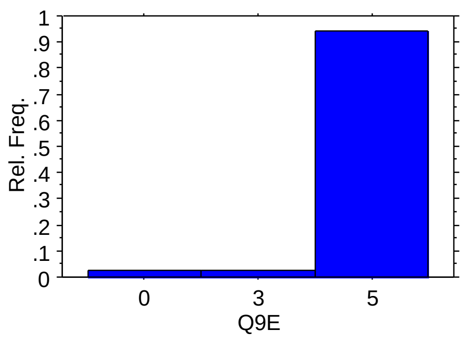
o) Appearance: 3% Dissatisfied (1), 3% Somewhat dissatisfied (2), 3%Neutral (3), 8% Somewhat satisfied (4), 83% completely satisfied (5)



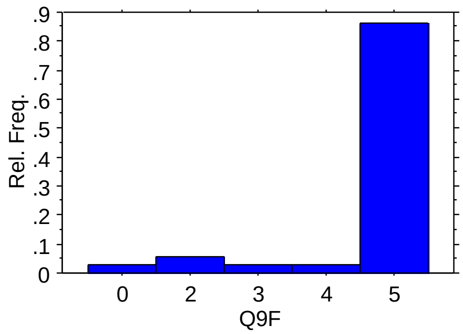
p) Noise: 0% Dissatisfied (1), 3% Somewhat dissatisfied (2), 3%Neutral (3), 17% Somewhat satisfied (4), 77% completely satisfied (5)



q) Leakage: 3% No Answer (0), 0%Dissatisfied (1), 0% Somewhat dissatisfied (2), 3%Neutral (3), 0% Somewhat satisfied (4), 94% completely satisfied (5)

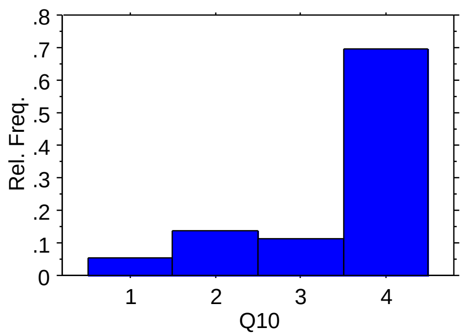


r) Maintenance: 3% No Answer (0), 0%Dissatisfied (1), 0% Somewhat dissatisfied (2), 3%Neutral (3), 0% Somewhat satisfied (4), 94% completely satisfied (5)



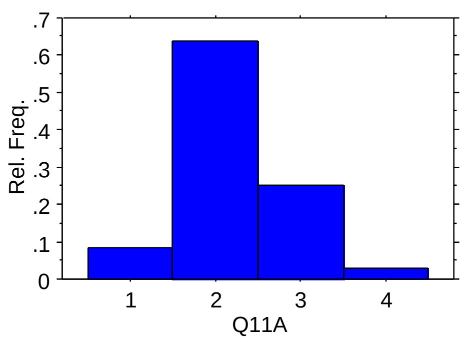
10. Compared to your old toilets, do you like your new toilet(s)?

5% Not sure (1), 14% Less (2), 11% Same (3), 70% More (4)

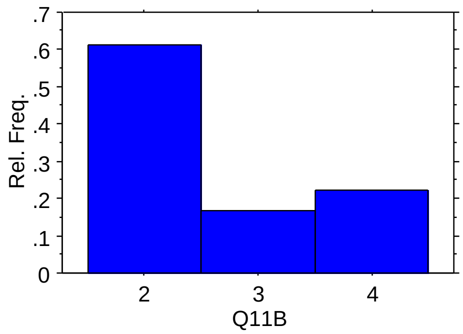


11. Compared to your old toilets, do your new toilet(s)?

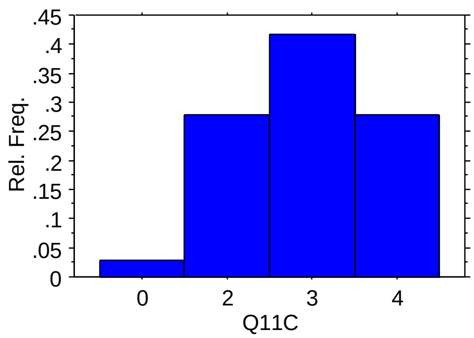
d) Clog: 8% Not sure (1), 64% Less (2), 25% Same (3), 3% More (4)



e) Require double flushing: 0% Not sure (1), 61% Less (2), 17% Same (3), 22% More (4)

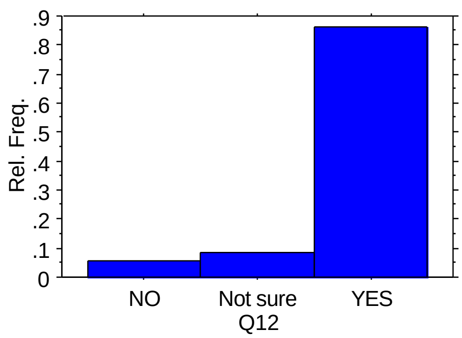


f) Require bowl cleaning: 2% NA (0), 0% Not sure (1), 28% Less (2), 42% Same (3), 28% More (4)



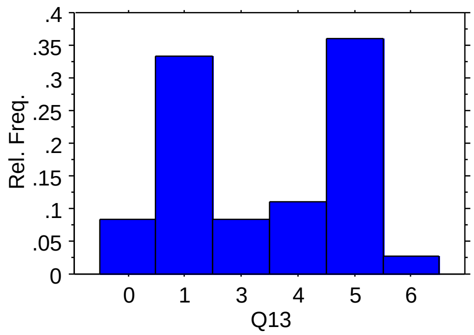
12. Would you recommend your new toilet to others?

    6% No, 8% Not sure, 86% Yes



13. If your new toilet(s) have a dual flush feature (two flush buttons), how often do you use the "half flush" button?

8% No Answer (0), 33% Don’t have (1), 0% Never (2), 8% Less than half (3), 11% about half the time (4), 36% More than half the time (5), 3% Always (6)



14. If there were one thing you would want the manufacturer of your toilets to change, what would it be?

    1. Size or shape of the toilet.
    2. More standing water in bowl.
    3. A larger water area.
    4. The toilet seat is made of thin plastic. I would like it better if it felt more substantial.
    5. The bottom of the bowl is so narrow it gets dirty quickly. Maybe a rounder bowl for easier cleaning.
    6. The seat.
    7. It needs to be improved so that they do not have to be cleaned as often.
    8. The shape of the interior of the bowl seems to cause the bowl to collect feces more easily.
    9. Change the under side of the seat to a flat not concave surface for easier cleaning.
    10. Make less noise.
    11. Better cleaning action- bowl shape collects excrement, doesn't always flush away.
    12. To offer a lower tank height.
    13. Nothing- it's great! I love this toilet.
    14. The flush could have been half a second longer to prevent a possible second flush..
    15. Color, I don't like the white lid. Otherwise it seems fine.
    16. A different toilet seat.
    17. Make it more likely that the solid waste falls in the water instead of the side.
    18. No complaints, we are very happy with our new toilets.
    19. Flat top of tank instead of rounded.
    20. Can not think of anything.
    21. Well I guess it would be to make them self cleaning.
    22. For pressure toilet. The bowl has a somewhat horizontal surface that the water does not get to.
    23. Tighten up the seat.
    24. Color- blue
    25. More water left in toilet, so solids won't adhere so much to walls of toilet or stronger flushing action to clean walls.
    26. Seat needs more rounded outside edge.
    27. Silent flush.

28. Seats seem to be not sturdy.
29. The seat is plastic and too flexible. Comparatively, it should be sturdier and flex less.
30. Bowl always requires cleaning after children have defecated, they sit closer to the front.

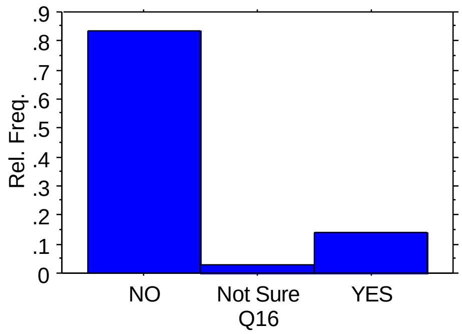
15. Other comments about your new toilet(s):

1. Set is loose, need to tighten often, screws are hard to tighten.
2. The seat needs to be more solid, it keeps sliding to the right.
3. Like the water saving features, but it would be nice if everything in the bowl would go down the drain.
4. Cleaning the deep part of the bowl is a problem. Some indentations the brush has trouble reaching. Required cleaning more often.
5. I like the look, I like the water saving features, but I am unhappy with the performance.
6. Do not like the buttons in the middle of the top; prefer levers on side of tank.
7. I like the seat, its great with a little boy who may not be as careful at lowering the seat after use.
8. Tank top flat, put flush button to the side to make room for tissue box.
9. Like the new slow down lids.
10. I'm extremely pleased with the toilets from the design to the operation. I know the savings do not amount to much now, but on an annual basis can be substantial.
11. Like them otherwise.
12. Pleased with water saving.
13. I never really though about it much, but the new ones flush better and take less time to recover.
14. We have a strong concern about repairs or replacement parts for a toilet made in Australia. We would like to be able to do it yourself repairs.
15. The seats are uncomfortable. The radius of the outside edge is to sharp and maybe not slope in so much.
16. Would prefer a flat top to be able to set Kleenex, etc on.
17. Does the manufacturer make different seats? If so, I am interested in changing them.
18. Excellent.

CLOTHES WASHER

16. Have you experienced any problems with your new clothes washer?

83% No, 3% Not sure, 14%% Yes



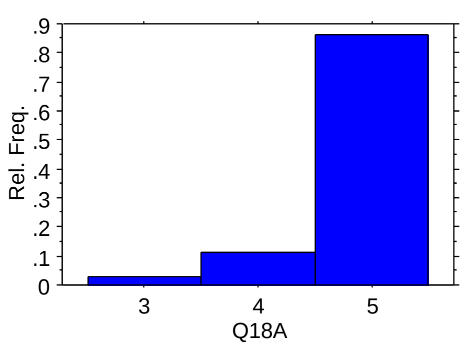
17. If yes, please describe any problems with your new clothes washer.

    1. We thought there was a problem with the balance, but the repairman informed us it was our floor. Said our floor was not solid enough.
    2. The door latch broke.
    3. Could not reverse door to open in right direction for the room.
    4. It is difficult to get the soap rinsed out, I only use about 1/8 a cup per load. The clothes seem stiff after they are dry. I bought the matching dryer and have had nothing but problems. The company has came out twice and it still does not work correct.
    5. At installation, out put hose was installed incorrectly and our utility room flooded.
    6. A few times the washer's spin cycle was not completed and the clothes were sopping wet. No off balance signal was indicated. Had to redo cycle.

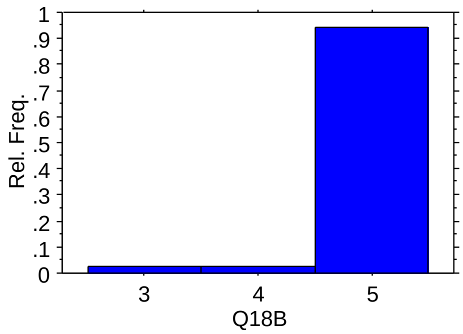
18. On a scale of 1 – 5, how satisfied are you with your new clothes washer in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

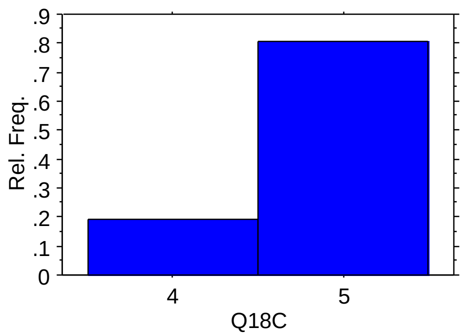
i) Cleaning of clothes: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 3% Neutral (3), 11%Somewhat satisfied(4), 86% Completely satisfied (5)



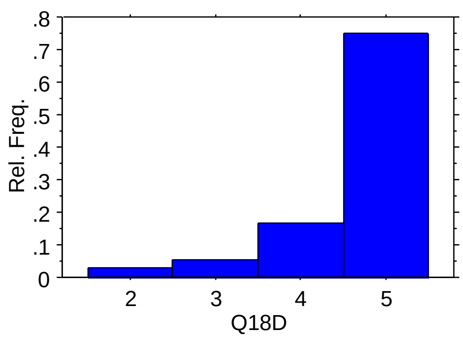
j) Maintenance/reliability: 0% Dissatisfied (1), 9% Somewhat dissatisfied (2), 3% Neutral (3), 3%Somewhat satisfied(4), 94% Completely satisfied (5)



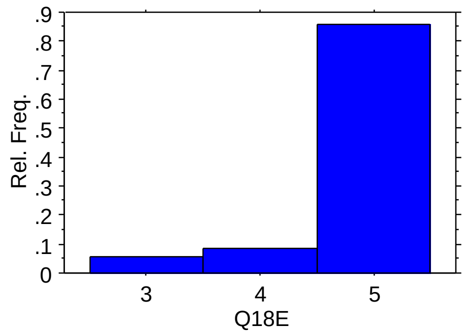
k) Noise: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 0% Neutral (3), 19%Somewhat satisfies (4), 81% Completely satisfied (5)



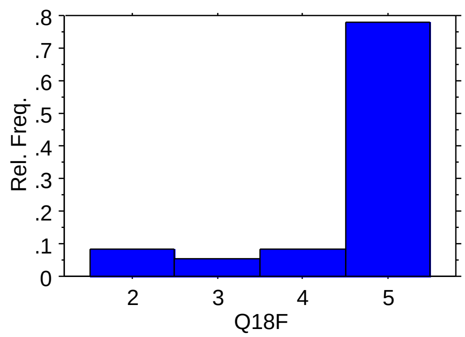
l) Moisture content of clothes: 0% Dissatisfied (1), 3% Somewhat dissatisfied (2), 6% Neutral (3), 17%Somewhat satisfied(4), 74% Completely satisfied (5)



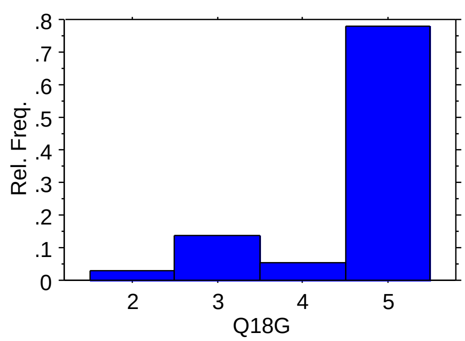
m) Cycle selection: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 6% Neutral (3), 9%Somewhat satisfies (4), 85% Completely satisfied (5)



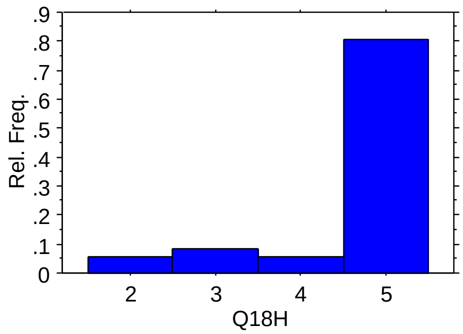
n) Capacity: 0% Dissatisfied (1), 8% Somewhat dissatisfied (2), 6% Neutral (3), 8%Somewhat satisfied(4), 78% Completely satisfied (5)



o) Wash cycle time: 0% Dissatisfied (1), 3% Somewhat dissatisfied (2), 14% Neutral (3), 6%Somewhat satisfies (4), 77% Completely satisfied (5)

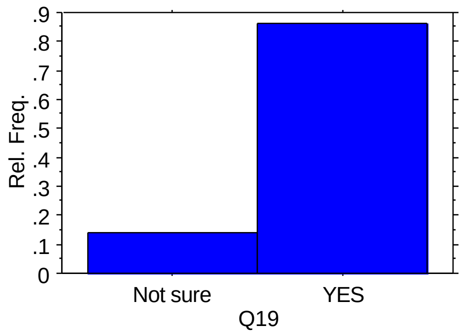


p) Detergent use: 0% Dissatisfied (1), 6% Somewhat dissatisfied (2), 8% Neutral (3), 6%Somewhat satisfies (4), 80% Completely satisfied (5)



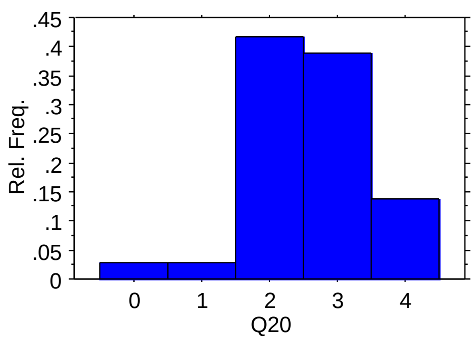
19. Does your new clothes washer have an extra rinse option?

14% Not sure, 0% No, 86% Yes



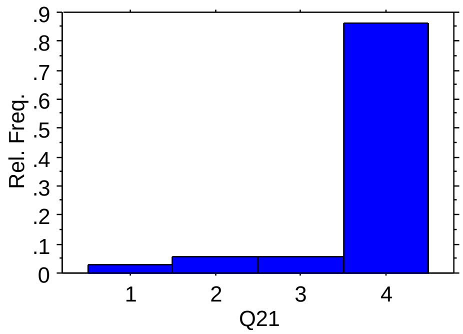
20. If your clothes washer has an extra rinse option, how often do you use it?

2% No answer (0), 3% Not sure (1), 42% Never (3), 39% Sometimes (4), 14% Always(4)



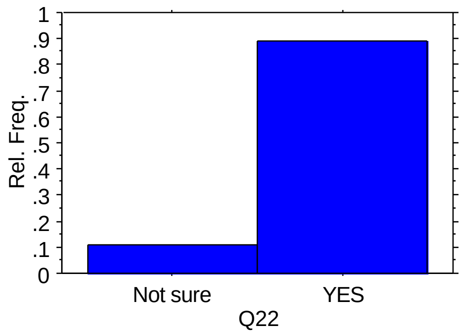
21. Compared to your old clothes washer, do you like the new clothes washer?

3% Not sure (1), 6% Less (2), 6% Same (3), 85% More (4)



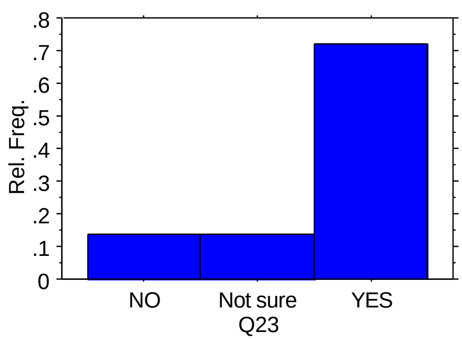
22. Would you recommend your new clothes washer to others?

    11% Not sure, 0% No, 89% Yes



23. You received your new washer free as part of this study. But, if you were *buying* a washer, would you pay $150 more for your new washer than for an equivalent quality, conventional (i.e., top loading, non-water saving) model?

    14% No, 14% Not sure, 72% Yes



24. If there were one thing you would want the manufacturer of your new clothes washer to change, what would it be?

    1. Soap information like where to buy.
    2. An adjustment for washing a small load of clothes.

3. Larger and higher opening.
4. The detergent, bleach, softener dispenser could be improved to retard spillage and prevent mix up.
5. Can not think of anything at this time.
6. Reduced capacity and sensitivity to balance. Also detergent is a problem.
7. Increase spin to remove more water.
8. Make the cycle selector dial easier to turn.
9. A little more capacity would be good, but this is fine for me.
10. Increase load capacity. Include a water level selection.
11. Less cycle time.
12. Fix gasket around front door so it won't leak when you open door to put extra items in after starting machine. Controls on front have to get on knees on floor the line up the arrows on the perm press cycle.
13. It's a bit difficult to stoop down to fill the machine, but it is not a burdensome labor.
14. Can not think of anything.
15. Soap ends up on outside rim of door and must be wiped off before taking clothes out.
16. Have a soaking cycle to soak clothes with bleach.
17. For old folks and tall people, make it like the Maytag. In regards to the opening there is some water leakage from machine when opening door after use.
18. Access door small and low down. Increase door access opening, as long as the unit were still stackable. A drum light would be nice.
19. Detergent container does end up looking messy.
20. Can not think of anything to improve.

25. Other comments about your new clothes washer:

1. It is to close to the floor, for an older person it is too hard to get clothes in and out.
2. I love the washer. An added surprise has been a reduction in my electricity bill due to less hot water use.
3. We are pleased with the performance, like the look of it and tell our friends about it when they ask.
4. Generally, we dislike the front-loading washers. As they are more difficult to load and unload.
5. I love the delayed washing cycle.
6. It is very quiet!
7. Light in tub and higher door would be more convenient.
8. It is great!
9. A detergent called HE was only available in Tide in our area. I cannot use a Tide product! Would like more choices for HE detergents. Where can Wisk HE be purchased?
10. I could not be more satisfied with the overall performance of my new clothes washer. The clothes are cleaner than with my top loading clothes washer.
11. It works well and is less damaging to my clothes. I don't really care if I save a little water but it is extra nice to save money on soap and water.
12. Like it very much.

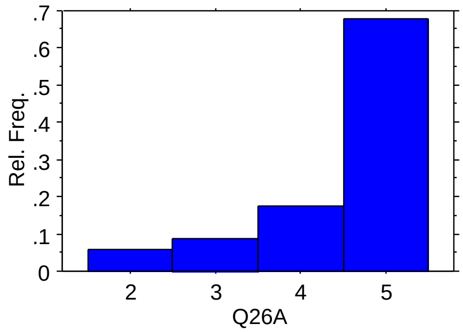
13. The new washer cleans your clothes cleaner.
14. A little bit of a hassle finding the special detergent.
15. Really like extra rinse option when using bleach, and extra drying when washing towels.
16. It took me a while to realize why it took longer for my clothes to dry. The loads are so much larger with a front loader.
17. The detergent is more expensive.
18. Very good on detergent requiring only two teaspoons of regular detergent. Happy with the cleaning of clothes on new machine.
19. Difficult to bend over to remove clothes. I purchased the matching dryer and stacked it on top of washer. Having dryer door at chest level is easier.
20. Very impressed with the spin cycle, it saves on drying time.

SHOWERHEADS

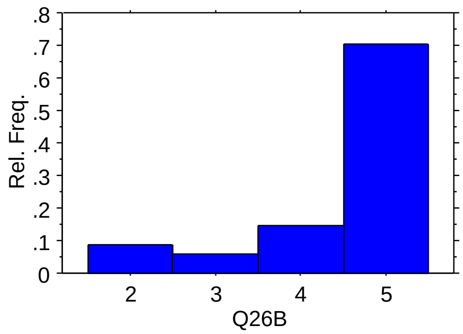
26. On a scale of 1 – 5, how satisfied are you with the performance of your new showerhead in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

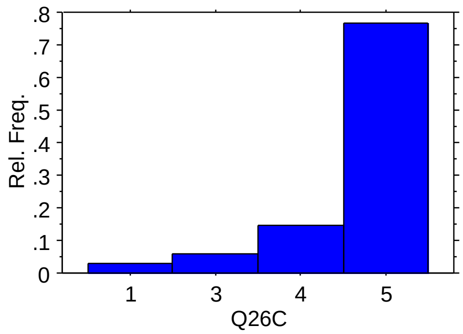
f) Water flow: 0% Dissatisfied, 6% Somewhat dissatisfied, 9% Neutral, 18% Somewhat satisfied, 67% Completely satisfied



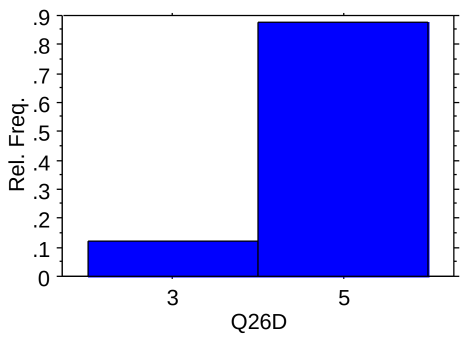
g) Flow pattern: 0% Dissatisfied, 9% Somewhat dissatisfied, 6% Neutral, 15% Somewhat satisfied, 70% Completely satisfied



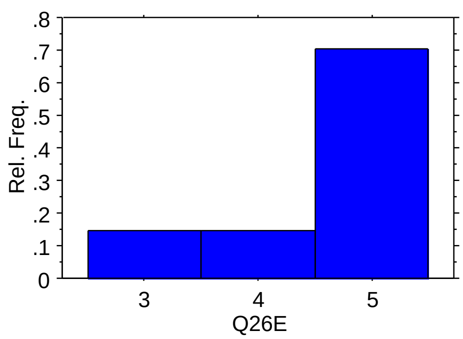
h) Appearance: 3% Dissatisfied, 0%Somewhat dissatisfied, 6% Neutral, 15% Somewhat satisfied, 76% Completely satisfied



i) Clogging: 0% Dissatisfied, 0% Somewhat dissatisfied, 12% Neutral, 0% Somewhat satisfied, 88% Completely satisfied

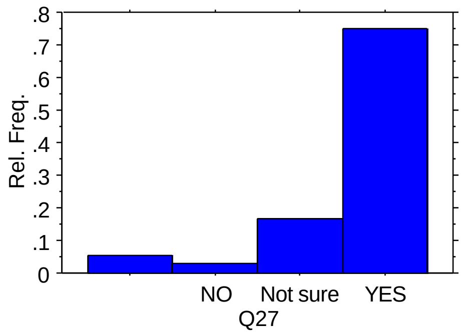


j) Adjustability: 0% Dissatisfied, 0% Somewhat dissatisfied, 15% Neutral, 15% Somewhat satisfied, 70% Completely satisfied



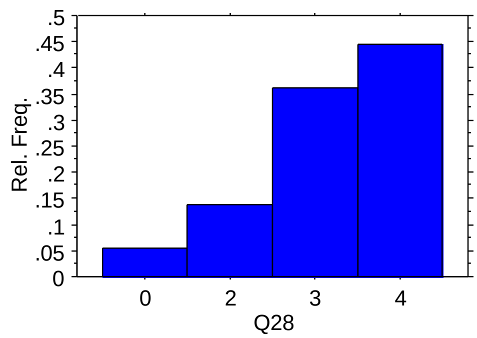
27. Would you recommend your new showerhead(s) to others?

5% No answer, 17% Not sure, 3% No, 74% Yes



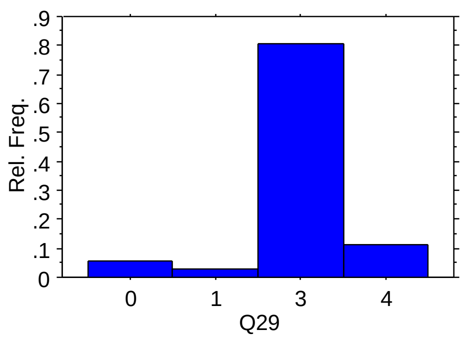
28. Compared to your old showerhead(s), do you like your new showerhead(s)?

    5% No answer (0), 0% Not sure (1), 14% Less, (2), 36% Same (3), 44% More (4)



29. Compared with your old showerhead(s), is your showering time with your new showerhead(s)?

    5% No answer(0), 3% Not sure(1), 0% Longer (2), 81% About the same (3), 11% Shorter (4)



30. Other comments about your new showerhead(s):

    1. It cuts the waterpower, I do not get a good massage.
    2. Shut off feature is inconvenient.

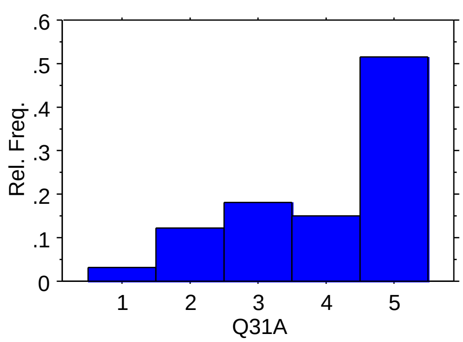
3. It does not feel like a low flow showerhead. The amount of water coming out is quite adequate, as is the force.
4. My husband likes it just fine. I think it needs more pressure.
5. When I'm on business trips and use hotel showers, I feel like it is a deluge of water. I'm sure we have saved a lot of water with this new showerhead.
6. Would be nice to have it on a flexible (hose) fixture.
7. Flow is just right.
8. The water flow and the adjustability with its wide showerhead allows me to take shorter showers, but just as effective as my much smaller head.
9. I liked old showerhead and was reluctant to change. My husband and I were surprised at the water pressure the head had. Other bathroom has problems with SH installed on hand held variety.
10. It's great!
11. I think I would like adjustable showerheads better, but you really can not tell much difference except it takes the water longer to get hot.
12. My all time favorite showerhead, even compared to some full flow models. The adjustment range is exceptional and the spray pattern/pressure excellent throughout range.

FAUCET AERATORS

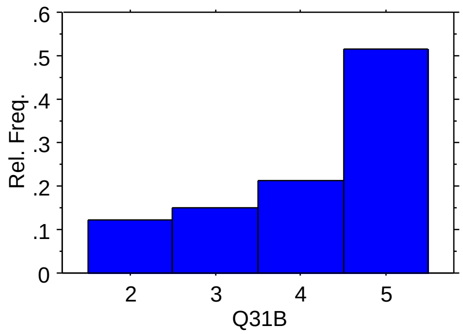
31. On a scale of 1 – 5, how satisfied are you with the performance of the new aerator(s) installed on your faucets in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

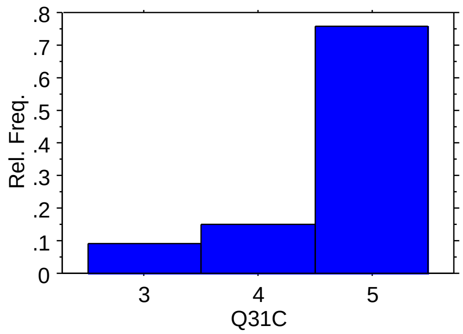
e) Water flow: 3% Dissatisfied (1), 12% Somewhat dissatisfied (2), 18% Neutral (3), 15%Somewhat satisfied(4), 52% Completely satisfied (5)



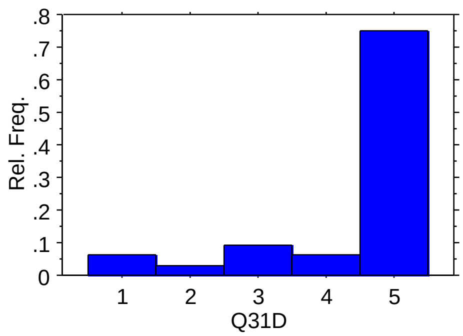
f) Flow pattern: 0% Dissatisfied (1), 12% Somewhat dissatisfied (2), 15% Neutral (3), 21%Somewhat satisfied(4), 52% Completely satisfied (5)



g) Appearance: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 9% Neutral (3), 15%Somewhat satisfied(4), 76% Completely satisfied (5)

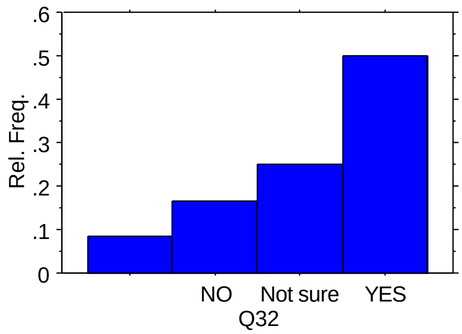


h) Clogging: 6% Dissatisfied (1), 3% Somewhat dissatisfied (2), 9% Neutral (3), 6%Somewhat satisfied(4), 76% Completely satisfied (5)



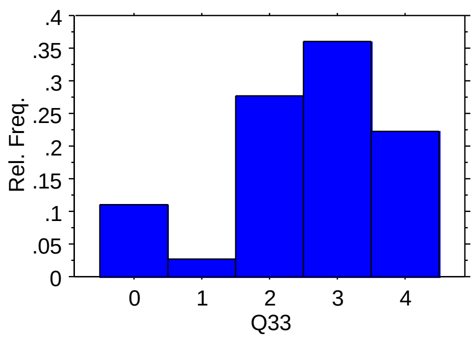
32. Would you recommend your new faucet aerators to others?

8% No answer, 17% No, 25% Not sure, 50% Yes



33. Compared to your old aerators, do you like the new aerators?

11% No answer (0), 3% Not sure (1), 28% Less (2), 36% Same (3), 22% More (4)



34. Other comments about your new aerators:

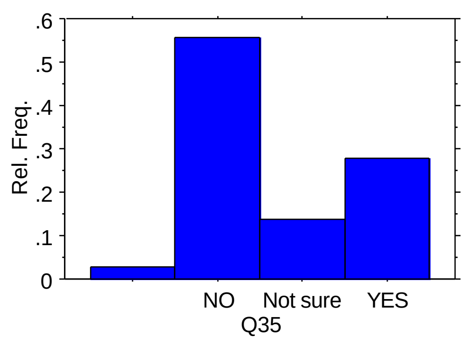
1. They have a good spray, but no power.
2. Above applies only to the bathroom sink aerator. Kitchen sink aerator was so unsatisfactory it was replaced.
3. Bathroom aerator was replaced because it took too long for the water to get hot. Kitchen aerator also seemed weak. It also seemed more sensitive to clogging.
4. Bathroom aerator was replaced because it took too long for the water to get hot. Kitchen aerator also seemed weak. It also seemed more sensitive to clogging.
5. I wish it had more swivel/ angle area.
6. The shower type spray pattern is useful when cleaning, but it seems I really have to run a lot of water to get the hot water to wash my face.
7. The aerator installed in upstairs bathroom was identical to the one it replaced.
8. The pattern causes splashing.
9. My flow was already very low, these aerators have made the faucets worse. Probably better if you are starting with normal faucets.
10. I do not like the "spray" pattern as it makes more mess. Also flow takes longer to fill a container as well as obtain hot water. I do try to save that extra water for other uses.
11. I very much like the appearance. I have had no problem with clogging so far.
12. I don't notice the difference I get plenty of water and good pressure I am surprised at how well these devices work
13. Bathroom aerator changed to higher flow rate because it took too long to get hot water.

14. The new aerator spatters a lot and takes longer to warm up.
15. The water actually feels stronger then the old ones and again it takes the water longer to get hot.
16. In utility room aerator is spray only. It will be changed to a spray and solid stream combo. The sink is a kitchen size sink.
17. Kitchen aerator excellent. Bathrooms are ultra low flow rate, so low that hot water never gets there without running water for a long time. I will replace the aerator in the upstairs bathroom.
18. We did not use aerators because the water pressure in this area is so low. The ones installed have not affected our lives, so they will remain in place.
19. We have a shallow basin and the aerator splashes and sprays, maybe because of the force with which it hits the basin. It sprays my young children's faces. They hate to use it at all.

STUDY PARTICIPATION

35. Have you changed any of your water use behaviors as a result of participating in this study?

3% No Answer, 14% Not sure, 56% No, 28% Yes



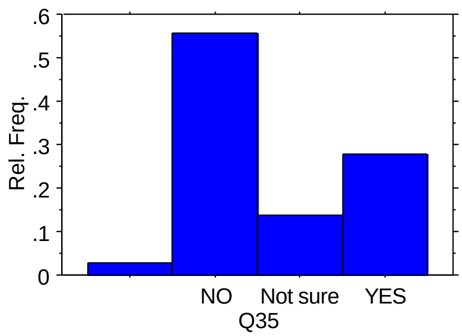
36. If yes, please describe the changes in your water use behaviors.

1. I think I have become more aware of my use of water and so I am more conscious.
2. Use much less water.
3. More conscious of our water usage. I understand the need for water conservation.
4. Maybe water the flowers and yard a little less.
5. Actually flush more now because of half flush option. Much better in terms of cleaning toilet.
6. My showers are shorter.
7. To be honest I don't think about the cost of water, as a Seattle native, I have always felt we have an abundant supply. I don't bother to water lawn in the summer so it probably balances my lack of conservation in the home.
8. I am more aware of wasting water.
9. Do not do laundry unless we have a full load. We tried to take shorter showers, but we've become lax about it.

10. Do not leave water running while shampooing and brushing teeth.
11. Less multiple flushing, avoid leaving sink running, more conscious of general water use/ outdoor watering. No more small washing loads.
12. I am not doing as many loads of laundry because the washer capacity is greater.

37. Do you plan on removing or changing any of the new products after the conclusion of this study *(fall 2000)*?

    11% Not sure , 67% No, 22% Yes

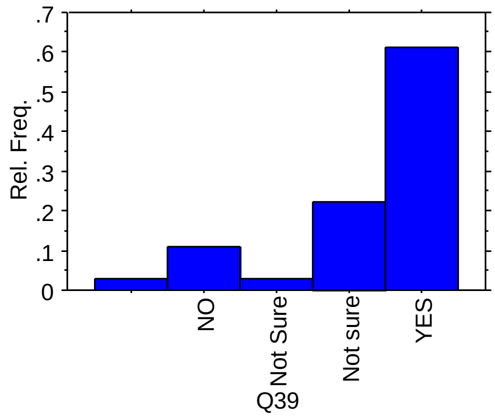


38. If yes, please list those you plan to remove or change and explain why.

    1. I will replace the washer back to my former top loader. It will be easier to load.
    2. Showerhead. Old head uses less water/ shower and has a better spray pattern.
    3. May put the old toilet back in. It was also a water-conserving toilet but the seat feels better. We will probably replace the kitchen aerator because of clogging.
    4. One sink aerator back to old style.
    5. Bathroom faucet aerator. Low flow and splashing.
    6. May change some of the aerators because of spray that results from its use. May change basement toilet because of counter interfere with led.
    7. I would like to put back the handheld shower in one bath. But wish it were a water-conserving model. Would trade the one I have for one that conserves water.
    8. Shower head.
    9. Downstairs utility sink aerator to a dual use.
    10. We are changing the shower when we update our plumbing. The aerator will go with the old shower.
    11. The toilet seats uncomfortable, and main floor bathroom flow rate too low, but I do not plan to change them.
    12. I will only remove the aerator in our downstairs bathroom due to the problems with my children.

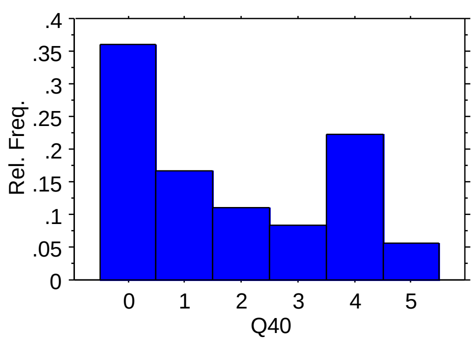
39. Have you noticed any reduction in your water and sewer bill as a result of participating in this study?

11% No, 25% Not sure, 61% Yes



40. If yes, by about how much do you think your bill has gone down?

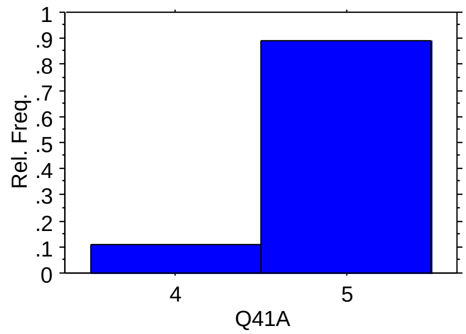
36% No answer(0), 17% More than 30% (1), 11% 21-30 (2), 8% 11-20 (3), 22% 5-10 (4), 6% less than 5 (5)



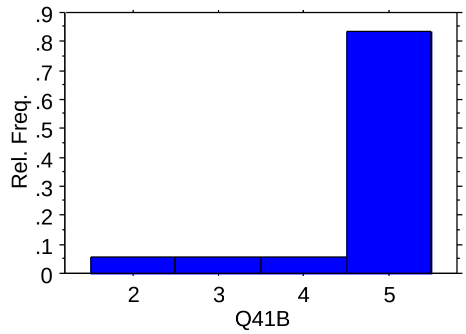
41. On a scale of 1 – 5, rank your experience participating in the home water conservation study in the following areas?

1=dissatisfied, 2=somewhat dissatisfied, 3=neutral, 4=somewhat satisfied, 5=completely satisfied

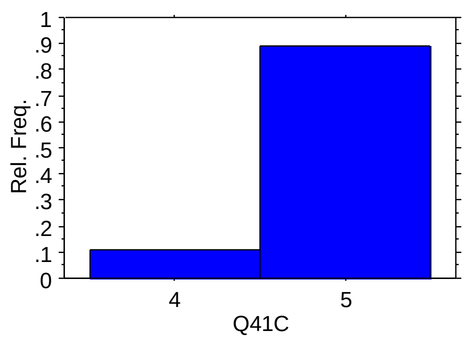
g) Ease of participation: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 3% Neutral (3), 11%Somewhat satisfied (4), 89% Completely satisfied (5)



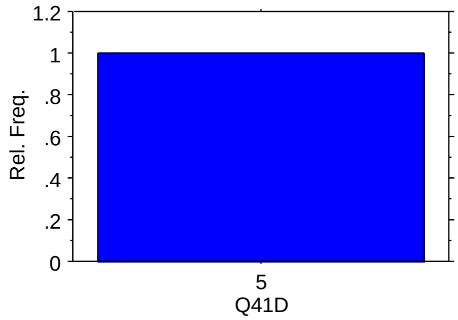
h) Response to problems: 0% Dissatisfied (1), 6% Somewhat dissatisfied (2), 6% Neutral (3), 6%Somewhat satisfied (4), 82% Completely satisfied (5)



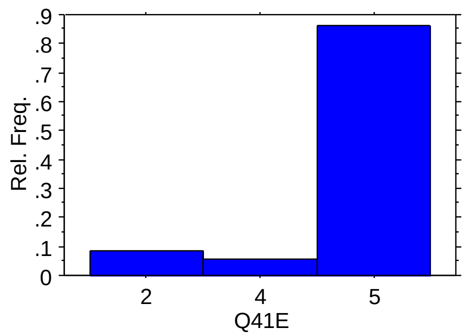
i) Scheduling convenience: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 0% Neutral (3), 11%Somewhat satisfied (4), 89% Completely satisfied (5)



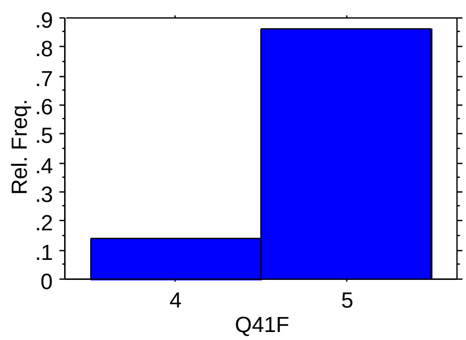
j) Courtesy of study staff: 0% Dissatisfied (1),0% Somewhat dissatisfied (2), 0% Neutral (3), 0 %Somewhat satisfied (4), 100% Completely satisfied (5)



k) Fixture installation: 0% Dissatisfied (1),8 % Somewhat dissatisfied (2), 0% Neutral (3), 6%Somewhat satisfied (4), 86% Completely satisfied (5)

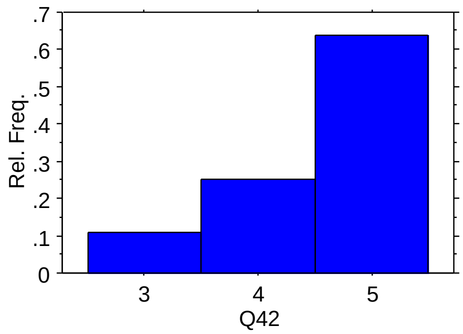


l) Overall experience: 0% Dissatisfied (1), 0% Somewhat dissatisfied (2), 0% Neutral (3), 14%Somewhat satisfied (4), 86% Completely satisfied (5)



42. Please respond to the following statement: “I feel my home has been improved by the installation of the water conserving products in this study”.

0% Strongly disagree (1), 0% Disagree (2), 11% Neutral (3), 25% Agree (4), 64 % Strongly agree (5)



43. If there were one thing you would change about the study, what would it be?

1. I would have liked to see a chart of water use by appliance.
2. Very impressed but, maybe could include dishwashers and outdoor water conserving (sprinklers, nozzles). Landscaping using drought tolerant plants that require less water.
3. The water usage journal need to be redone so that you have enough space to write the dates and times etc..
4. The plumber.
5. Better initial water-tracking forms. I almost made one in excel to accurately track all water usage.
6. Make the form for recording water use with bigger boxes to fill in. I was wondering if anyone would understand my data recording, the boxes were so small to write in.
7. The length of time.
8. Staff were courteous and helpful
9. More help with landscape watering and water saving.
10. I have absolutely no complaints about the study.
11. Can not think of anything.
12. I thought everything was great. Installation was faster then I thought it would be and not one problem has happened from the work done.
13. Nothing. Everyone, especially Jenna was great. We feel very fortunate to have been a part of the study. Thanks very much.
14. A better chart to log usage.
15. Have a choice in appliance to be installed.
16. Water use recording sheets should provide one sheet per location. IE one for washer, one for each bathroom, etc. Otherwise very awkward to find sheet to note exact time fixture in use.

44. Other comments:

1. This study was simple. My questions were always answered politely and simply. Problems were handled quickly. I hope the study was successful for you.
2. The study was conducted in a very non-invasive, respectful manner. The people involved were friendly and professional- the best combination.
3. We are pleased and thankful that we were selected to participate in this study.

4. Thanks for letting us be a part of your study. The washing machine was a great incentive to participate. If we can be of help in any other way, please let us know! Can we get the results of the study? (Both general and our house).
5. The study was really pretty simple and straightforward. I appreciate all the free products and especially like the washing machine. It makes me feel good to know I am conserving consciously.
6. I really like saving water, more than anything. I feel I am doing my part not just saving money.
7. I would like to know the final results.
8. We really like the new, quiet dishwasher. Thanks for offering it!
9. My overall opinion of the study; it helps the residents of Washington state, save water for future use, also increases are resources, it's good not only for citizen's but our environment too.
10. It would of been difficult to sell this devices to me without having tested them
11. Being a part of the study was good. Everyone involved has been very friendly!
12. We appreciate being chosen for the study and are grateful for the new appliance.
13. Water usage so for vastly decreased. However, usage will go up during the summer as garden sprinkler system in use then. All staff of water study performed in an outstanding way.
14. A very good experience and grateful for the new washer and reduced water.
15. We did go to stores in our area to look at these appliances from the viewpoint of our needs. The Maytag offered what we felt a superior design for older people and tall people for loading and unloading. Thanks for having us as part of your study.
16. Very impressed with products overall and very grateful to have these home improvements. I purchased a matching dryer to stack on washer, I like it so much. Suggest a similar program for outdoor water use. I see so much water running down the street.
17. Thank you very much for selecting us for the study.
18. We are grateful for having been included in the study. The products are a vast improvement on what was there before.

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ABBREVIATIONS

ANOVA	analysis of variance
ATTN.	Attention:
Ave.	avenue
AWC	average winter consumption
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
Blvd.	boulevard
CCF	hundred cubic feet
CDM	conditional demand model
CF	cubic feet
CIS	customer information system
CUSTID	customer identification number
e.g.	for example
EBMUD	East Bay Municipal Utility District
EGLS	estimated generalized least-squares
ET	evapotranspiration
gal.	gallon
gcd	gallons per capita per day
gpcd	gallons per capita per day
gpd	gallons per day
gpf	gallons per flush
gpm	gallons per minute
gpsf	gallons per square foot
HCF	hundred cubic feet
HUD	U.S. Department of Housing and Urban Development
i.e.	for example
Inc.	incorporated

KEYCODE	unique identifying number for survey respondents
kgal	thousand gallons
kL	thousand liters
L	liter
Lcd	liters per capita per day
LF	Low-flow
Lpd	liters per day
Lpf	liters per flush
Lpm	liters per minute
Lpsf	liters per square foot
min.	minute
MWD	Municipal Water District
PC	personal computer
pop.	population
Q1000	systematic random sample of 1000 single family accounts
Q125	sample of 125 accounts for data logging
Q150	sample of 150 accounts for data logging
QA	quality assurance
QAQC	quality assurance and quality control
R^2	coefficient of determination
Rd.	road
RE	random effects
REUWS	Residential End Uses of Water Study
RMSE	root mean square error
SHWCS	Seattle Home Water Conservation Study
sf	square foot
SPU	Seattle Public Utilities
St.	street
St. Dev.	Standard deviation
Std. Dev.	Standard deviation

TW	Trace Wizard
ULF	Ultra-low-flush
ULFT	Ultra-low-flush toilet
UPS	United Parcel Service
WD	Water District