Single Family Water Fixture Energy-Related Measurements

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Seattle City Light

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Marc Schuldt (SBW Consulting, Inc.) and Debra Tachibana (Seattle City Light).

"Energy-Related Water Fixture Measurements:

Securing the Baseline for Northwest Single Family Homes."

In Proceedings of the American Council for an Energy-Efficient Economy

2008 Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA (pp. 2.253–2.266).

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Introduction

The purpose of this study was to investigate the energy-related flows of water fixtures in a representative sample of 75 single-family residences in the City of Seattle, and acquire other useful data on characteristics of water appliances in the sampled homes. Due to recruitment difficulties, measurements were actually made of all relevant bathroom water fixtures in seventy-one (71) single-family homes.

The study had the following four objectives:

1. **Showerhead Measurements.** Measure the full throttle flow rates for existing and efficient showerheads in a sample of 75 homes in the City of Seattle.

2. **Bathroom Faucet Aerator Measurements.** Measure the full throttle flow rates for existing and efficient faucet aerators in a sample of 75 homes in the City of Seattle.

3. **Other Water Measurements.** Measure the static water pressure, flowing water pressure, and hot water temperature for each showerhead in the sampled homes. Note the time taken for the hot water showerhead flow to reach maximum (constant) temperature. Also measure the flushing volume of each toilet tank.

4. **Water Appliance Characteristics.** Take a digital photo of each existing showerhead. To the extent possible, record other important characteristics for each sampled home, including hot water fuel type, brand name of the existing showerhead, age of existing showerhead, presence of multiple-head or spa-like showers, age of toilet, age and type of clothes washer and dishwasher.

Methodology

This study was completed as a sequence of six tasks, which investigated water and energy-related flows of bathroom water fixtures in a representative sample of single-family residences in the City of Seattle. The study targeted a sample of 75 homes for the measurements. However, due to the difficulty of cost-effectively recruiting homes that were in the desired geographic areas and age categories, Seattle City Light decided to limit the sample to 71 homes. The water fixtures measured as part of this study include showerheads, bathroom sink aerators, and toilet tanks. The study also acquired useful data on the characteristics of water appliances in the sampled homes. The tasks are described below.

Workplan

The study began with the development of a workplan. The workplan was an enhanced version of the contract scope of work that refined the data collection procedures. It provided a detailed description of the data elements, which reflected the results from discussions with Seattle City Light and Seattle Public Utilities program staff and Seattle City Light evaluation staff. Additionally, it included the data collection forms and procedures that were developed in the early stages of the contract. The final workplan was approved by both Seattle City Light and Seattle Public Utilities.

Sample Targets

Data collection was performed on single-family homes that were representative of the population of homes in the Seattle City Light and Seattle Public Utilities service areas. In an effort to select representative homes, Seattle City Light compiled and analyzed real estate records in the Metroscan® database (licensed from First American Real Estate Solutions), which mirrors to a great extent records also accessible from the King County Property Tax Assessor's office. The purpose was to determine the distribution of homes with respect to the following important parameters:

- General Location (in one of five major geographical areas of Seattle)
- Period built
- Square footage
- Assessed property value
- Number of bathrooms

A sample of homes that included a range within each of these parameters would provide a representative cross-section of water fixtures and conditions (e.g., degree of corrosion, water pressures, and plumbing system age) that would be expected city-wide.

This information is shown in Table 1 below:

Table 1: Distribution of Seattle Single Family Detached Homes

General Location	Suffix	*Zipcode group:*	
Lake City & North of UW	N, NE	*981--5*	22.4%
Ballard, Magnolia, Queen Anne	W, NW	*981--7, 981--9*	19.4%
UW, Lake Union, Capitol Hill, Central Area	E, --	*981--2, 98102_03_45_95*	15.7%
First Hill, I.D., Sodo, Beacon Hill, SE, Duwamish	S, SE	*981—4, 981—8*	16.4%
West Seattle	SW	*981—6*	17.1%

(excludes areas in King County, north (5.7%) and south (3.2%) of Seattle City limits)

Period Built	
1900-1919	22.8%
1920-1939	24.0%
1940-1959	35.4%
1960-1979	8.3%
1980-2006	9.5%

Square Footage	
Under 1600	21.9%
1600-1999	19.2%
2000-2399	21.5%
2400-2799	16.9%
2800 & More	20.5%

Property Value	
$100,000-249,999	20.3%
$250,000-299,999	17.0%
$300,000-349,999	17.2%
$350,000-449,999	21.4%
$450,000 & More	24.1%

Bathrooms	
1	46.2%
1.25-1.75	24.7%
2	9.0%
2.25-2.75	13.8%
3 or More	6.3%

With this information, SBW Consulting (SBW) and Seattle City Light created a series of bins, across which the sample was distributed, to achieve a representative baseline of important water system characteristics and performance measurements. It was agreed that, with an intended sample size of only 75 homes, it was not reasonable to vary more than two parameters to create a total of 25 bins. Based on a review of the single-family home real estate data for the jurisdiction of Seattle, Seattle City Light and SBW agreed that the two most appropriate parameters would be General Location and Period Built. Seattle City Light distributed the planned sample of 75 homes across the 25 bins according to the proportions found in the single-family home population. The target distribution is summarized in Table 2 below. The counts in each bin were viewed as targets to achieve during sample selection, to the extent that they can be supported by the candidate sites available to the study.

Table 2: Target Sample Counts

General Location	Period Built 1990-1919	1920-1939	1940-1959	1960-1979	1980-2006	Area Total
Lake City & North of UW	2	5	8	2	2	**19**
Ballard, Magnolia, Queen Anne	4	5	5	1	1	**16**
UW, Lake Union, Capitol Hill, Central Area	6	4	1	1	1	**13**
First Hill, I.D., Sodo, Beacon Hill, SE, Duwamish	3	2	4	2	2	**13**
West Seattle	3	3	6	1	1	**14**
Total All Locations	**18**	**19**	**24**	**7**	**7**	**75**

Sample Selection

Candidates for selection into the sample came from one of the four sources described below. The initial intent was to obtain the entire sample from the first source. After it was determined that this data source was not sufficient, three additional data sources were added. In the end, the last data source, which included acquaintances of the study team staff, proved to be most fruitful.

.... Real Estate Open Houses

Seattle Public Utilities and Windermere Real Estate established a cooperative arrangement where lists of homes for sale in the City of Seattle that were offering an open house to real estate agents were provided to Seattle Public Utilities. Homes on the list were pre-screened by Windermere so that they were available for use in this study without further recruitment by SBW. Windermere provided written permission from the homeowner for the measurement work to be done in the homes. This was initially expected to be the primary source of candidate homes. However, getting a sufficient count of candidate sites from this source proved to be more difficult than expected. Fifteen of the 71 sampled homes came from this data source.

.... Seattle City Light Neighborhood Power Program “Green Audit” Service

Homes enrolled in the Neighborhood Power Program’s Green Audit service, offered by Seattle City Light, were used a secondary source. The Green Audit service is presently offered in West Seattle only, so homes from this program were only used to meet the target requirements in the West Seattle geographic area. Data collection at these homes was limited to three days per week. Seventeen of the 71 sampled homes came from this source.

.... Senior Services Program Audit Service

The Senior Services Program is offering energy home audits and minor home repairs to eligible senior homeowners. Homes that received an audit under this program were used as a secondary source for this study. Data collection from these homes was limited by the availability of eligible homes within the project schedule. Only two of the 71 sampled homes came from this source.

.... Acquaintances of the Study Team

Most of sampled homes (37 of the 71 sampled homes) came from lists of acquaintances compiled by members of the SBW staff. In compiling the list, special attention was placed on selecting homes that addressed bins not filled by the other data sources. Care was also taken to select homes that did not have an unusually high level of water conservation. As an incentive to participate in the study, efficient showerheads and aerators were installed at no charge as part of the study. In addition two compact fluorescent light bulbs were left with each homeowner.

Data Collection

SBW field staff visited the sampled homes and implemented the procedures documented in the workplan. SBW collected the required data and recorded observations on the field data collection form(s). The two data collection forms that were used to document the fieldwork are discussed in detail in Appendix A. Form 1 was completed for all homes. Form 2 was completed when there is more than one showerhead in a bathroom. Instructions in Appendix A clarify the circumstances under which Form 2 was used as a supplemental form. The data collection procedures that were applied to each home are as follows.

Field staff began data collection at each site by finding the identified site contact and making an appropriate introduction. In many cases the site contact was not the homeowner, particularly if the home was identified through the Windermere Real Estate Open House list. Field staff enlisted the help of the site contact to the extent appropriate to determine the information required for the data collection forms.

.... Hot Water System

Field staff immediately located the hot-water tank or tanks and the bathrooms in the home. For each tank the *fuel type* (gas or electric) and the *system type* (tank, demand, heat pump, or unusual features) were documented along with the bathrooms they serve. Unusual features of the hot-water system, such as a circulating system, were noted in the Site Notes.

.... Showerheads

If the home had more than one shower, field staff determined which shower was situated farthest from the hot-water tank. The required information was collected using the procedures described below. The required information was recorded on the data collection form provided in Appendix A.

1. A photograph of the existing showerhead was taken. The photo was matched with the bathroom number and home ID or address, for future reference.

2. In the bathroom farthest from the hot-water tank, the showerhead was turned on to *full flow* using *only hot* water (no cold water during this test). The amount of time that elapsed until the temperature reached *105 degrees F*. was recorded. Observation of the time continued until *maximum temperature* was reached, when the temperature became more or less stable (10 seconds pass with no additional temperature rise). The *time to 105 degrees, time to maximum,* and the *maximum temperature* reached were recorded.

3. The existing showerhead was removed carefully, holding the shower arm tightly with a non-marking wrench to avoid any twisting behind the wall. The showerhead was not removed if it did not come off easily or their appeared to be a problem in terms of removal or potential for damage. Showerheads with old-style cast ball joint assemblies were not threaded to accept new showerheads, so only the *existing flow rate* was measured and no attempt was made to remove them.

4. The pressure gauge assembly was installed. The existing showerhead was then reinstalled. At all times the existing plumbing was not marked or damaged in any way.

5. Both *hot-and-cold temperature* water flow controls on the shower were opened to the maximum setting and the *static* water pressure with *no flow* was measured from the existing showerhead. The *dynamic* pressure with *full flow* from the existing showerhead was also measured.

6. With both *hot- and-cold water* flow controls on the shower at the maximum setting, the existing showerhead flow rate was measured using the graduated bucket capture method. The time needed to fill a measured volume of water was recorded.

7. If there was any leakage through the tub diverter valve when the shower was on, the leakage was measured and recorded on the data sheet.

8. The existing showerhead was removed from pressure gauge assembly. The new efficient 2.0 gpm flow showerhead (supplied by Seattle Public Utilities) was installed.

9. Both the *hot-and-cold temperature* water flow controls on the shower were opened to the maximum setting and the *static* water pressure with *no flow* from the new efficient showerhead was measured. The *dynamic* pressure with *full flow* from the new efficient showerhead was also measured.

10. With both *hot- and-cold water* flow controls on the shower at the maximum setting, the new efficient showerhead flow rate was measured using the graduated bucket capture method. The time needed to fill a measured volume of water was recorded.

11. The new efficient showerhead and pressure gauge assembly were removed. The existing showerhead was reinstalled, if the customer did not want the efficient

showerhead. In all actions, the shower arm was held down tightly with a non-marking wrench to avoid any twisting behind the wall. The shower was turned on and the existing showerhead was tested for leaks, using Teflon tape to correct any joint leaks found.

12. The *manufacturer or brand name* of the existing showerhead was determined (if possible) and recorded. The *rated flow rate* was also recorded, if labeled on the showerhead.

13. The *manufacturing date* of the existing showerhead was estimated, using judgment based on bathroom having original equipment or suspicion of bathroom remodel, date of home construction, age of toilet, etc.

14. Notation was made if the shower had multiple heads or body sprays that could be turned on at the same time, or was a luxury spa-like shower. The information for the additional showerheads was recorded on Form 2. An attempt was made to measure *combined flow* or *total individual flows* from multiple heads and sprays. The designation, Showerhead '111' (bath 1, showerhead 1 of 1), '122' (bath 1, showerhead 2 of 2), and so forth was used to identify multiple showerheads or sprays in the same shower stall.

The preceding steps were repeated for each showerhead in the home, except measurement of hot water flow-rate and warm-up time.

.... Faucet Aerators

The required flow rate information for each bathroom faucet aerator was collected, using the procedures described below. The required information was recorded on the data collection form provided in Appendix A.

1. The *mixed water temperature* flow-rate from the existing faucet aerator was measured at full throttle. A plastic bag or other small collection device was used to capture and measure water. In a situation with very high flow-rates, it was necessary to measure flow for a shorter amount of time.

2. If possible, the existing aerator was replaced with a new efficient (1.0 gpm) aerator and the flow-rate measurement was repeated. The existing aerator was re-installed, if the customer did not want the efficient aerator.

.... Toilets

The required information for each toilet was collected using the procedures described below. The required information was recorded on the data collection form provided in Appendix A.

1. The lid of the toilet tank was removed.

2. The 'Full' level of water in the tank was marked with a small pencil line on the inside of the tank.

3. A record was made of cases where water was observed to flow over the top of the overflow tube. A record was also made of noises that indicated that the fill valve was slowly running. In addition a record was made if the toilet tank fill valve was most likely the original or an upgraded unit.

4. The incoming water to the tank was disabled by preventing the float from dropping during the flush.

5. The toilet was flushed by depressing the lever or button for three seconds.

6. The tank was refilled with water from a graduated bucket and notation was made of the amount of water needed to refill the toilet tank to the original level.

7. The year of manufacture of the toilet was noted. In many cases the date of manufacture was stamped on the inside of the porcelain tank or lid. Otherwise, the manufacture date was estimated from the age of the home, or estimated from the remodel year. If the date is not found stamped on the toilet, an E was added to the date (for example, '1963E') to indicate the date was estimated.

8. Any other observations regarding toilet leakage were recorded.

9. Before leaving each bathroom, absorbent towels were used to dry any dripped or standing water on fixtures, counters, or floors near the shower, sink, and toilet.

Other Water Appliance Characteristics Data

The required information was collected using the procedures described below. The required information was recorded on the data collection form provided in Appendix A.

1. The *type of clothes washer* (vertical or horizontal) and *manufacturer* were observed and recorded. Notation was made if the appliance was labeled *Energy Star*. The clothes washer door was opened and nameplate information was observed near the hinge area. If available, *model number*, *serial number*, and *year of manufacture* were also noted.

2. The *dishwasher manufacturer* was observed and recorded. Notation was made if the appliance was labeled *Energy Star*. The door of the dishwasher was opened and the nameplate information near the hinge area was observed. If available, *model number*, *serial number*, and *year of manufacture* were noted.

Data Analysis

SBW developed an Excel spreadsheet to compile data that were collected. SBW entered all data from the field data collection forms into the spreadsheet. SBW also computed the flow rates from the collected volume and time measurements. The data were subjected to quality control procedures to ensure that the information was accurate and reasonable. SBW computed summary statistics for each measured parameter, including minimum, maximum, mean, median and standard deviation. SBW also prepared a frequency distribution for important characteristics variables.

Report and Documentation

SBW prepared this summary report to document work performed in this study. The report summarizes the methodology that was used to for data collection and data analysis. The Excel spreadsheet containing the collected data, along with accompanying notes, was delivered to Seattle City Light at the conclusion of the project. The showerhead photographs, identified for each bathroom and home, were also delivered electronically to Seattle City Light.

Findings

The methodology described above was applied to a representative sample of 71 single-family residences in the City of Seattle. Throughout the selection of the sample, an attempt was made to achieve the distribution of homes that was targeted in Table 2 above. The ability to achieve the counts in each targeted bin was limited by the availability of candidates from the four sources of sample homes described above. The actual count of homes within each of the bins is summarized in Table 3. This table shows that some homes were treated in 21 of the 25 bins. The targets were reached exactly in 11 of the 25 bins. Due to the limitations of candidates from the sample sources, the remaining 14 bins were slightly over or under sampled. Across the 71 homes, data was collected from a total of 151 bathrooms. Nearly all of the bathrooms had one or more faucets, one toilet and one shower (or tub/shower combination). In few cases a bathroom consisted of just one faucet, or one shower or one toilet.

Table 3: Actual Sample Counts

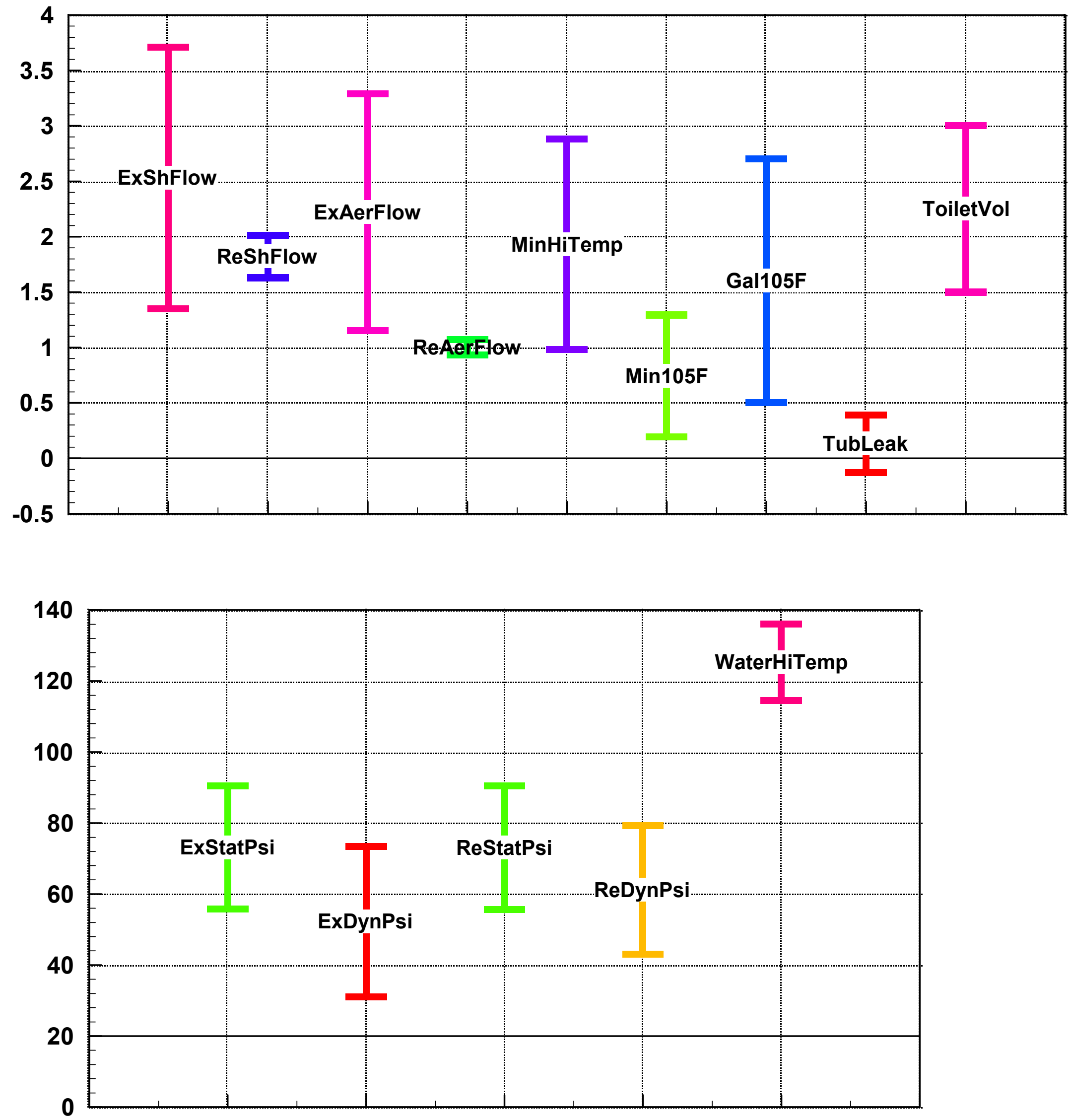
	Period Built					
General Location	**1990-1919**	**1920-1939**	**1940-1959**	**1960-1979**	**1980-2006**	**Area Total**
Lake City & North of UW	2	3	8	2	1	**16**
Ballard, Magnolia, Queen Anne	3	4	5	0	1	**13**
UW, Lake Union, Capitol Hill, Central Area	4	5	1	0	1	**11**
First Hill, I.D., Sodo, Beacon Hill, SE, Duwamish	5	5	4	0	0	**14**
West Seattle	3	3	7	1	3	**17**
Total All Locations	**17**	**20**	**25**	**3**	**6**	**71**

Table 4 provides summary statistics for the measured parameters; Figure 1, using acronyms, displays the means and standard deviations for these parameters, with the label placed at the position occupied by the mean value. The existing values reflect the measured baseline equipment that currently exists in the home. The efficient replacement values reflect the measured performance after the installation of a rated 2.0 gpm showerhead and a rated 1.0 gpm aerator on the bathroom sink. The difference between the existing and efficient values reflects the performance of the efficiency improvements.

Table 4: Summary Statistics of Measured Parameters

	Units	N	Min	Median	Max	Mean	Std Dev
Existing Fixtures							
Static Pressure	psi	133	36.0	69.0	128.0	73.1	17.4
Dynamic Pressure	psi	133	10.0	53.0	112.0	52.2	21.2
Mixed Shower Flow	gpm	139	1.0	2.2	9.0	2.5	1.2
Aerator Flow	gpm	154	0.4	2.0	8.8	2.2	1.1
Tub Diverter Leak	gpm	94	0.0	0.01	1.3	0.1	0.3
Max Hot Water Temp	ºF	71	105.0	123.0	159.0	125.2	10.7
Time to Max ºF	minutes	70	0.4	1.8	7.0	1.9	1.0
Time to 105 ºF	minutes	67	0.1	0.7	4.5	0.7	0.5
Hot Gallons to 105 ºF	gal	67	0.2	1.4	8.5	1.6	1.1
Toilet Volume	gal	145	1.3	2.0	4.5	2.2	0.7
Efficient Replacements							
Static Pressure	psi	102	36.0	69.0	128.0	73.1	17.4
Dynamic Pressure	psi	132	22.0	61.0	111.0	61.2	18.1
Mixed Shower Flow	gpm	132	1.2	1.8	2.4	1.8	0.2
Aerator Flow	gpm	116	0.8	1.0	1.2	1.0	0.1
Tub Diverter Leak	gpm	93	0.0	0.00	1.3	0.1	0.3

Figure 1: Means and Standard Deviations of Measured Parameters



Below are some observations made regarding the measured parameters.

.... Showerheads

- The study examined 144 showerheads in the 71 homes. The study measured the pre-retrofit full throttle flow rate for a total of 139 showerheads in 71 homes. The flow rate measurement could not be made in five cases because the water to the showerhead was shut off. The full throttle flow rate across the 139 showerheads where measurements could be made ranged from 1.0 to 9.0 gpm. ***The average flow rate was measured at 2.5 gpm. This value was slightly greater than the median baseline flow rate of 2.2 gpm.***

- The study measured the post-retrofit full throttle flow rate for a total of 132 showerheads. Fewer measurements were made for the post-retrofit case because seven of the showerheads had ball joints that could not be retrofit. The full throttle flow rate for the efficient showerheads (rated 2.0 gpm) ranged from 1.2 to 2.4 gpm. ***The average flow rate was measured to be 1.8 gpm. This value was the same as the median efficient flow rate. This observed value is lower than the rated flow rate for this showerhead (2.0 gpm).***

- The efficient showerhead reduced the flow rate in all but a few cases where it replaced an existing clogged showerhead or a showerhead with the same rating. ***On average the flow rate was reduced from 2.5 gpm to 1.8 gpm. This results in a water savings rate of 0.7 gpm.***

- A measurement of static pressure was made before and after the installation of the efficient showerheads. ***The static pressure did not change with the installation of the efficient showerheads.*** The average static pressure was measured to be 73 psi. This was slightly greater than the median value of 69 psi. The static pressure ranged across the sampled homes from a high of 128 psi to a low of 36 psi.

- A measurement of dynamic pressure was made for each showerhead before and after the installation the efficient showerheads. ***The average dynamic pressure increased slightly, from 52 psi to 61 psi, with the installation of the efficient showerhead. A similar change is noted for the median pressure.*** The existing system dynamic pressure ranged from a low of 10 psi to a high of 112 psi. A similar range of 22 psi to 111 psi is noted for the efficient case.

- A total of 94 tub diverters were observed across the 71 homes. A range of 0 gpm (no leaks) to 1.25 gpm was measured across these cases. ***On average the measured tub diverter leak rate was 0.1 gpm. The median leak rate was 0.006 gpm.*** The leak rate did not change with the installation of the efficient showerheads.

.... Aerators

- The study measured the pre-retrofit full throttle flow rate for a total of 154 faucets in 71 homes. The full throttle flow rate ranged from 0.4 to 8.8 gpm. ***The average flow rate was measured to be 2.2 gpm. This value was slightly greater than the median baseline flow rate of 2.0 gpm.***

- The study measured the post-retrofit full throttle flow rate for a total of 116 faucets. Fewer measurements were made for the post-retrofit case because the efficient aerators would not fit on the faucets in 38 cases (25 percent). The flow rate of the efficient aerators (rated 1.0 gpm) ranged from 0.8 to 1.2 gpm***. The average flow rate was measured to be 1.0 gpm. This value was the same as the median efficient flow rate. This value accords with the rated flow rate for this aerator.***

- The efficient aerator reduced the flow rate in all but a few cases where it replaced an existing clogged aerator. ***On average the full throttle flow rate was reduced from 2.2 gpm to 1.0 gpm. This results in a water savings rate of 1.2 gpm.***

.... Toilets

- The study examined a total of 150 toilets in the 71 homes. One bathroom did not have a toilet (shower only). The tank volume could be measured for a total of 144 toilets. The tank volume could not be measured in 6 cases because the toilets had pressure tanks or the bathroom water was shutoff. The toilet volumes ranged from 1.3 to 4.5 gallons across these cases. ***The average tank volume of 2.3 gallons was slightly greater than the median value of 2.0 gallons.***

- ***Water efficient toilets, rated at 1.6 gallons per flush, were observed in 49 percent of the cases (73 of 150).***

- Leaking/running toilets were rarely observed.

.... Water Temperature

- The maximum hot water temperature was measured at all 71 homes in the sample. The maximum hot water temperature ranged from 105F to 159F. ***The average maximum temperature across the 71 cases was 125F. The average was only slightly greater then the median temperature of 123F.***

- In all cases it was necessary to run some water through the test showerhead to reach the maximum temperature. The amount of time required to reach the maximum temperature ranged from 0.4 minutes to 7.0 minutes***. On average it took 1.9 minutes to reach the maximum temperature. This value was slightly greater than the median time of 1.8 minutes.***

- The comfortable shower temperature was assumed to be 105F. In all cases it was necessary to run some water through the test showerhead to reach this temperature. The amount of time required to reach the comfort temperature ranged from 0.1 to 4.5 minutes. ***On average it took 0.7 minutes to reach a temperature of 105F. This value was the same as the median time.***

- The amount of water that was used to reach the comfort temperature varied from 0.2 to 8.5 gallons. ***On average 1.6 gallons of water were used before the comfort temperature was reached. This value was slightly greater than the median volume of 1.4 gallons.***

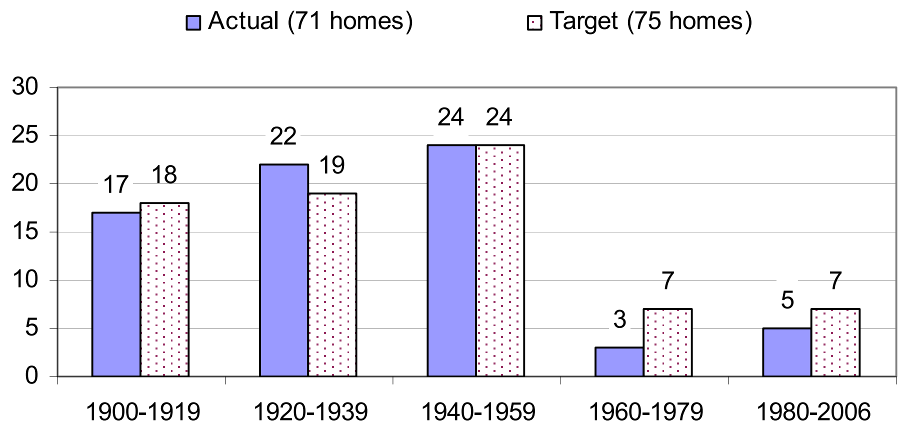
Figure 2 through Figure 11 provide frequency distributions for several important water system characteristics that were observed during the site visits. Below are observations made regarding the characteristics data.

.... Year Home Built

Figure 2 provides a graphical display of the distribution of the 71 sampled homes by category of year constructed. For comparison the figure also provides the targeted counts for each category of year constructed. The increments of construction year in the figure are consistent with the period built ranges in Table 2 and Table 3. The figure shows that the largest portion of the sampled homes (24 homes) was constructed in the period between 1940 and 1959. This group is closely followed by the period between

1920 and 1939. These results are consistent with the age distribution noted in Table 1, showing that the actual age distribution is similar to the targeted distribution.

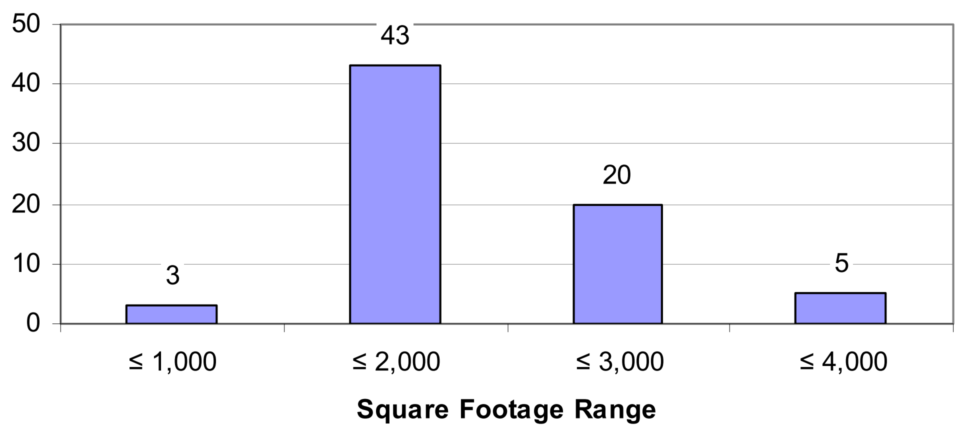
Figure 2: Frequency of Year Built



Home Floor Area

Figure 3 provides a graphical display of the distribution of home floor area across the sample. The figure shows that the greatest number of homes in the sample (61 percent) have a floor area between 1,000 and 2,000 square feet. Homes with floor area between 2,000 and 3,000 square feet were the next highest count. Homes with floor areas less than 1,000 square feet and greater than 3,000 square feet account for a relatively small portion of the sample. The average floor area across the entire sample was 1,857 square feet.

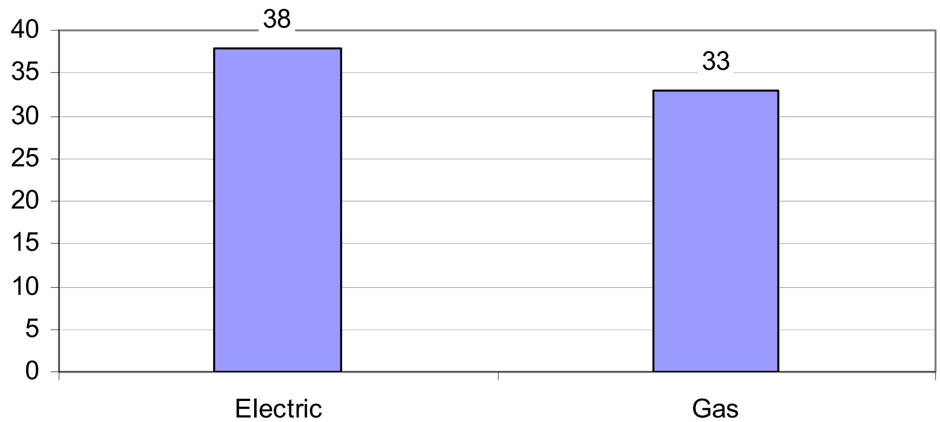
Figure 3: Frequency of Home Floor Area



Hot Water Fuel Type

Figure 4 shows the distribution of hot water fuel type across the 71 home sample. All homes in the sample had either an electric or natural gas fuel type. The figure shows that the majority of the homes (54 percent or 38 homes) used electricity to heat hot water. The remaining 46 percent used natural gas.

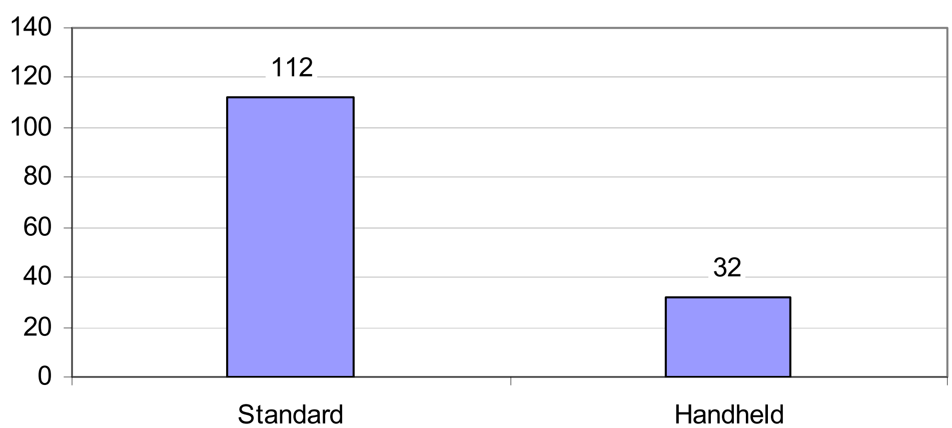
Figure 4: Frequency of Hot Water Fuel Type



Showerhead Type

Figure 5 shows the distribution of the 144 showerheads between standard and hand-held types. No luxury showerheads were observed. The vast majority (78 percent) were standard showerheads.

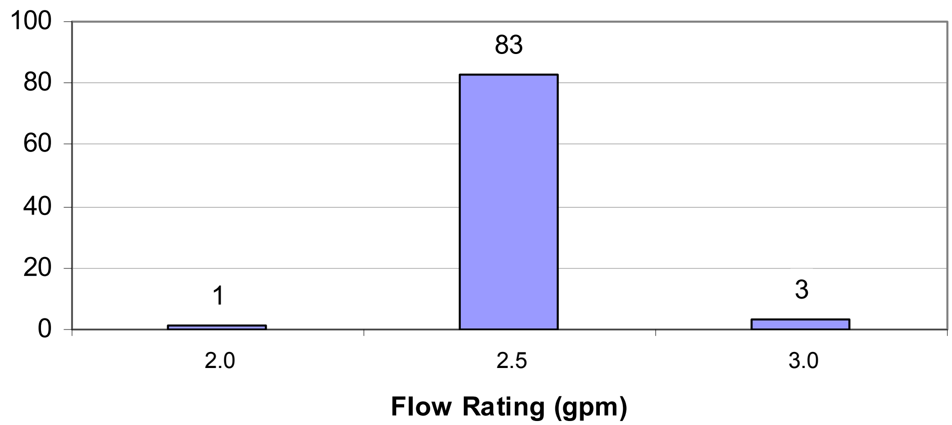
Figure 5: Frequency of Existing Showerhead Type



.... Existing Showerhead Flow Ratings

Figure 6 shows the distribution of the existing showerhead ratings across the 87 showerheads where the rating could be identified. The figure shows that the largest portion of the flow ratings (95%) were 2.5 gpm. Only one showerhead was rated lower than 2.5 gpm and only 3 were rated above 2.5 gpm.

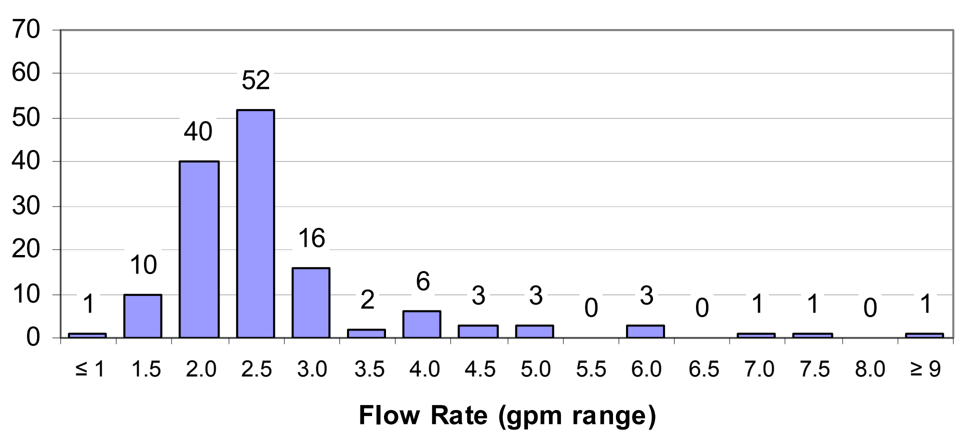
Figure 6: Frequency of Existing Showerhead Flow Ratings



.... Existing Showerhead Measured Flow Rates

Figure 7 shows the distribution of the measured pre-retrofit flow rates across the 139 existing showerheads where measurements were made. The figure shows that the largest portion of the measured flow rates were between 2.0 and 2.5 gpm. The second most common flow rate range was between 1.5 and 2.0 gpm. A total of 67 percent of the flow rate measurements were between 1.5 and 2.5 gpm. The remaining 33 percent were distributed across the remaining intervals.

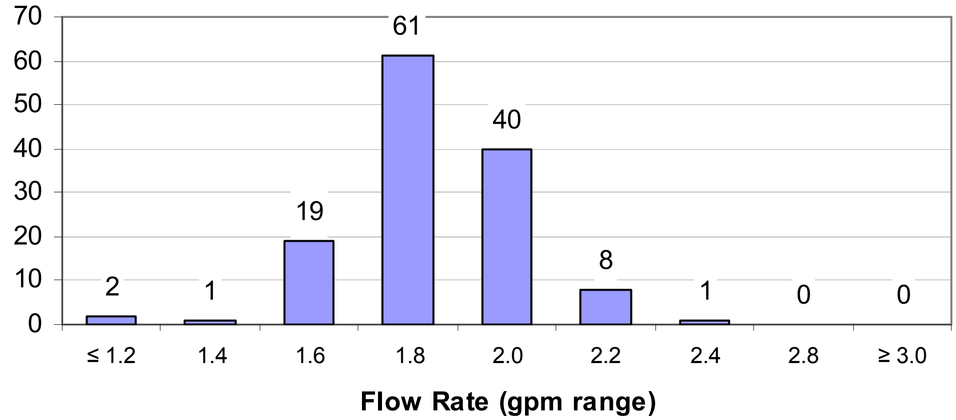
Figure 7: Frequency of Existing Showerhead Measured Flow Rates



.... Efficient Showerhead Measured Flow Rates

Figure 8 shows the distribution of the measured pre-retrofit flow rates across the 132 efficient showerheads where measurements were made. The figure shows that the largest portion of the measured flow rates (46%) were between 1.6 and 1.8 gpm. An additional 30 percent of the measured flow rates were between 1.8 and 2.0 gpm. The remaining 24 percent were distributed across the other intervals.

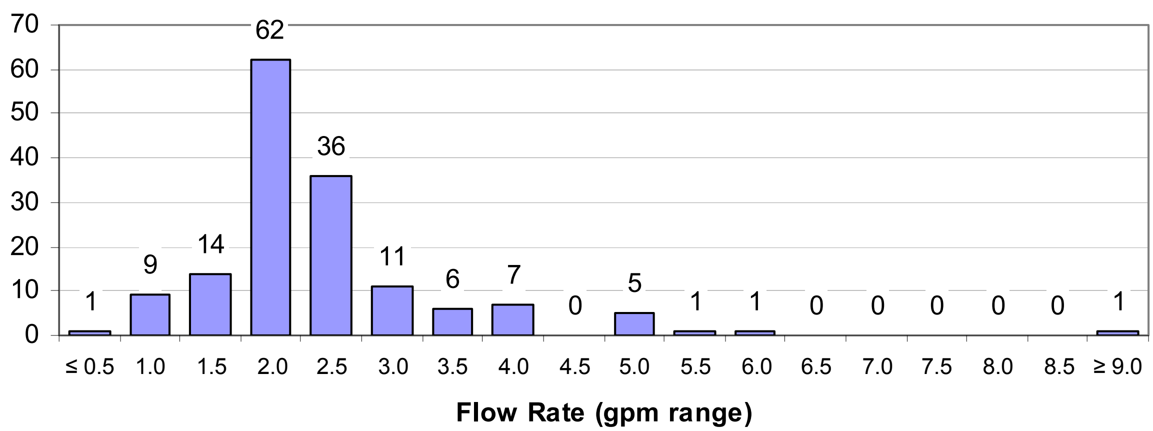
Figure 8: Frequency of Efficient Showerhead Measured Flow Rates



.... Existing Faucet Aerator Measured Flow Rates

Figure 9 shows the distribution of the measured pre-retrofit flow rates across the 154 existing faucets where measurements were made. The figure shows that the largest portion of the measured flow rates (40%) were between 1.5 and 2.0 gpm. The second most common flow rate range was between 2.0 and 2.5 gpm. A total of 64 percent of the flow rate measurements were between 1.5 and 2.5 gpm. The remaining 36 percent were distributed across the remaining intervals.

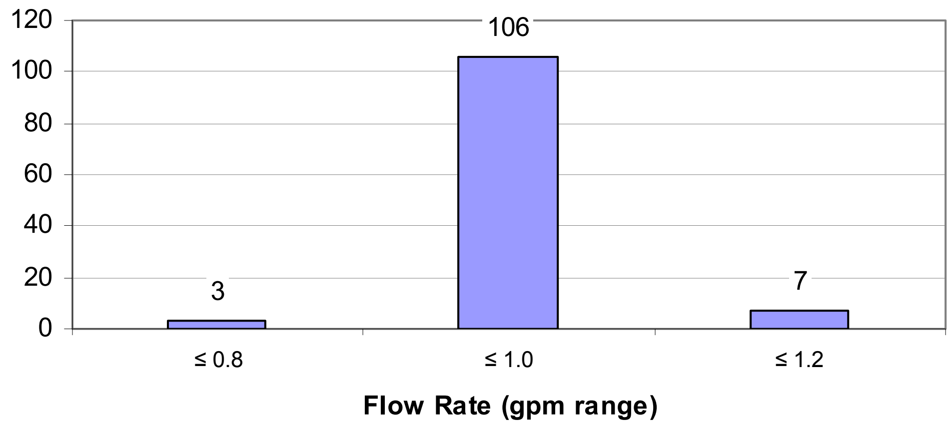
Figure 9: Frequency of Existing Faucet Aerator Measured Flow Rates



.... Efficient Faucet Aerator Measured Flow Rates

Figure 10 shows the distribution of the measured pre-retrofit flow rates across the 116 efficient aerators where measurements were made. The figure shows that the largest portion of the measured flow rates (91%) were between 0.8 and 1.0 gpm. The remaining 9 percent were distributed across the remaining intervals.

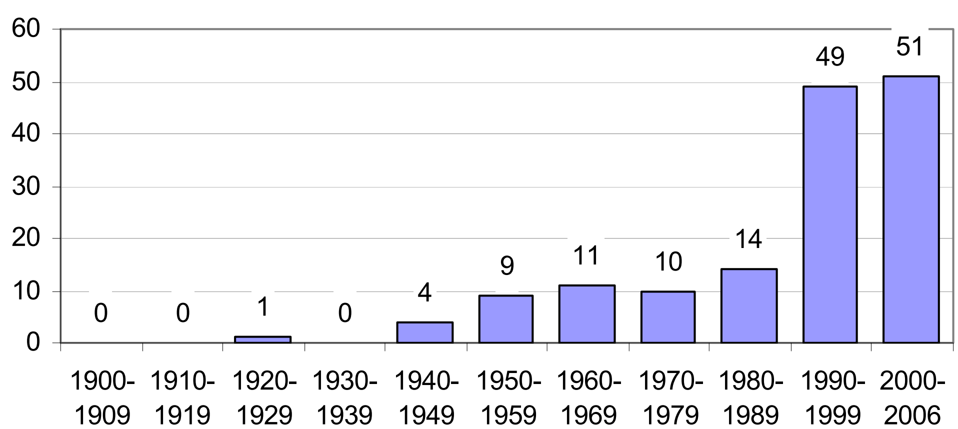
Figure 10: Frequency of Efficient Faucet Aerator Measured Flow Rates



.... Toilet Year

Figure 11 provides a graphical display of the distribution of the sampled toilets by year manufactured. The year manufactured was either directly observed or estimated for 149 toilets. The increments of manufactured year in the figure are decades between 1900 and 2006. The figure shows that the largest portion of the sampled toilets (51 Toilets or 34 percent) were manufactured between 2000 and 2006. The second largest portion of the sampled toilets (49 toilets or 33 percent) were manufactured during the decade of 1990 and 1999. This indicates that toilet replacements are common in the Seattle housing stock, with 67 percent being replaced within the last 16 years. Most of the replacement toilets were the 1.6 gpf efficient models.

Figure 11: Frequency of Toilet Manufacture Year



Appendices

Gathering Data on Energy-related Water Using Fixtures in Single Family Homes

Appendix A. Data Collection Procedures and Forms

Form 1 was used to record data as described in this Workplan. Form 2 was used in situations where there were multiple showerheads in a single bathroom. The following procedures were used by field staff to collect the required information.

Site Identification

Enter a unique site ID. The site ID will follow the convention of:

- First three characters– Installer initials
- Next six characters– Date in month day year format
- Next two characters– Sequential number of homes measured that day

For instance, 'RLB 10182006 05' represents the fifth house Randy Birk measured on October 18, 2006.

Site ID

Address. Enter the address of the home.

Contact. Enter the name provided as the contact. This may be a real estate listing agent for a home that is offered for sale.

Phone Number. Enter the phone number provided for the contact. This will not likely be the resident of the home if the real estate agent is the contact.

Year Residence Built. Enter the year that the home was initially constructed.

Year Remodel. If the home has had a major remodel or addition, determine the year of the remodel from the site contact and enter on the form. In the notes section at the end of the form, provide more detailed information about remodel or addition that would help to explain the data that are collected for the water systems.

Square Feet. Enter the approximate floor area of the home.

Full Bath, ¾ Bath, ½ Bath. Observe the number of bathrooms and record.

Clothes Washer. Record manufacturer, model, serial number and approximate year of manufacture of the clothes washer, if possible. The serial number can usually be found by opening the door to the washer and looking near the hinge area. Note if washer is horizontal or vertical axis. Note if the appliance is labeled “Energy Star”.

Dishwasher. Record manufacturer, model, serial number and approximate year of manufacture of the dishwasher, if possible. This information can usually be found by opening the door of the dishwasher and looking near the hinge area. Note if the appliance is labeled “Energy Star”.

Site Data

.... Bathroom 1

If there is more than one bathroom in a home, the bathroom located farthest from the source of hot water is designated as Bathroom 1.

Showerhead Identification. Assign a unique identifier to each showerhead using the following convention:

111 – First bathroom, showerhead 1 of 1

112 – First bathroom, showerhead 1 of 2

122 – First bathroom, showerhead 2 of 2

211 – Second bathroom, showerhead 1 of 1

212 – Second bathroom, showerhead 1 of 2

222 – Second bathroom, showerhead 2 of 2

The pattern is repeated for additional bathrooms and showerhead with bathrooms. All the data for the extra showerheads is entered on Form 2.

DHW Fuel. Observe the fuel source for domestic hot water. Record electric, natural gas or propane.

DHW Type. Observe the hot-water heater type. Record tank, demand, heat pump, or unusual. Unusual would refer to atypical characteristics such as a recirculating system or other items of energy or water conservation interest. Make a note describing these unusual characteristics.

Showerhead Picture Taken. Check box to indicate that a digital photograph was taken of the existing showerhead. Identify each picture by bathroom and by home ID or address.

Showerhead Date. If it is possible to determine an approximate year of manufacture for the showerhead, enter that information here. Note if this is an estimated date.

Showerhead Brand. Note the brand name of the showerhead, if available.

Showerhead Type. Observe the type of showerhead and enter standard head, hand held unit or a high flow “spa type” head.

Shower Temperature. Follow the data collection procedures for shower temperature. Record the time needed for the water at the shower to reach 105 degrees Fahrenheit, and then monitor and record the time needed to reach the maximum temperature. Record the maximum temperature in degrees Fahrenheit also.

Hot Shower Flow Data – Existing. Follow the data collection procedures for hot-water flow rate. This measurement is taken with hot water only. Use full flow. Enter the measured gallons and number of seconds for the collection period. The measurement is taken with the existing showerhead only.

Mixed Shower Flow Data – Existing and Efficient. Follow the data collection procedures for mixed shower flow rate. This measurement is taken with full flow of mixed water. Enter the measured gallons and number of seconds for the collection period. The measurement is taken with the existing showerhead and repeated with an efficient showerhead.

Tub Diverter Leak Data. Follow the data collection procedures for tub diverter leak rate, if applicable. Enter the measured volume and number of seconds for the collection period. This measurement is taken for both the existing showerhead and the efficient showerhead.

Shower Pressure Data. Follow the data collection procedures for shower pressure. Enter measured static and dynamic pressure for existing and efficient showerheads.

Aerator 1 Flow Data. Follow the data collection procedures for faucet aerator flow rate. Enter the measured gallons and number of seconds for the collection period. The measurement is taken with the existing sink aerator and repeated with an efficient aerator.

Aerator 2 Flow Data. Follow the data collection procedures for faucet aerator flow rate. Enter the measured gallons and number of seconds for the collection period. The measurement is taken with the existing aerator and repeated with an efficient aerator.

Toilet Date. Observe the date of manufacture for the toilet. This date may be found stamped into the porcelain of the toilet tank. Note if the date stated here is an estimate.

Toilet Tank Volume. Follow the data collection procedures for measuring toilet volume. Enter the number of gallons measured as replacement volume after a 3-second timed flush.

.... Bathroom 2, etc.

Repeat all measurements and record data for all additional bathrooms, with the exception that the shower temperature and hot-water flow measurements are taken only at the first bathroom.

Form 2 (Multiple Showerheads)

Additional showerhead data for installations with more than one showerhead in a single bathroom are recorded on this form. Measurement procedures are the same as for single showerhead installations. Note whether the second showerhead flows simultaneously with or alternatively to the primary showerhead (for example, a handheld operated by a diverter from the wall-mounted head).

Single Family Water Fixture Measurements

Form 1

Site ID:

SITE INFO

Address

Contact | Phone

Year built | Year Remodel | Sq. Ft. | Full | 3/4 | 1/2

Clothes washer Horiz Vert EnergyStar

Dishwasher EnergyStar

SITE DATA

Bathroom 1

Showerhead ___ of ___ If multiple showerheads use Form 2

DHW fuel | DHW type (T-tank, D-demand, H-ht pump, S-same, U-unusal sys.) | Showerhead picture taken | Estimated

Showerhead date

Showerhead mfg/rated flow

Showerhead type (S-standard, H-hand held, L-luxury)

Shower temperature: Time to 105 F | Time to Max Temp | Max Temp

Hot Shower flow data

	Existing
Gal.	
Sec.	

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Aerator1 Flow data

	Existing	Efficient
Gal.		
Sec.		

Aerator2 Flow data

	Existing	Efficient
Gal.		
Sec.		

Toilet date | Toilet mfg/flush

Toilet tank vol (Gal.) | Toilet leak issues listed (Y-see notes, N-No leaks) | Toilet fill valve condition (O-Original, U-Upgraded)

Bathroom 2

Showerhead ___ of ___ If multiple showerheads use Form 2

DHW fuel | DHW type (T-tank, D-demand, H-ht pump, S-same, U-unusal sys.) | Showerhead picture taken | Estimated

Showerhead date

Showerhead mfg/rated flow

Showerhead type (S-standard, H-hand held, L-luxury)

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Aerator1 Flow data

	Existing	Efficient
Gal.		
Sec.		

Aerator2 Flow data

	Existing	Efficient
Gal.		
Sec.		

Toilet date | Toilet mfg/flush

Toilet tank volume (Gal.) | Toilet leak issues listed in (Y-see notes, N-No leaks) | Toilet fill valve condition (O-Original, U-Upgraded)

SITE DATA

Bathroom 3

Showerhead [ ] of [ ] If multiple showerheads use Form 2

DHW fuel [ ] DHW type [ ] T-tank D-demand H-ht pump S-same U-unusal sys.

Showerhead picture taken [ ]

Showerhead date ______ Estimated [ ]

Showerhead brand / rated flow ______

Showerhead type [ ] S-standard H-hand held L-luxury

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Aerator1 Flow data

	Existing	Efficient
Gal.		
Sec.		

Aerator2 Flow data

	Existing	Efficient
Gal.		
Sec.		

Toilet date ______ Toilet mfg/flush ______

Toilet tank vol Gal. [ ] Toilet leak issues [ ] Y-see notes N-No leaks Toilet fill valve condition [ ] O-Original U-Upgraded

Bathroom 4

Showerhead [ ] of [ ] If multiple showerheads use Form 2

DHW fuel [ ] DHW type [ ] T-tank D-demand ht pump S-same U-unusal sys. H-

Showerhead picture taken [ ]

Showerhead date ______ Estimated [ ]

Showerhead brand / rated flow ______

Showerhead type [ ] S-standard H-hand held luxury L-

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Aerator1 Flow data

	Existing	Efficient
Gal.		
Sec.		

Aerator2 Flow data

	Existing	Efficient
Gal.		
Sec.		

Toilet date ______ Toilet mfg/flus h ______

Toilet tank vol Gal. [ ] Toilet leak issues [ ] Y-see notes N-No leaks Toilet fill valve condition [ ] O-Original U-Upgraded

SITE NOTES

Single Family Water Fixture Measurements
Form 2 (Multiple Showerheads)

Site ID:

Bathroom

Showerhead ☐ of ☐

Showerhead picture taken ☐

DHW fuel ☐

DHW type ☐ T-tank, D-demand, H-ht pump, S-same, U-unusal sys.

Showerhead date ______ Estimated ☐

Showerhead brand / rated flow ______

Showerhead type ☐ S-standard, H-hand held, L-luxury

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Combined Multihead Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Bathroom

Showerhead ☐ of ☐

Showerhead picture taken ☐

DHW fuel ☐

DHW type ☐ T-tank, D-demand, H-ht pump, S-same, U-unusal sys.

Showerhead date ______ Estimated ☐

Showerhead brand / rated flow ______

Showerhead type ☐ S-standard, H-hand held L· luxury

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Combined Multihead Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Bathroom

Showerhead ☐ of ☐

Showerhead picture taken ☐

DHW fuel ☐

DHW type ☐ T-tank, D-demand, H-ht pump, S-same, U-unusal sys.

Showerhead date ______ Estimated ☐

Showerhead brand / rated flow ______

Showerhead type ☐ S-standard, H-hand held, L-luxury

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Combined Multihead Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Bathroom

Showerhead ☐ of ☐

Showerhead picture taken ☐

DHW fuel ☐

DHW type ☐ T-tank, D-demand, H-ht pump, S-same, U-unusal sys.

Showerhead date ______ Estimated ☐

Showerhead brand / rated flow ______

Showerhead type ☐ S-standard, H-hand held L· luxury

Mixed Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Combined Multihead Shower flow data

	Existing	Efficient
Gal.		
Sec.		

Tub diverter leak data

	Existing	Efficient
Oz.		
Sec.		

Shower pressure data

	Existing	Efficient
Static psi		
Dynamic psi		

Appendix B. ACEEE 2008 Conference Paper

Energy-related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes

Marc Schuldt, SBW Consulting, Inc.
Debra Tachibana, Seattle City Light

ABSTRACT

Reducing hot water consumption in single family homes is a mutual goal of Seattle City Light and partnering water utilities. In order to better quantify this savings potential, the City of Seattle sponsored updated research on hot water use by bathroom water fixtures in single-family homes. The research goal was to enable program planners to update parameters from several water and energy metering studies of the mid-1990s, in order to better estimate the hot water savings potential from high efficiency showerheads and faucets. The study investigated the water and energy-related flows in a representative sample of 71 homes having 151 bathrooms. The sample was selected from a broad range of homes based on property assessment characteristics such as year built and geographic location, so that results from the study could be extrapolated to the utility service area. This paper presents in situ flow rate measurements before and after installation of new efficient products, as well as observation of other water system and appliance characteristics such as water pressure, hot water temperature, and hot water wait times. The paper details step-by-step protocols for taking measurements. Based on the data collected, the paper adds an estimation of energy and water savings that would likely occur from installation of more efficient showerheads and aerators in the utility service area.

Introduction

This study arose out of the need to re-assess the state of showerhead and faucet aerator flow efficiencies in the Puget Sound area. Fifteen years had passed since a major market intervention and subsequent revisions to plumbing codes and standards. The current baseline was unknown; meanwhile area utilities were planning to mount new programs to improve and secure efficiencies in bathroom water and energy use, and needed updated information.

Prior detailed metering and survey research in the early 1990s (see References) clearly established known factors for calculating programmatic energy savings, including the persons per household, number of daily showers per person, average shower length, proportion of shower water from the hot tap, and the water temperature rise (water heater outlet minus inlet).

However, over time since the mass showerhead distribution programs of 1992-1994, uncertainty had been building about various unknown factors. These include the median measure lifetime of 1992 showerheads (originally estimated at 15 years), subsequent replacement by changing market products, the impact of the 2.5 gpm plumbing code (1994), and the current baseline average flow rates for bathroom fixtures.

Therefore in 2006, Seattle City Light, a Pacific Northwest municipal electric utility, managed a study of bathroom water fixtures in single-family homes. The study was designed and conducted jointly with Seattle Public Utilities, the municipal water and sewer provider, to update parameters from the dated water and energy metering studies (PSE & BPA 1994; BPA & SCL 1994; Warwick & Bailey 1993; Warwick 1995). Critical new data were acquired to replace baseline parameters first measured fifteen years ago, prior to the 1992 citywide mass distribution of efficient-flow faucet aerators and showerheads.

In 1992, existing baseline showerheads flowed at 3.0 gpm (SD=1.3) at full throttle and 2.5 gpm (SD=0.9) at user settings. Pressure-compensating program showerheads that had a maximum rated flow of 2.5 gpm were found by metering research to actually flow at 1.8 gpm (SD=0.3), at both full throttle and user settings *in situ* (PSE & BPA 1994; BPA & SCL 1994). During the intervening years, state plumbing codes and federal standards have brought most retail market showerheads down to rated 2.5 gpm or less.

Seattle City Light undertook this study to prepare for and justify a distribution in 2007 of new pressure-compensating showerheads rated 2.0 gpm, in partnership with long-time utility collaborators in the Puget Sound area: Puget Sound Energy (electric/gas), Seattle Public Utilities and the Saving Water Partnership (water/sewer). The new program was planned to secure a continued advantage over baseline conditions, and extend the life of efficient-flow showerheads for another fifteen years.

This paper describes methods employed and empirical findings from an observational and measurement-based study. Based on the field measurement data, the paper ends with a planning projection of water and energy savings that would likely occur from installation of more efficient showerheads and aerators in the utility service area.

Measurement Study Objectives

The purpose of this study were to investigate the energy-related flows of sink and shower fixtures in a representative sample of 75 single-family residences in the City of Seattle, and to acquire other data on characteristics of water appliances in the sampled homes that might be useful in future water and electric utility program planning. The study would help planners determine potential water and energy savings from replacing existing fixtures with energy efficient ones in typical homes. The study would also set the foundation for identifying, in the future, the average replacement (retirement) rate of plumbing fixtures and water-and-energy using appliances. At the same time, the study would help planners examine the trend toward installation of multiple showerheads in configurations that subvert utility efficiency goals and plumbing codes. The study investigators had the following four specific objectives:

1. **Showerhead Measurements.** Measure the full throttle flow rates (and corresponding static pressures) for existing and efficient showerheads in a sample homes in the City of Seattle.

2. **Bathroom Faucet Aerator Measurements.** Measure the full throttle flow rates for existing and efficient faucet aerators in a sample homes in the City of Seattle.

3. **Other Water Measurements.** Measure the flowing water pressure and hot water temperature for each showerhead in the sampled homes. Note the time taken for the hot water showerhead flow to reach a comfort temperature and the maximum (constant) temperature. Also measure the flushing volume of each toilet tank.

4. **Water Appliance Characteristics.** Take a digital photo of each existing showerhead. To the extent possible, also observe and use digital photography to record other important characteristics for each sampled home, including hot water fuel type, brand name of the existing showerhead, age of existing showerhead, presence of multiple-head or spa-like showers, age of toilet, age and type of clothes washer and dishwasher.

Methodology

A unique aspect of the study methodology was the attempt to overcome traditional barriers to in-home data collection and privacy by piloting a collaboration with real estate agents, taking measurements during scheduled realtor open houses. Due to the difficulty of cost-effectively recruiting homes that were in the desired geographic areas and age categories, in the end the study was limited to a sample of 71 homes. The study began with the development of a work plan, data collection forms and carefully designed procedures. It provided a detailed description of the data elements, which reflected the results from discussions among the consultant team, managing evaluator, and program staff from Seattle City Light and Seattle Public Utilities (SCL 2007).

Sample Targets

Data collection was performed on single-family homes representative of the population of homes in the Seattle City Light and Seattle Public Utilities service areas. In an effort to select representative homes, investigators compiled and analyzed real estate records in the Metroscan® database (licensed from First American Real Estate Solutions), which mirrors to a great extent records also accessible on the Internet from the King County Property Tax Assessor's office. The purpose was to determine the distribution of homes with respect to the following important parameters: general location (in one of five major geographical areas of Seattle); period built (five major construction periods); square footage; assessed property value, and number of bathrooms. Table 1 summarizes four of these parameters.

Table 1. Distribution of Seattle Single Family Detached Homes

Period Built		Square Footage		Property Value		Bathrooms	
1900-1919	22.8%	Under 1600	21.9%	$100,000-249,999	20.3%	1	46.2%
1920-1939	24.0%	1600-1999	19.2%	$250,000-299,999	17.0%	1.25-1.75	24.7%
1940-1959	35.4%	2000-2399	21.5%	$300,000-349,999	17.2%	2	9.0%
1960-1979	8.3%	2400-2799	16.9%	$350,000-449,999	21.4%	2.25-2.75	13.8%
1980-2006	9.5%	2800 & More	20.5%	$450,000 & More	24.1%	3 or More	6.3%

With this information, the investigators created a series of bins, across which the sample was distributed, to achieve a representative baseline of important water system characteristics and performance measurements. With an intended sample size of only 75 homes, it was not reasonable to vary more than two parameters to create a total of 25 bins. Based on a review of the single-family home real estate data for the jurisdiction of Seattle, the investigators agreed that the two most appropriate parameters would be General Location and Period Built. A sample of homes that included a range within each of these parameters would provide a representative cross-section of water fixtures and conditions (e.g., degree of corrosion, water pressures, and plumbing system age) that would be expected city-wide. Geography is particularly important as Seattle is a hilly city with open water reservoirs and a wide range of residential water pressures.

The managing evaluator distributed the planned sample of 75 homes across the 25 bins according to the proportions found in the single-family home population. The target distribution is summarized in Table 2. The counts in each bin were viewed as targets to achieve during sample selection, to the extent that they can be supported by the candidate sites available to the study.

Throughout sample selection, an attempt was made to achieve the targeted distribution of homes. The ability to achieve the counts in each targeted bin was limited by the availability of candidates from the four sources of sample homes described below. The actual count of homes within each of the bins is also summarized in Table 2. It shows that some homes were treated in 21 of the 25 bins. The targets were reached exactly in 11 bins. Due to the limitations of candidates from the sample sources, the remaining 14 bins were slightly over- or under-sampled.

Table 2. Target and Actual Sample Cases

Period Built by Location	1900-1919	1920-1939	1940-1959	1960-1979	1980-2006	Area Total
TARGET BINS						
N / NE	2	5	8	2	2	**19**
W / NW	4	5	5	1	1	**16**
E / Central	6	4	1	1	1	**13**
S / SE	3	2	4	2	2	**13**
SW	3	3	6	1	1	**14**
Total	**18**	**19**	**24**	**7**	**7**	**75**
ACTUAL SAMPLE						
N / NE	2	3	8	2	1	**16**
W / NW	3	4	5	0	1	**13**
E / Central	4	5	1	0	1	**11**
S / SE	5	5	4	0	0	**14**
SW	3	3	7	1	3	**17**
Total	**17**	**20**	**25**	**3**	**6**	**71**

.... Sample Selection

Candidates for selection into the sample came from one of four sources described below. The initial intent was to obtain the entire sample from the first source. After it was determined that this source was not sufficient, three additional data sources were added. In the end, the last data source, which included acquaintances of the study team staff, proved to be the most fruitful.

Real Estate Open Houses. Seattle Public Utilities and Windermere Real Estate established a cooperative arrangement whereby lists were provided to Seattle Public Utilities of homes for sale in the City of Seattle that were offering an open house to real estate agents. Homes on the list were pre-screened by Windermere so that they were available for use in this study without further recruitment. Windermere provided written permission from the homeowner for the measurement work to be done in the homes. This was initially expected to be the primary source of candidate homes. However, getting a sufficient count of candidate sites from this source proved to be more difficult than expected. Fifteen homes came from this data source.

Seattle City Light Neighborhood Power Program "Green Audit" Service. Homes enrolled in the Green Audit service, offered by Seattle City Light, were used a secondary source. The Green Audit service was being offered in West Seattle only, so homes from this program were only used to meet the target requirements in the that geographic area. Seventeen homes came from this source.

Senior Services Program Audit Service. The Senior Services Program offers energy home audits and minor home repairs to eligible senior homeowners. Homes that received an audit under this program were used as a secondary source for this study. Data collection was limited by the availability of eligible homes within the project schedule. Only two homes came from this source.

Acquaintances of the Study Team. Half of sampled homes (37 of the 71 sampled) came from lists of acquaintances compiled by the investigators. Selected homes did not have unusual levels of water conservation attitudes, actions, or water consumption. Residents in these homes were not employed by the utilities, consultants, or conservation organizations. Investigators were not aware of any participant characteristics that would bias results; a statistical bias analysis was not performed. In compiling the list, special attention was placed on selecting homes that addressed bins not filled by the other data sources.

As a thank-you for participating, efficient showerheads and aerators were installed at no charge as part of the study, and two compact fluorescent light bulbs were left with each homeowner.

Data Collection and Analysis

Investigating field staff visited the sampled homes and implemented the procedures documented in the detailed work-plan. Staff collected the required data and recorded observations on the field data collection forms. Field staff began data collection at each site by finding the identified site contact and making an appropriate introduction. In many cases the site contact was not the homeowner, particularly if the home was identified through the Windermere Real Estate Open House list. Field staff enlisted the help of the site contact to the extent appropriate to determine the information required.

The field data from collection forms were transferred to a spreadsheet, which computed the flow rates from the collected volume and time measurements. The data were subjected to quality control procedures to ensure that the information was accurate and reasonable. Summary statistics for each measured parameter included minimum, maximum, mean, median and standard deviation, along with frequency distributions for important characteristics variables. The digital photographs, identified for each bathroom and home, were electronically linked to the spreadsheet as well.

Measurement Error. An analysis of measurement error was not performed in this study. However, instruments are calibrated periodically before being used in the field. According to the manufacturer, measurement errors are ±1% for the Ashcroft pressure gauge and Ashcroft thermometer (±1°F at 100°F).

Hot Water System. Field staff first located the hot-water tank or tanks and the bathrooms in the home. For each tank the *fuel type* (gas or electric) and the *system type* (tank, demand, heat pump, or unusual features) were documented along with the bathrooms they serve. Unusual features of the hot-water system, such as a circulating system, were recorded.

Showerheads. If the home had more than one shower, field staff determined which shower was situated farthest from the hot-water tank. A photograph of the existing showerhead was taken. The photo was matched with the bathroom number and home ID or address, for future reference linkage in the database. Hot water flow and delay time, the first measurements made, were taken only at the shower farthest from the tank. With that exception, the following steps were repeated for each showerhead in the home.

1. In the bathroom farthest from the hot-water tank, the showerhead was turned on to *full flow* using *only hot* water (no cold water during this test). The amount of time that elapsed until the temperature reached 105 °F was recorded. Observation of the time continued until *maximum temperature* was reached, when the temperature became more or less stable (10 seconds pass with no additional temperature rise). The *time to 105 °F*, *time to maximum*, and the *maximum temperature* reached were recorded. As a caveat, time from previous draw (before or during investigator time on site) was not recorded, so average occupant wait times may be longer.

2. For all showerhead removals and attachments, care was taken to hold the shower arm tightly with a non-marking wrench to avoid any twisting behind the wall. The showerhead was not removed if it did not come off easily or there appeared to be a problem in terms of removal or potential for damage. Showerheads with old-style cast ball joint assemblies were not threaded to accept new showerheads, so only the *existing flow rate* was measured and no attempt was made to remove them.

3. The pressure gauge assembly was installed. The existing showerhead was then reinstalled.

4. Both *hot and cold temperature* water flow controls on the shower were opened to the maximum setting and the *static* water pressure with *no flow* was measured from the existing showerhead. The *dynamic* pressure with *full flow* from the existing showerhead was also measured.

5. With both *hot and cold water* flow controls on the shower at the maximum setting, the existing showerhead flow rate was measured using the graduated bucket capture method. The time needed to fill a measured volume of water was recorded.

6. If there was any leakage through the tub diverter valve when the shower was on, the leakage was measured and recorded on the data sheet.

7. The existing showerhead was removed from pressure gauge assembly. The new efficient 2.0 gpm flow showerhead (supplied by Seattle Public Utilities) was installed.

8. Step 4 was repeated for the new efficient showerhead

9. Step 5 was repeated for the new efficient showerhead

10. The new efficient showerhead and pressure gauge assembly were removed. The existing showerhead was reinstalled, if the customer did not want the efficient showerhead. The shower was turned on and the existing showerhead was tested for leaks, using Teflon tape to correct any joint leaks found.

11. The *manufacturer or brand name* of the existing showerhead was determined (if possible) and recorded. The *rated flow rate* was also recorded, if labeled on the showerhead.

12. The *manufacturing date* of the existing showerhead was estimated, using judgment based on bathroom having original equipment or suspicion of bathroom remodel, date of home construction, age of toilet, etc.

13. Notation was made if the shower had multiple heads or body sprays that could be turned on at the same time, or was a luxury spa-like shower. An attempt was made to measure *combined flow* or *total individual flows* from multiple heads and sprays. The designation, Showerhead '112' (bath 1, showerhead 1 of 2), '122' (bath 1, showerhead 2 of 2), and so forth was used to identify multiple showerheads or sprays in the same shower stall.

Faucet Aerators. The required flow rate information for each bathroom faucet aerator was collected, using the procedures described below.

1. The mixed water temperature flow-rate from the existing faucet aerator was measured at full throttle. A plastic bag or other small collection device was used to capture and measure water. In a situation with very high flow-rates, it was necessary to measure flow for a shorter amount of time.

2. If possible, the existing aerator was replaced with a new efficient (1.0 gpm) aerator and the flow-rate measurement was repeated. The existing aerator was re-installed, if the customer did not want the efficient aerator.

Toilets. The required information for each toilet was collected using these procedures.

1. The lid of the toilet tank was removed.

2. The 'Full' level of water in the tank was marked with a small pencil line inside the tank.

3. A record was made of cases where water was observed to flow over the top of the overflow tube; of noises that indicated that the fill valve was slowly running; and if the toilet tank fill valve was most likely the original or an upgraded unit.

4. The incoming water to the tank was disabled by preventing the float from dropping during the flush.

5. The toilet was flushed by depressing the lever or button for three seconds.

6. The tank was refilled with water from a graduated bucket and notation was made of the amount of water needed to refill the toilet tank to the original level.

7. The year of manufacture of the toilet was noted. In many cases the date of manufacture was stamped on the inside of the porcelain tank or lid. Otherwise, the manufacture date was estimated from the age of the home, or estimated from the remodel year. If the date is not found stamped on the toilet, an E was added to the date (for example, ‘1963E’) to indicate the date was estimated.

8. Any other observations regarding toilet leakage were recorded.

9. Before leaving each bathroom, absorbent towels were used to dry any dripped or standing water on fixtures, counters, or floors near the shower, sink, and toilet.

Other Water Appliance Characteristics Data. The required information was collected using the procedures described below.

1. The type of clothes washer (vertical or horizontal) and manufacturer were observed and recorded.

2. The dishwasher manufacturer was observed and recorded.

3. For both clothes washers and dishwashers, notation was made if the appliance was labeled Energy Star. The appliance door was opened and nameplate information was observed near the hinge area. If available, model number, serial number, and year of manufacture were also noted.

Findings

Across the 71 homes, data were collected from a total of 151 bathrooms. The homes averaged 2.1 bathrooms each, slightly more than the city average of 1.6 recorded in the property assessment files. Nearly all bathrooms had one or more faucets, one toilet, and one shower (or tub/shower combination), but in a few cases consisted of just one faucet, or one shower, or one toilet. Two circulating pumps were found but one was disengaged. The majority (54%) of the homes used electricity to heat hot water, while the remaining 46% used natural gas. The age of homes was representative of home ages in the city as a whole, with an average of 70 years. The average floor area was 1,857 square feet, about 400 square feet smaller than the city average (there were fewer “high-end” homes than exist in the city as a whole).

Table 3. Summary Statistics of Measured Parameters

Measurement	Fig.1	Units	N	Min	Median	Max	Mean	Std Dev
EXISTING FIXTURES								
Static Pressure	ExStatPsi	psi	133	36.0	**69.0**	128.0	**73.1**	17.4
Dynamic Pressure	ExDynPsi	psi	133	10.0	**53.0**	112.0	**52.2**	21.2
Mixed Shower Flow	ExShFlow	gpm	139	1.0	**2.2**	9.0	**2.5**	1.2
Aerator Flow	ExAerFlow	gpm	154	0.4	**2.0**	8.8	**2.2**	1.1
Tub Diverter Leak	—	gpm	94	0.0	**0.0**	1.3	**0.1**	0.3
Max Hot Water Temp	WaterHiTemp	ºF	71	105.0	**123.0**	159.0	**125.2**	10.7
Time to Max ºF	MintHiTemp	minutes	70	0.4	**1.8**	7.0	**1.9**	1.0
Time to 105 ºF	Mint 105F	minutes	67	0.1	**0.7**	4.5	**0.7**	0.5
Hot Gallons to 105 ºF	Gal 105F	gal	67	0.2	**1.4**	8.5	**1.6**	1.1
Toilet Volume	ToiletVol	gal	145	1.3	**2.0**	4.5	**2.2**	0.7
EFFICIENT REPLACEMENTS								
Dynamic Pressure	ReStatPsi	psi	132	22.0	**61.0**	111.0	**61.2**	18.1
Mixed Shower Flow	ReShFlow	gpm	132	1.2	**1.8**	2.4	**1.8**	0.2
Aerator Flow	ReAerFlow	gpm	116	0.8	**1.0**	1.2	**1.0**	0.1
Tub Diverter Leak	—	gpm	93	0.0	**0.0**	1.3	**0.1**	0.3

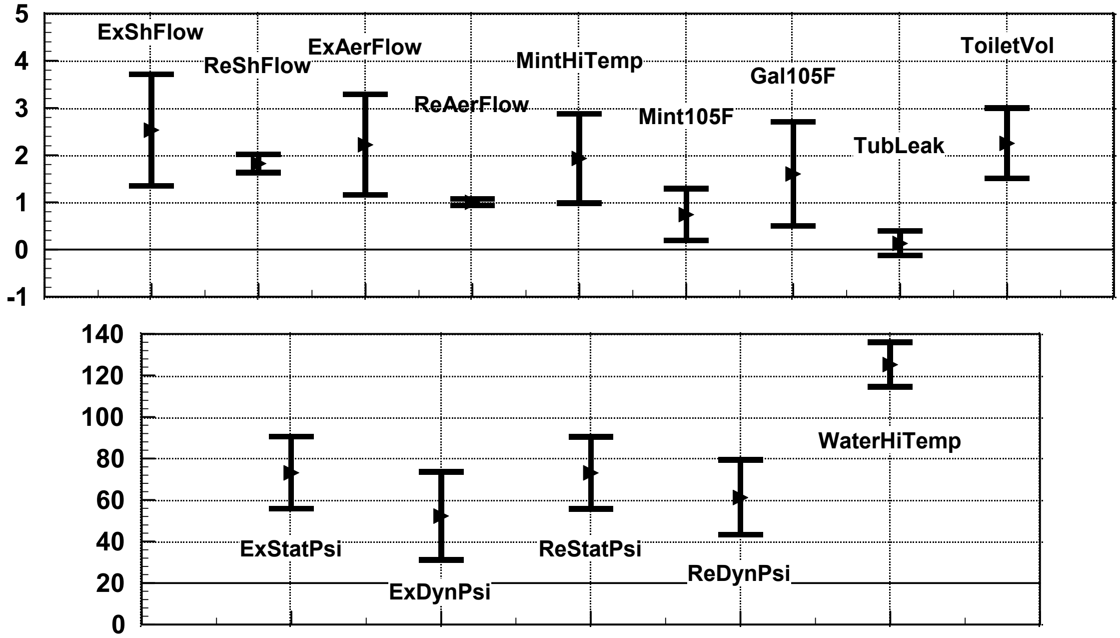
Table 3 provides summary statistics for the measured parameters. Figure 1, using acronyms found in Table 3, displays the statistics for these parameters. The existing values reflect the measured baseline equipment that currently exists in the home. The efficient replacement values reflect the measured performance after the installation of a Rated-2.0 gpm showerhead and a Rated-1.0 gpm aerator on the bathroom sink. The difference between the existing and efficient values reflects the performance of the efficiency improvements. Following are some observations made regarding the measured parameters.

.... Showerhead Measurements

Marked Rating. Of the 144 showerheads, the vast majority (78%) were standard showerheads, while 22% were hand-held types. No luxury showerheads were observed. Across the 87 showerheads where the existing flow rating was marked and could be identified, the largest portion of the showerheads (95%) was marked 2.5 gpm. Only one showerhead was rated lower than 2.5 gpm and only three were rated above 2.5 gpm

Existing Flow Rate. The study measured the pre-retrofit full throttle flow rate for a total of 139 showerheads in 71 homes. The flow rate measurement could not be made at five shower arms because the water to the showerhead was shut off. The full throttle flow rate across the 139 showerheads where measurements could be made ranged from 1.0 to 9.0 gpm. *The mean flow rate was measured to be 2.5 gpm—slightly greater than the median flow rate of 2.2* gpm.

Figure 1. Means and Standard Deviations of Measured Parameters



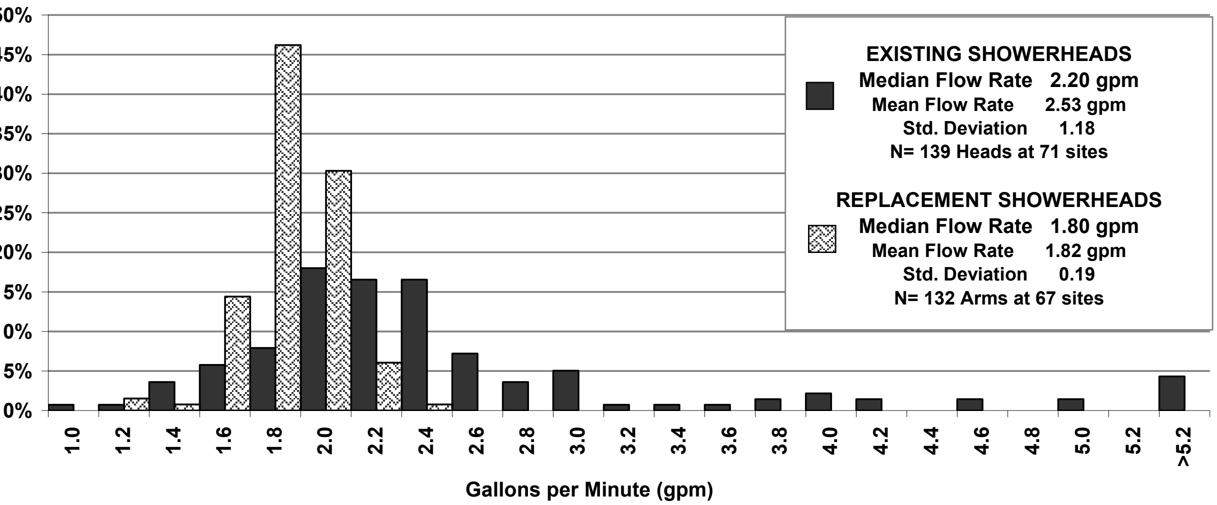
Replacement Flow Rate. The study measured the *in situ* post-retrofit full throttle flow rate for a total of 132 showerheads. Fewer measurements were made for the post-retrofit case because seven of the showerheads had ball joints that could not be retrofit. The full throttle flow rate for the efficient showerheads (rated 2.0 gpm) ranged from 1.2 to 2.4 gpm. The largest portion (46%) was between 1.6 and 1.8 gpm, while another 30% were between 1.8 and 2.0 gpm. *The mean flow rate was measured to be 1.8 gpm—the same as the median flow rate. This observed value is lower than the marked rating for this showerhead (2.0 gpm).*

Flow Change. The efficient showerhead reduced the flow rate in all but a few cases where it replaced an existing clogged showerhead or a showerhead with the same rating. *On average the flow rate was reduced from a mean of 2.5 gpm to 1.8 gpm, resulting in water savings of 0.7 gpm.*

Distribution of Showerhead Flow Rates: Existing versus Replacement

Figure 2 shows the distribution of the measured pre-retrofit flow rates across the 139 existing showerheads where measurements were made. The figure shows that the largest portion of the measured flow rates was between 2.0 and 2.5 gpm. The second most common flow rate range was between 1.5 and 2.0 gpm. A total of 67% of the flow rate measurements were between 1.5 and 2.5 gpm. The mean flow rate was 2.53 gpm, while the median was 2.20 gpm. Among the 132 shower arms where post-retrofit measurements were made using the replacement showerhead, the mean flow rate was 1.82 gpm with a very narrow standard deviation.

Figure 2. Existing and Replacement Showerhead Measured Flow Rates



.... Aerator Measurements

Existing Flow Rate. The study measured the pre-retrofit full throttle flow rate for a total of 154 faucets in 71 homes. The full throttle flow rate ranged from 0.4 to 8.8 gpm. *The mean flow rate was measured to be 2.2 gpm—slightly greater than the median flow rate of 2.0 gpm.*

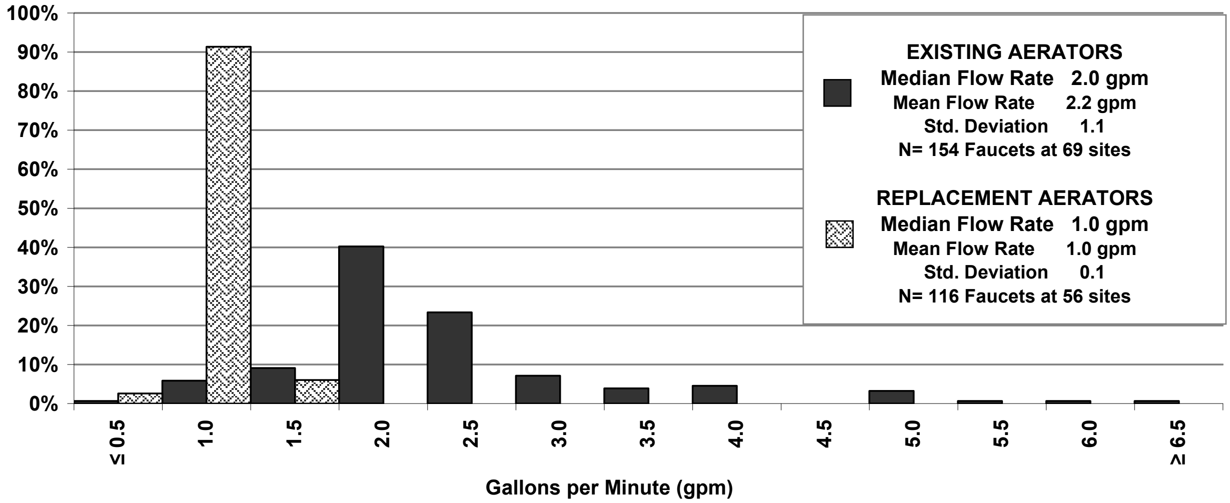
Replacement Flow Rate. The study measured the post-retrofit full throttle flow rate for a total of 116 faucets. Fewer measurements were made for the post-retrofit case because the efficient aerators would not fit on the faucets in 38 cases (25%). The flow rate of the efficient aerators (rated 1.0 gpm) ranged from 0.8 to 1.2 gpm. Of the 116 efficient aerators where measurements were made, the largest portion (91%) was between 0.8 and 1.0 gpm. *The mean flow rate was measured to be 1.0 gpm—the same as the median flow rate. This value accords with the marked flow rate for this aerator.*

Flow Change. The efficient aerator reduced the flow rate in all but a few cases where it replaced an existing clogged aerator. *On average the full throttle flow rate was reduced from a mean of 2.2 gpm to 1.0 gpm, resulting in water savings of 1.2 gpm.*

.... Distribution of Aerator Flow Rates: Existing versus Replacement

Figure 3 shows the distribution of the measured pre-retrofit flow rates across the 154 existing bathroom faucets where measurements were made. The figure shows that the largest portion of the measured flow rates (40%) was between 1.5 and 2.0 gpm. The second most common flow rate range was between 2.0 and 2.5 gpm. A total of 64% of the flow rate measurements were between 1.5 and 2.5 gpm. The replacement faucet aerator is designed to flow at 1.0 gpm, which was confirmed by the *in situ* measurements.

Figure 3. Existing Faucet Aerator Measured Flow Rates



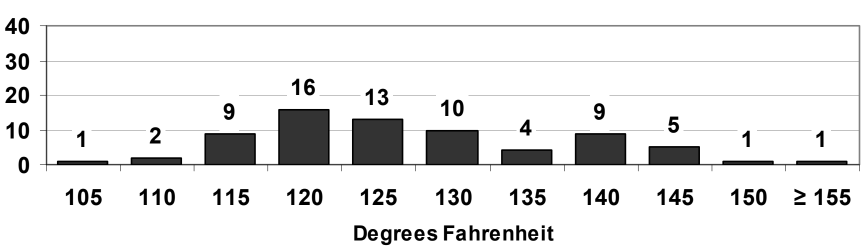
Water Temperature, Pressure, and Other Measurements

Static Pressure. A measurement of static pressure was made before and after the installation of the efficient showerheads. *The static pressure did not change with the installation of the efficient showerheads.* The average static pressure was measured to be 73 psi. This was slightly greater than the median value of 69 psi. The static pressure ranged across the sampled homes from a high of 128 psi to a low of 36 psi.

Dynamic Pressure. A measurement of dynamic pressure was made for each showerhead before and after the installation the efficient showerheads. *The average dynamic pressure increased slightly, from 52 psi to 61 psi, with the installation of the efficient showerhead. A similar change is noted for the median pressure.* The existing system dynamic pressure ranged from a low of 10 psi to a high of 112 psi. A similar range of 22 psi to 111 psi is noted for the replacement case.

Maximum Temperature. The maximum hot water temperature was measured at all 71 homes in the sample. The maximum hot water temperature ranged from 105°F to 159°F. *The average maximum temperature across the 71 cases was 125°F. The average was only slightly greater then the median temperature of 123°F.*

Figure 4. Maximum Temperature of Hot Water

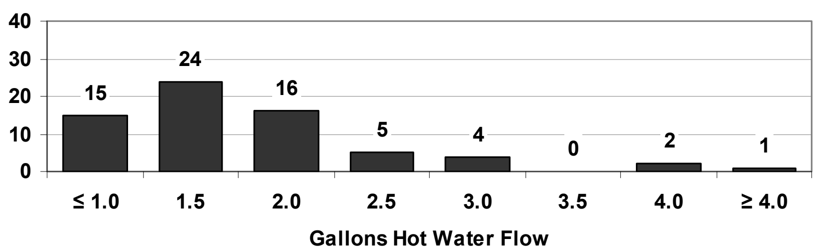


Comfort Delay. The comfortable shower temperature was assumed to be 105°F, based on prior research (PSE & BPA 1994; BPA & SCL 1994). In all cases it was necessary to run some hot-tap water through the first test showerhead to reach this temperature. This is true even in the two homes that had circulating pumps; their wait times were close to the median value. The amount of time required to reach the comfort temperature ranged from 0.1 to 4.5 minutes. *On average it took 0.7 minutes to reach a temperature of 105°F. This value was the same as the median time.*

Maximum Delay. In all cases it was necessary to run some water through the first test showerhead to reach the maximum temperature. The amount of time required to reach the maximum temperature ranged from 0.4 minutes to 7.0 minutes. *On average it took 1.9 minutes to reach the maximum temperature. This value was slightly greater than the median time of 1.8 minutes.*

Comfort Volume. The amount of water that was used to reach the comfort temperature varied from 0.2 to 8.5 gallons. *On average 1.6 gallons of hot-tap water were used before the comfort temperature was reached. This value was slightly greater than the median volume of 1.4 gallons.*

Figure 5. Volume of Water Flow to Reach 105°F Comfort Temperature



Tub Diverter. A total of 94 tub diverters were observed across the 71 homes. A range of 0 gpm (no leaks) to 1.25 gpm was measured across these cases. *On average the measured tub diverter leak rate was 0.1 gpm. The median leak rate was 0.006 gpm.* The leak rate did not change with the installation of the efficient showerheads.

Measurement Study Conclusions

The sample for this measurement study was small, but care was taken to ensure that it was fairly representative of the City of Seattle, based on geography and age of homes (and pipes). The high cost of in-home measurements generally limited sample size and dictated how extensive this research study could be. Investigators attempted a new technique to access homes through realtor open houses, which they conclude only partially mitigated this limitation. The up-to-date baseline data from this study are critical for projecting savings for future programs, especially since past programs and code changes have altered the mix of measures in homes.

The investigators also concluded that collecting robust baseline data is not simple—it must be done carefully. This paper detailed some of the procedures implemented to ensure the quality and usefulness of data gathered, not only for planning the upcoming showerhead and aerator distribution program, but also to inform future program designs for the local partnership of water and electric utilities.

Projected Energy Savings from Showerhead and Aerator Replacements

Subsequent program plans have drawn upon this in-home measurement study to generate projections for a 2007 program to replace existing showerheads and aerators with the studied products. Table 4 summarizes energy savings expected in Seattle area single-family homes. The new baseline study updated two key parameters, *in situ* full-throttle flow rates with the existing and replacement showerheads, while prior research provided parameters that were not expected to change significantly over time.

The algorithm for estimating energy savings from showerhead replacements multiplies showerhead flow rate reduction (gallons/minute, adjusted from full-throttle to user-setting) by shower duration (minutes), shower water from hot tap (%), hot water temperature rise (°F), persons/household, showers/person/day, annual occupancy (days), conversion factor for electric heat (8.29 Btu/°F/gallon/3413), heat element loss factor, and delivered products installed (%).

Key parameters carried over from prior research (PSE & BPA 1994; Warwick 1995; Geist 2001; Mayer et al. 2000) include the following: ratio of user-setting to full-throttle flow rate (0.83 existing, 0.95 replacement), 7.84 minutes average shower length, 68% of shower water derived from the hot tap, 75ºF water temperature rise (tank outlet minus inlet °F), 2.51 persons per household, 350 days annualized occupancy, and a 98% adjustment for heat lost from the element through the tank connection. Prior research has shown that the daily average number of showers per person is 0.55 in primary showerhead locations, 0.28 in secondary locations, and 0.64 regardless of shower location in the home (Brattesani & Okumo 1993; Brattesani & Tachibana 1994). Program planning projections are that 90% of showerheads delivered by the program will be installed. This is based on a pilot study survey with 704 respondents, which found that 93% installed delivered showerheads (Hampton 2006). The new program plan also estimates that 67% of households will request a single showerhead, while 33% will request a second showerhead as well. Post-implementation survey research in 2008 will test that assumption and provide correcting factors for the last two parameters.

Table 4. Projected Energy Savings from Average Electric Water Heat Customer in Seattle City Light Service Area

Expected Showerhead Savings per Household	Average Household	Showerhead 1 Primary	Showerhead 2 Secondary
Annual kWh Electricity Savings	201	172	88
Annual Gallon Water Savings	1593	1364	694
Daily Gallon Water Savings	4.55	3.90	1.98

As a result of calculations based on the new measurement study, the average energy savings expected from households requesting one program showerhead will be 172 kWh per year, and a second showerhead (in the subset of homes that have two showers) will add 88 kWh. The citywide annual average per participating household is thus expected to be 201 kWh. Bathroom faucet aerators, saving 1.2 gpm, will provide an additional 50 kWh per installation.

Based on this hot water energy savings potential, Seattle City Light, in partnership with area water utilities, completed design of a cost-effective single family bathroom fixture retrofit program. The low cost per kWh of obtaining these savings, along with the leveraged financial partnership with water utilities, could make plumbing fixture retrofits one of the more cost-effective measures in the Seattle City Light energy conservation portfolio.

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[SCL] Tachibana, Debra. 2007. *Single Family Water Fixture Energy-related Measurements*. SBW Consulting, Inc., for Seattle, Wash.: Seattle City Light.

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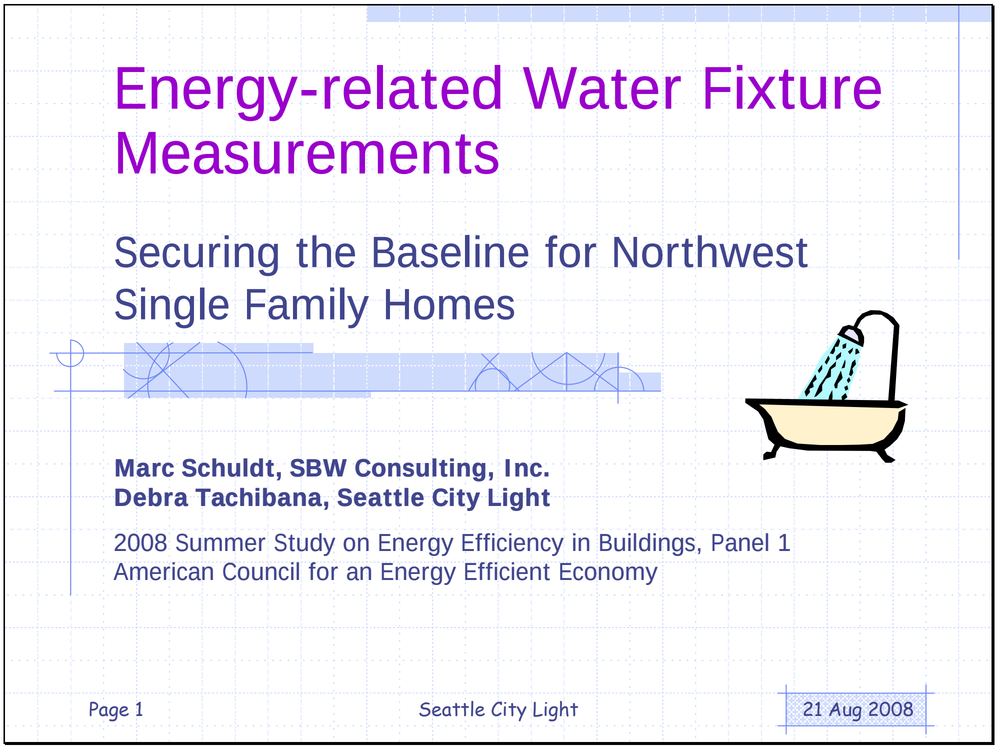
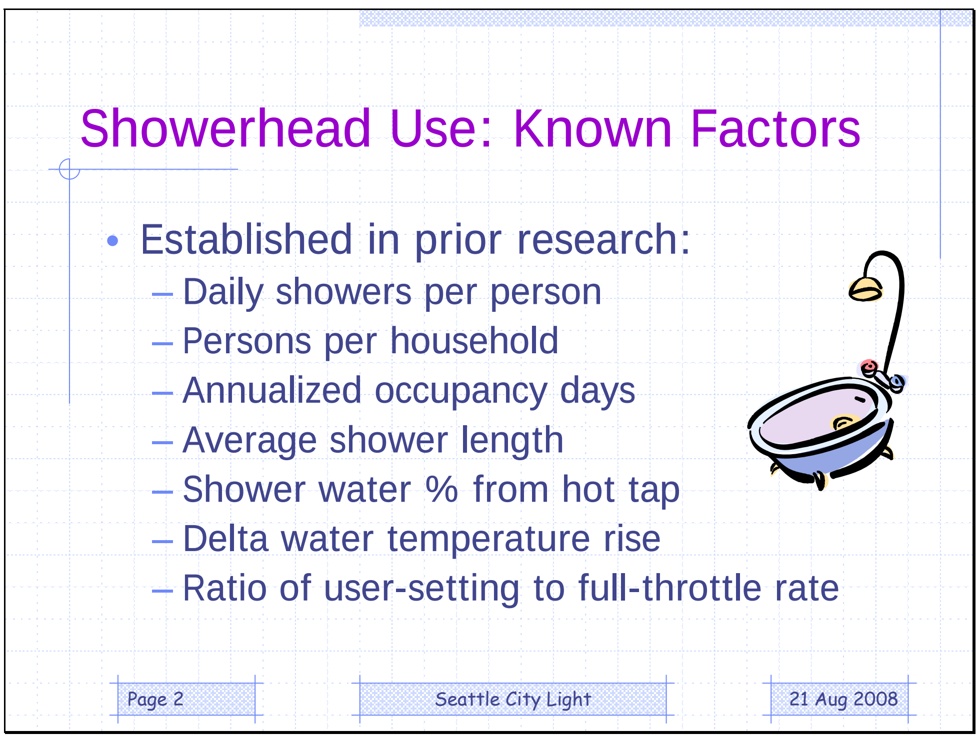
Warwick, W.M. and S.A. Bailey. 1993. *Results from an Energy Efficient Showerhead Field Study*. Richland, Wash.: Battelle/Pacific Northwest National Laboratory for the Bonneville Power Administration.

Appendix C. Presentation Slides





Greatest Uncertainty

- Since 1992 Seattle Blitz Programs:
  - Replacement by market products
  - 2.5 gpm code impact (1994)
  - Measure lifetime (15 years?)
  - *Current baseline average flow rate*
- Hence design of current study

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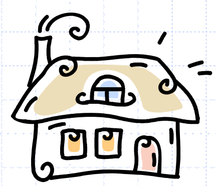
In Situ Measurements



- Representative Seattle Sites:
  - Hilly city, open water reservoirs
  - Varied plumbing age, corrosion, pressures
  - Five neighborhood groupings
    - N/NE, W/NW, E/C, S/SE, SW
  - Five construction periods
    - 1900-19, 1920-39, 1940-59, 1960-79, 1980+

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In Situ Measurements

- Sites: 71 single-family homes, 151 Rms.
- Full throttle flow rates:
  - Showerheads
  - Bathroom Faucets
- Pressures: static & dynamic (flowing)
- Temperatures & Flow Times:
  - Hot water, time to reach 105°F, time to maximum °F

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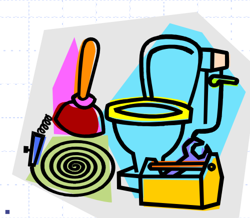
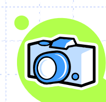
In Situ Measurements



- Water Appliance Characteristics
  - Hot water fuel, tank type
  - Toilet age, flush volume
  - Clothes washer, dishwasher
  - Digital photos of nameplates 
- Paper details the observation protocols

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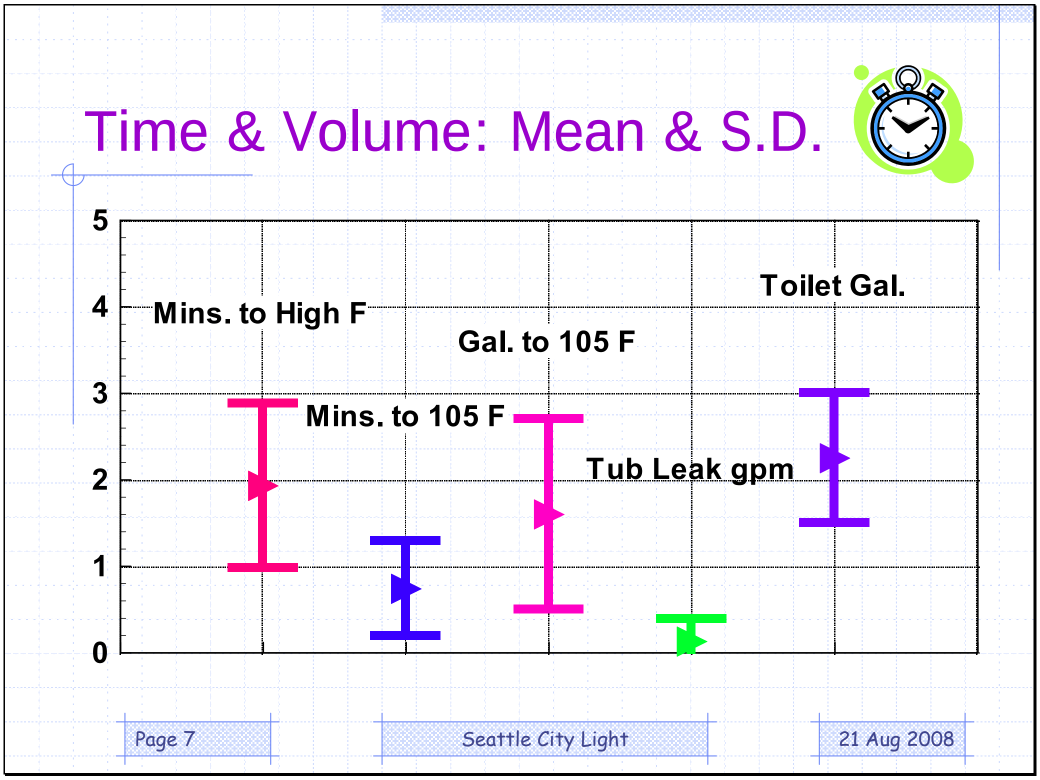
Time & Volume: Mean & S.D.
5
4
3
2
1
0
Mins. to High F
Gal. to 105 F
Toilet Gal.
Mins. to 105 F
Tub Leak gpm
Page 7
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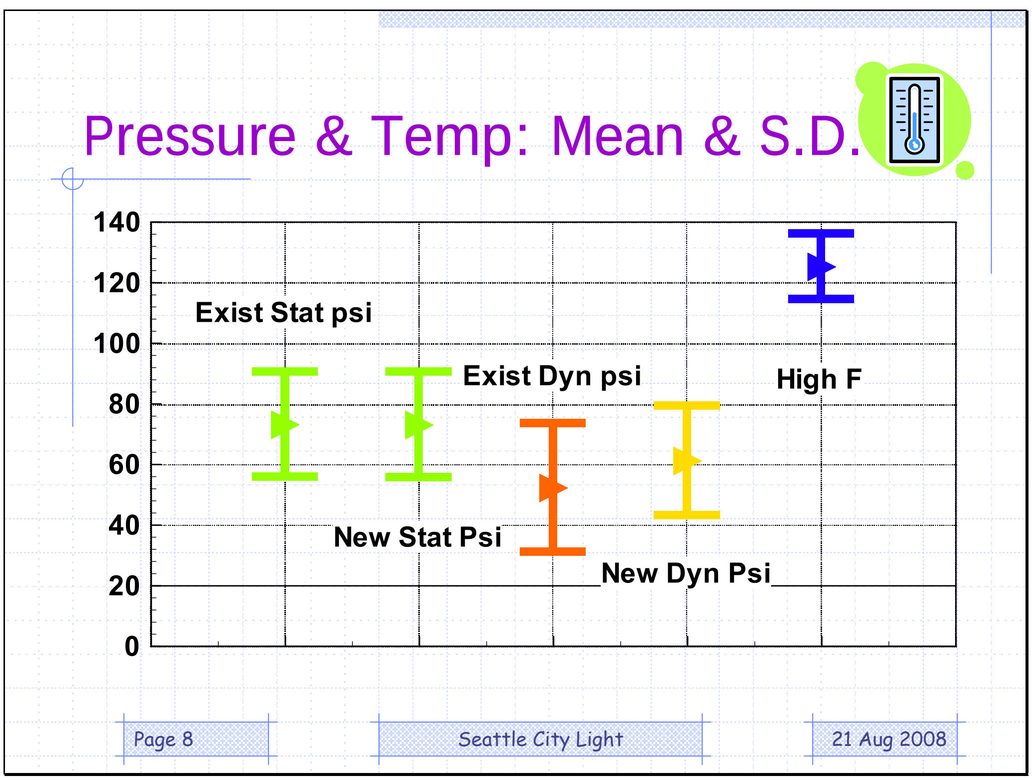
Pressure & Temp: Mean & S.D.
140
120
100
80
60
40
20
0
Exist Stat psi
Exist Dyn psi
High F
New Stat Psi
New Dyn Psi
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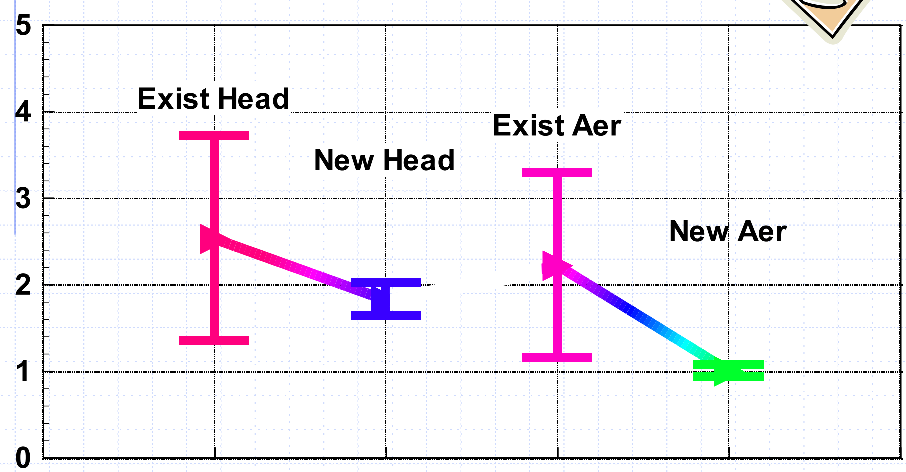
Flow Rates: Mean & S.D.



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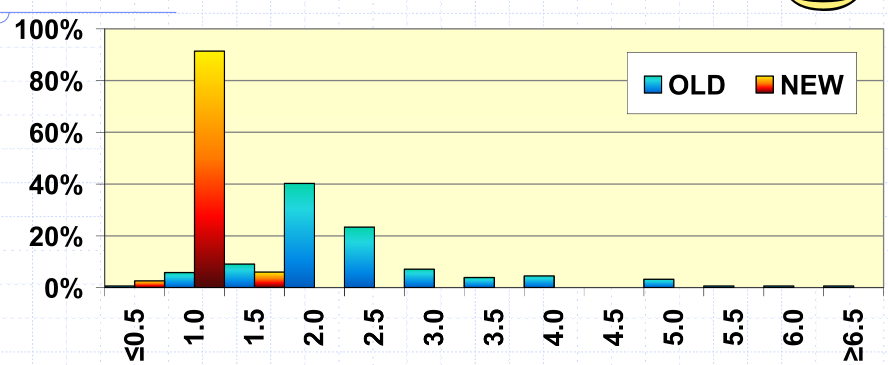
Faucet Aerator Flow Rates



	Median gpm	Mean gpm	S.D. gpm	No. at sites
Existing	2.0	2.2	1.1	154 at 71
New	1.0	1.0	0.1	116 at 56

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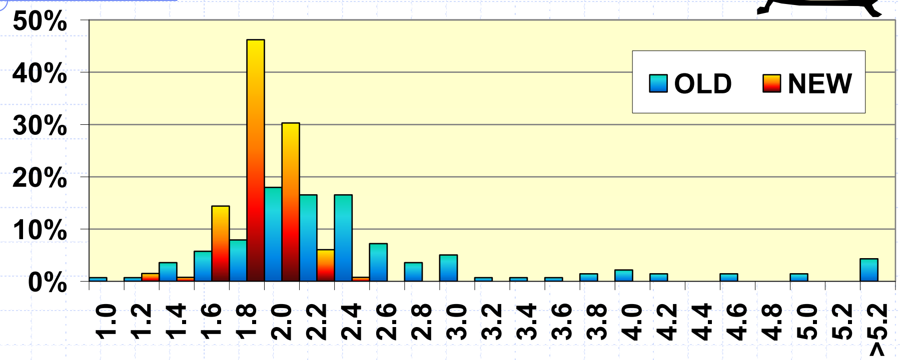
Showerhead Flow Rates



	Median gpm	Mean gpm	S.D. gpm	No. at sites
Existing	2.20	2.53	1.18	139 at 71
New	1.80	1.82	0.19	132 at 67

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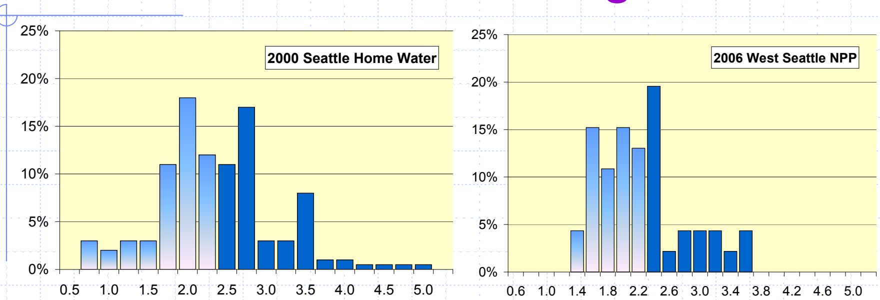
Corroboration of Existing Rates



- Seattle 2001 Study & West Seattle 2006 over-sample

	Median gpm	Mean gpm	S.D. gpm	No. at sites
2001	2.34	2.25	0.74	54 at 37
2006	2.20	2.24	0.57	46 at 39

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Study Conclusions

- Showerhead Flow Rates:
  - Adjusted to User Setting
  - Measured *In Situ* Median 2.2 gpm
  - Replacement Head 1.8 gpm
  - **Delta Water Savings 0.4 gpm**
- Faucet Aerator Flow Rates:
  - Measured *In Situ* Median 2.0 gpm
  - Replacement Head 1.0 gpm
  - **Delta Water Savings 1.0 gpm**

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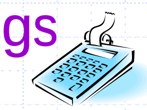
Calculating Showerhead Savings



- Household Showers:
  Minutes per Year = D * S * P *Y

D =	7.84	Average duration minutes / shower
S =		Daily average showers / person / day
	0.55	✓ if installed in primary / most used location
	0.28	✓ if installed in secondary / less used location
	0.50	✓ if installed in an unspecified location
P =	2.51	Persons / household
Y =	350	Occupancy days / year

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Calculating Showerhead Savings

- Shower Water Saved:
Gallons per Minute $= (V_X * R_X) - (V_E * R_E)$

V =		Observed full-throttle flow rate (gallons / minute)
	2.53	✓ X: if existing showerhead
	1.82	✓ E: if efficient replacement showerhead
R =		Ratio of user-setting to full-throttle flow rate
	0.83	✓ X: if existing showerhead
	0.95	✓ E: if efficient replacement showerhead

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Calculating Showerhead Savings

- Water Heat Energy:
kWh per Gallon $= H * W * B / ((1-C) * K)$

H =	68%	Proportion of shower water from hot tap
W =	75	Hot water temperature rise (tank outlet °F minus inlet °F)
B =	8.29	Water heating energy (Btu/°F/gallon)
C =	2%	Heat lost from the element through the tank connection (steady state heat loss factor)
K=	3413	Electric energy (Btu / kWh)

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Calculating Showerhead Savings

- kWh Energy / Year = cross-product of
  - Household Showers:
    Minutes per Year $= D * S * P * Y$
  - Shower Water Saved:
    Gallons per Minute $= (V_X * R_X) - (V_E * R_E)$
  - Water Heat Energy:
    kWh per Gallon $= H * W * B / ((1-C) * K)$

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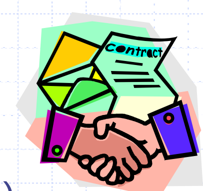
Replacement Program: Sponsors



- Puget Sound partnership:
  - Seattle City Light (electric, municipal)
  - Puget Sound Energy (gas/electric, IOU)
  - Seattle Public Utilities (water/sewer, municipal)
  - Saving Water Partnership (water/sewer, public)
- To secure continued advantage over baseline
- To extend life of efficient-flow showerheads
  - 1992-2007 >> 2008-2022

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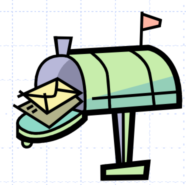
Replacement Program: Process

- Solicitation letter to all 174,000 SF/2x homes
- Follow-up postcard
- Boxed kit to all 50,000 requestors
  - 1 Showerhead 2.0 gpm, 2nd on request
  - 1 Bathroom faucet aerator 1.0 gpm
  - Strip Teflon tape
  - Informational literature
- Tracking system + Phone hotline



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Program Plan vs. Actuals

- Highline Water District Pilot (2005)
  - 704 survey respondents (56% of 1,260)
  - Delivered Heads Installed: 93%
- Puget Sound Post-Pgm. Survey (2008)
  - 684 survey respondents (23% of 2,983)
  - Homes installing 1-2 Heads: 90%
  - Delivered Heads Installed: 83%
  - Location: 82% primary, 18% secondary

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Pre Program Assumptions

Savings by Location		Typical / Unspecified	Primary / Most Used	Secondary / Less Used
Per showerhead installed			*100%*	*33%*
Household water	gals.	1587	1364	694
Household hot water	gals.	1079	927	472
Electric energy	kWh	201	172	88
Gas energy	therms	9.1	7.8	3.0
Per showerhead delivered	*90%*			
Electric energy	kWh	181	155	79
Gas energy	therms	8.2	7.1	2.7
Per participant household			*67%*	*33%*
Electric energy	kWh	130	104	26
Gas energy	therms	5.9	4.7	0.9

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Post Program Findings

Savings by Location		Typical / Unspecified	Primary / Most Used	Secondary / Less Used
Per showerhead installed			*100%*	*18%*
Household water	gals.	1653	1515	771
Household hot water	gals.	1124	1030	525
Electric energy	kWh	209	192	98
Gas energy	therms	9.5	8.7	3.3
Per showerhead delivered	*83%*			
Electric energy	kWh	173	159	81
Gas energy	therms	7.9	7.2	2.8
Per participant household			*82%*	*18%*
Electric energy	kWh	145	130	15
Gas energy	therms	6.6	5.9	0.5

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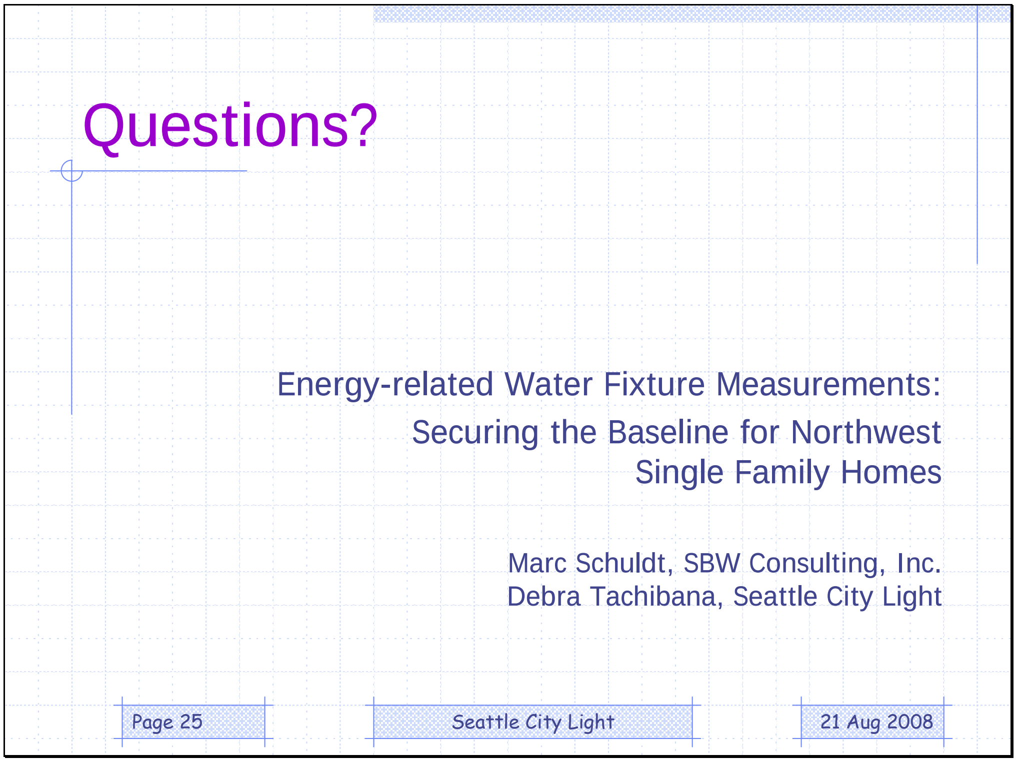
Questions?
Energy-related Water Fixture Measurements:
Securing the Baseline for Northwest
Single Family Homes
Marc Schuldt, SBW Consulting, Inc.
Debra Tachibana, Seattle City Light
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