SHOW ME THE SAVINGS! DO NEW HOMES USE LESS WATER?

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INTRODUCTION

New homes built in the U.S. should all come equipped with conserving toilets, showerheads, and faucets as mandated by the Federal Energy Policy Act of 1993. But do these homes actually use less water than older homes built under previous plumbing standards?

In this study, Aquacraft, Inc. and staff members from the City of Westminster Department of Public Works and Utilities, Water Resources and Treatment Division examined water use in four samples of homes in the City of Westminster, Colorado located northwest of Denver.

1. Homes built prior to 1977 (pre-77 group)
2. Homes built from 1984-1993 (post-84 group)
3. Homes built after 1997 (standard new home group)
4. Water Wise homes built in 1998 specifically to use less water (Water Wise group)

Water use in each home was disaggregated into component end uses such as toilets, faucets, clothes washers, showers, etc. using Aquacraft's flow trace analysis technique that employs portable flow recorders and Trace Wizard signal processing software (Mayer et. al. 1999, DeOreo et. al. 1996). Water use was compared at the fixture level, on a daily per capita basis, and in terms of annual demand. In addition, irrigation usage was compared. The impact of ULF toilets, LF showerheads, LF faucets, and horizontal axis clothes washers was examined. In

addition, demand in these homes was compared with demand in the 1,200 homes studied as part of the AWWARF Residential End Uses of Water Study (REUWS), also conducted by Aquacraft.

Results show that residents in new homes do use less water indoors per capita when compared against residents in older housing. This result has important implications for water planners projecting demands in growing communities and for policy makers who seek to change current plumbing regulations.

BACKGROUND: CITY OF WESTMINSTER/HBA STUDY

In 1995 Aquacraft, Inc. and AquaSan Network, Inc. conducted a study of water use in two sets of single family homes in Westminster. The 1995 study was funded by the City of Westminster and the Home Builders Association of Metropolitan Denver (HBA) through a special tap fee assessment on new housing construction. This study examined the differences in water use patterns between homes that were built prior to 1977 and homes that were built between 1984 and 1993. New plumbing standards were adopted by Westminster (e.g. the 3.5 gallon per flush toilet) and came into effect in 1977. Any savings accomplished by changes in these standards should have taken full effect by 1984. A total of 40 households participated in this study, 20 from each study group. These homes were selected using a stratified random sampling technique so that each study group would be as representative of the population they were drawn from as possible. In 1999, water use in two sets of new homes was studied: standard new homes (those built after January 1, 1997) and "Water Wise Homes" (those built expressly to be efficient through the inclusion of water conserving fixtures and devices beyond code requirements). A total of 32 standard new homes were selected from the housing stock in Westminster.

Water Wise Home Program

As part of the 1995 study, Carmine Iadarola of AquaSan developed a detailed design concept for a "Water Wise" home. In 1998, working closely with the HBA, eight homes meeting these design criteria were built in the City of Westminster. As part of the 1999 study, water use in these eight Water Wise homes was evaluated to quantify any additional water savings.

METHODOLOGY

The research design for the 1999 single-family study called for the selection of a representative sample of single family homes built after January 1, 1997. Only eight Water Wise homes were completed and occupied at the time of the study. It was decided to have a total sample size of 40 homes, including the eight Water Wise homes, which comprised the 8 Water Wise homes and 32 single-family "standard new" homes being selected for the study.

In order to identify the exact water using fixtures present in each study home and to obtain demographic data about the residents an individual household water audit was performed on each of the 40 selected participants. David Lewis of Aquacraft and Katie Parrot of the City of Westminster conducted the audits at the 40 homes. These audits provided much more accurate

information on the demographics and fixtures present in the homes than was available for the 1995 study group.

Portable, battery powered flow recorders (also called data loggers) were installed on the water meter at each study home prior to the audit. Flow recording technology makes the task of measuring water use much easier and less expensive that it has been in the past. Each flow recorder has a small magnetic sensor that is strapped to the register of the water meter. The sensor picks up a signal from the rotation of the small magnet mounted on the disk within the meter, which in turn is rotated by water passing through the meter. The logger records the average volume of water passing through the meter every 10 seconds. Using these data, water use inside the home can be disaggregated into component end uses such as toilet flushes, showers, clothes washers, etc. using the specially designed signal processing software, Trace Wizard, developed by Aquacraft. This software provides a variety of statistics for each disaggregated water use event including volume, duration, start and end time, peak flow rate, etc. This technique makes it possible to measure the impact of the different types of water using fixtures in use in single family residences.

During each audit, signature flows for all of the toilets, faucets, showers, baths, etc. were obtained to assist with the flow trace analysis process. A signature flow is simply one or more uses of the fixture during the logging period for which the analyst notes the exact time. This can then be located on the flow trace data and used to define the characteristics of the fixture for future analysis.

Evaluation of water use in the different study groups was completed using a combination of historic billing data provided by the City, the analyzed flow trace data, and the audit results. In addition, updated billing data were obtained for the 40 homes in the pre-77 and post-84 study groups that participated in the 1995 study.

Standard New Home Sample

Selection of the standard new home sample was accomplished using a systematic random sampling procedure similar to the one developed for the American Water Works Association Research Foundation Residential End Uses of Water Study (Mayer, DeOreo, et. al. 1999). In this case it was known that a representative sample of 32 accounts was desired from the population of 180 willing participants, which required that the population be divided into 6 subsets for sampling ($180/32 \cong 6$).

The 180 willing participants were sorted from lowest to highest by 1998 annual water use. The number 5 was randomly selected as a starting point, and every sixth record from this sorted list of 180 accounts was selected until 32 records were selected. Because of the selection process, these accounts represented the entire range of annual water use in the population of willing participants.

Table 1 shows a comparison of the water use among the new home groups. Statistical analyses were conducted to determine if the mean annual water use of the proposed study sample was significantly different from the mean annual water use of either the entire population of standard new homes or that of the willing participants. The results of the statistical comparison tests

indicated that there was no significant difference in annual water use between the study sample and that of either the population of new homes or the group of willing participants.

Table 1: Comparison of Water Use in Standard New Homes

GROUP	NUMBER	1998 WATER USE (kgal/yr)	1998 WATER USE (gpd)
All new homes	492	144	394.5
Willing Participants	180	138	378.1
Non-respondents	312	147	402.7
New Home Sample	32	132	361.6

Figure 1 is a histogram showing four frequency distributions of annual demand from the 1999 study: Study Group (n=32), Replacements (n=28), Willing Participants (n=180), and Population (n=492). This frequency diagram shows that all four of these distributions are very similar in shape, bearing out the results that the mean annual water use final study sample is not statistically different from the mean annual demand of the population of homes built since 1997.

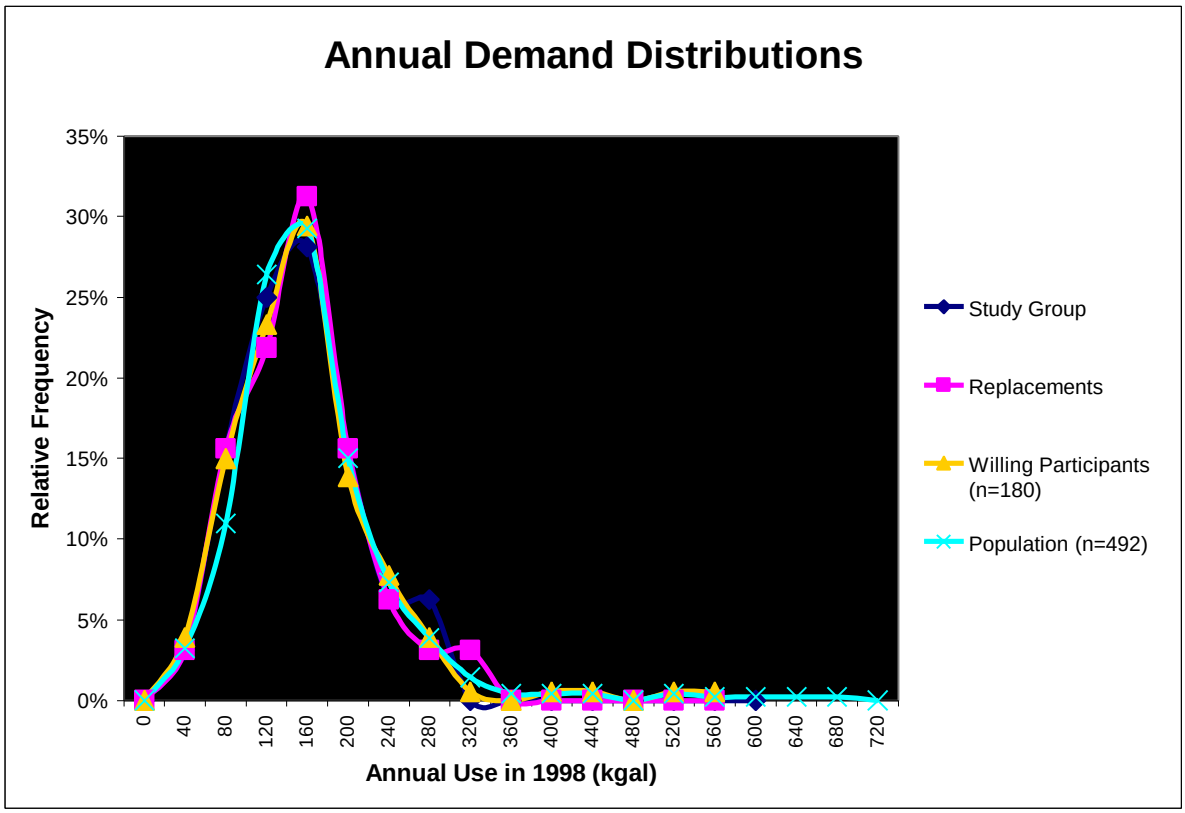

Figure 1: Annual demand distributions for the 1999 residential water use study

Water Wise Homes

There was no sampling procedure involved in the selection of the Water Wise homes. HBA member builders under the supervision of AquaSan Network, Inc. built a total of nine Water Wise homes in Westminster. Only eight of these homes were occupied at the time of this study and all of these were included. With the inclusion of the eight Water Wise homes, a total of 40 homes were selected to participate in the 1999 study.

Pre-77 and Post-84 Study Groups (1995)

Two study groups of 20 homes each were selected for the 1995 study – homes built before 1977 and homes built between 1984 and 1993. Each of these study groups was selected using the stratified random sampling procedure developed in conjunction with Dr. Peter J. Bickel, Professor of Statistics from the University of California, Berkeley. In reviewing the results of these studies it is important to keep in mind that a stratified sample is significantly different than a simple random sample in that it selects from each quartile of the population in proportion to the number in that group. Consequently the results must be weighted rather than simply averaged across the group. The results tables also show the weighting factors. This technique was used to increase the accuracy from a relatively small sample.

RESULTS

Household Characteristics

While the 1999 study included a detailed audit of each participating household, the 1995 study obtained household characteristics solely from a mail survey. Because of the differences in the survey forms and the information collected it is not possible to compare all characteristics of the four study groups. Instead, the focus will be on describing the audited homes and comparing the 32 standard new homes with the 8 Water Wise homes. A comparison of basic characteristics from all four study groups is presented in Table 2.

The Water Wiser homes were by far the largest both in total lot size and in the size of the actual house. The Post-84 study group had the highest number of residents because of the number of children in that study group. The average number of adults in all four study groups was relatively similar.

Four households in the Pre-77 study group and four households in the Post-84 study group reported owning a swamp cooler. But when it came to actual usage, only one of the Post-84 homes actually used their cooler while all four of the Pre-77 homes used their coolers during the logging period.

In the Post-84 study group, 90 percent of the homes were equipped with automatic sprinkling systems while in the Pre-77 study group only 25 percent had automatic sprinklers. One of the homes in the Pre-77 study group had a swimming pool. None of the homes in the Post-84 study group had a pool.

Table 2: 1995 and 1999 study group comparison

Category Average	Pre-77 Homes (n=20)	Post-84 Homes (n=20)	Standard New Homes (n=32)	Water Wise Homes (n=8)
Residents	2.54	3.67	2.81	2.75
Adults	1.85	2.22	2.16	2.00
Children	0.69	1.44	0.65	0.75
Lot size (sf)	9196	7042	10608	13192
Irrigable area (sf)	6922	4859	6864	7836
Auto sprinkler %	25%	90%	97%	75%

All 40 homes in the 1999 study were equipped with 1.6 gpf ultra low-flush (ULF) toilets. In the Water Wise homes, each toilet was equipped with a dual flush mechanism that allowed for two flushing modes – a 1.6 gallon flush when the handle is pressed and released and a larger, 3.5 gallon flush if the handle is held down. These, however, were not the toilets that AquaSan had specified, and appear to have been installed due to a misunderstanding with the plumbers. The plan called for dual flush toilets that used less than a gallon for the quick flush and a maximum of 1.6 gallons for the full flush, with the handle depressed. The dual flush toilets installed in the Water Wise homes appear to be older 3.5 gallon toilets made capable of delivering a 1.6 gallon flush. Four of the standard new homes were also equipped with the 1.6/3.5 dual flush toilets. The faucet fixtures and showerheads in all 40 homes appeared to be low flow models meeting current 1.0 and 2.5 gpm standards. Many of the bathtubs in the standard and Water Wise homes were larger than standard size and often had jets. Two of the standard homes had a hot tub that constantly held water. None of these study homes had a swimming pool.

The most significant difference in the eight Water Wise homes was that each was equipped with a new horizontal axis clothes washer. Three different models and brands were represented. Five homes had the Maytag Neptune model, two homes had the Frigidaire Gallery model, and one had the Kenmore front loading model. (The Kenmore is virtually identical to the Gallery, but is marketed by Sears using their Kenmore brand name.) All of these clothes washers are designed to use less water and energy than standard top loaders. One of the standard homes had a horizontal axis clothes washer – an Asko made in Sweden. This is a high quality machine from Sweden that uses even less water and energy than the U.S. made washers. The remaining clothes washers in the standard homes were typical top loaders ranging in age from brand new to a 1976 model.

Six of the Water Wise homes were equipped with on-demand hot water re-circulating systems. These devices constantly re-circulate hot water through the pipes in the home so that when a faucet, shower, or bath is turned on, hot water is immediately available. Theoretically, these systems should save water because they eliminate the need to run water through the tap before it is warm enough to use for showering or washing. One of the standard new homes was equipped with a water softener. None of the homes in the 1999 study was equipped with evaporative coolers.

All of the homes with finished landscapes in the 1999 Study group had automatic sprinkler systems. One of the standard new homes was a patio home without any landscape and two of the Water Wise homes (with unfinished landscapes) lacked an automatic system. The common area for the patio home was sprinkler irrigated, and the landscapes for the Water Wise homes will be sprinklered once they are complete. Most of the homes in both study groups had standard turf landscaping. Because these homes were so new, in many cases the landscape plans had not yet been fully implemented. Fourteen (44 percent) of the standard new homes had at least a small section of Xeriscape landscape. Six of the eight Water Wise homes (75 percent) incorporated Xeriscape into their landscape design. Only the two Water Wise homes without any landscape did not have at least some Xeriscaping. All of the homes, however, had landscapes in the "plant establishment mode" meaning that their water use patterns are likely to be higher than normal as necessary to establish the

Annual Demand

Annual water demand for 1998 and 1999 was obtained for all four study groups from the City of Westminster water billing database. Because the Water Wise homes were brand new, a full year of billing data was only available using the 1999 billing data. Table 3 presents the average annual demand for each study group in 1999.

The Pre-77 study group, which had the fewest number of people and the fewest automatic sprinkler systems, used the least water in 1999. The Water Wise homes used the most water of all four groups – 151.9 kgal, but had the smallest component of indoor use. The high demand in the Water Wise Homes was due to outdoor demand for establishment of new landscapes, and the larger irrigable area at those homes. While the annual demand in the Water Wise homes was 12,000 greater than that of the standard new homes a z-test indicated that this was not a statistically significant variation between the two groups.

Table 3: Water demands from 1999 billing data, all four study groups

	Average Annual Use, 1999 (kgal)	Average daily use, 1999 (gal)	Average daily per capita use, 1999 (gal)
Water Wise Homes	151.9	416	151
Standard New Homes	143.7	394	140
Pre-77 Homes	106.9	293	115*
Post-84 Homes	147.3	403	110*

+Estimated using the average winter consumption method (average consumption in Jan., Feb. & Dec * 12 = annual indoor demand)
*May not be accurate – calculated using mail survey data from 1995 on the number of occupants

End Uses of Water

Using the disaggregated flow trace data and occupancy information from the water audits, per capita water use was estimated for each end use at each study home. These end uses were separated into three general categories: (1) Indoor Use, (2) Outdoor Use, and (3) Leaks and Unknown. Indoor use included all water used for baths, showers, toilets, faucets, dishwashers,

clothes washers, and home water treatment/softeners. Outdoor use included all water used for automatic and manual irrigation as well as miscellaneous hose usage. Leaks included both indoor and outdoor leaks (because it is often impossible to determine the location of a leak using flow trace analysis), and Unknown use included all water use events that could not be confidently classified into any of the above categories.

The primary focus of this research study was on indoor use and the impact of current plumbing technology on per capita demand. Because the landscapes at the Water Wise homes were brand new and because the logging period was only two weeks in length it is not possible to make broad comparisons of outdoor use between the Water Wise homes and any of the other study groups.

Indoor Use

Mean daily per capita indoor water use in the two 1999 study groups differed by only 3.6 gallons per capita per day (gpcd). Per capita indoor use was quite similar for all end use categories except clothes washing. The Water Wise homes, which were equipped with horizontal axis clothes washers, used 30 percent less water for clothes washing than the standard new homes, which were primarily equipped with top loading washers. A comparison of the mean daily per capita indoor water use in the two 1999 study groups is presented in Table 4.

The standard new homes used more water for showering and the Water Wiser homes use more water for baths. If the water used for showering and bathing is combined, then the study groups differed by only 0.1 gpcd.

Table 4: Mean daily per capita indoor use, 1999 study groups

End Use Category	Standard New Homes (gpcd)	Water Wise Homes (gpcd)	Difference (gpcd)
Clothes washer	15.3	10.7	-4.6
Shower	13.2	11.1	-2.1
Toilet	9.5	11.1	1.6
Faucet	10.5	10.7	0.2
Bath	2.3	4.3	2.0
Dishwasher	1.2	1.1	0.1
Treatment	0.4	0.0	-0.4
Total Indoor	52.4	49.0*	-3.6

*If the Water Wise Homes had been equipped with standard ULF toilet so that their per capita use equaled that of the standard new homes, the total indoor daily per capita demand could have been 47.6 gpcd.

The difference in toilet usage is worthy of further mention. As discussed previously the Water Wiser homes were mistakenly equipped with old dual flush mechanisms that were designed to offer a *minimum* flush of 1.6 gallons and a maximum flush of 3.5 gallons instead of a minimum flush of less than a gallon with a maximum flush of 1.6 gallons. As a consequence, they used *more* water than the standard 1.6 gpf toilets in the standard homes. The average toilet flush volume in the standard homes was 1.90 gallons per flush (gpf) and the average flush volume in the Water Wiser homes was 2.05 gpf. Both of these mean flush volumes are higher than the

ULF rating of 1.6 gpf – probably because of dual flush toilets (there were four such toilets in the standard group).

Figure 2 shows the mean per capita use percentage for indoor water use in the two 1999 study groups. In the standard new homes, clothes washing is the largest indoor end use followed by showers, faucets, and then toilets. In homes without ULF toilets, toilet usage is typically the largest indoor end use (Mayer, DeOreo, et. al. 1999). In the Water Wiser homes, water use for toilets, showers, clothes washers, and faucets was almost identical. In both study groups, water use for baths and dishwashers were the smallest components of indoor demand.

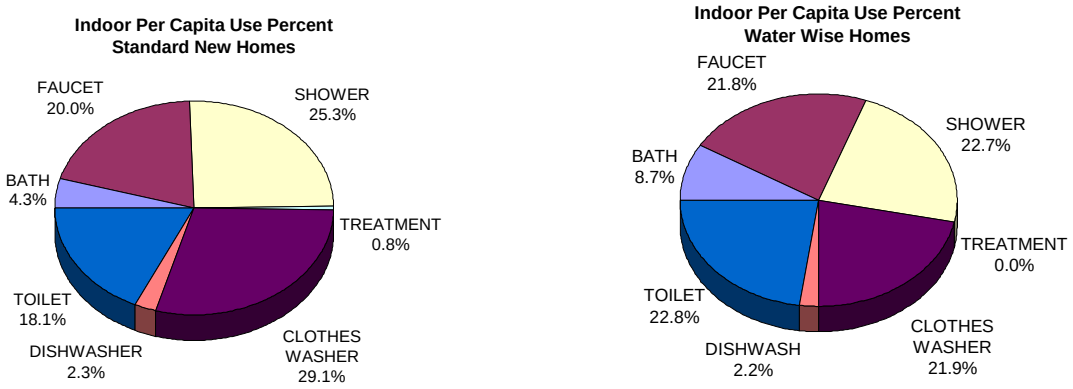

Figure 2: Indoor use per capita use percent, 1999 study groups

On-Demand Hot Water Systems

There were six Water Wiser homes equipped with on-demand hot water re-circulating systems. These devices constantly re-circulate hot water through the pipes in the home so that when a faucet, shower, or bath is turned on, hot water is immediately available. Proponents of these systems believe that they save water because it is not necessary to run water through the tap before it is warm enough to use for bathing or washing dishes.

The six homes with on-demand hot water systems did use less water for showering than the other 34 homes (9.1 vs.13.5 gpcd), but coincidentally, they used more water for baths (5.7 vs. 2.1). It seems highly unlikely that the increase in bathing use was caused by the hot water systems, and is probably a result of the small sample size and personal preference. However, the fact remains that the total for showering and bathing combined in the two groups was identical. The two groups had an almost identical amount of faucet usage as well,(10.5 vs. 10.6 gpcd). Overall, the homes equipped with re-circulating hot water systems used 49.1 gpcd for indoor purposes compared to 52.4 gpcd for the other new homes.

Since the impact of the on-demand hot water systems is expected to be greatest in showers due to its elimination of the wait for hot water the showering demand in these homes was examined more closely. The average shower in homes with the on-demand hot water used 13.3 gallons and lasted 7.1 minutes at a typical flow rate of 1.9 gpm. In homes without these special hot water systems, the average shower used 17.4 gallons and lasted 8.3 minutes at a typical flow rate of 2.1

gpm. Clearly the residents in the on-demand hot water homes did take shorter showers. If we liberally attribute all of the reduction in shower use to the on-demand systems the data suggest that they may reduce shower use by an average of 4.1 gallons, and showering time by 1.2 minutes. This represents a savings of nearly 25%, however, it is impossible to say from the small sample whether this is due to the on-demand hot water systems or the habits of the persons involved. Additional evaluation of these devices in a larger group of new homes is needed to clarify this question.

Outdoor Use

Historically, household outdoor water use has been estimated by subtracting the average winter consumption (AWC) from the metered consumption. AWC is normally represented by the consumption during the minimum one to three months during the winter. In this approach the AWC is used as a proxy for indoor use by assuming that there is no outdoor use during the period which the AWC is calculated. This is how indoor and outdoor use was estimated in Table 3. The AWC approach can lead to over estimates of indoor use since many people use water outdoors during the winter months. This is especially true in warmer climate, but even in colder climates outdoor use frequently occurs in the winter during dry spells.

On the other hand, if used by itself, the flow trace data approach is also prone to errors in estimating outdoor demands because of the limited duration of the logging period. Prorating the outdoor use observed during the logging period in Westminster would not provide a precise measure of irrigation usage throughout the entire year because the data were obtained in the peak summer period. Extrapolating this over the year would lead to an over-estimate of outdoor use.
Rather than rely exclusively on either estimated measurements of outdoor use from billing data or from the data logging, the leveraged approach estimates outdoor water use through a combination of two different data sources - historic billing data and logged indoor usage data. Since indoor use does not vary nearly as much as outdoor use it is possible to use the logged indoor use to estimate annual indoor use.[1] This is referred to this as the leveraged approach. In this approach, outdoor use is extracted from the historic billing data from each site by first calculating the average daily *indoor* consumption for each household from the data logging results, extrapolating this consumption over an entire year, and subtracting this from the historic billing consumption. This calculation uses the best available information about indoor consumption in order to calculate outdoor consumption.

Because the landscapes in both the Water Wise and the standard new homes are new (or not yet put in) measuring outdoor use was not a primary goal of this study. Estimates of outdoor use were made using the leveraged approach described above and it is hoped that further research will be conducted into the outdoor demand in standard new homes and in homes with some Xeriscape.

Table 5 presents the results from the leveraged outdoor use analysis. The standard new homes use more water indoors on an average annual basis, primarily because there are a few more

[1] A statistical comparison of data obtained from the 14 REUWS sites showed that indoor use was significantly different between seasons in only a single case. All other indoor use measurements were statistically indistinguishable. (Mayer and DeOreo, 1999, Table 5.12)

people living in those homes. The Water Wise homes used more water outdoors on average, but because their lots and irrigable areas were considerably larger, their application rates were only slightly higher than the standard new homes. The Water Wise homes all had fairly recently installed landscaping which may have required additional irrigation.

Table 5: Outdoor use in 1999 study groups

Average Use Categories	Standard New Homes (n=32)	Water Wise Homes (n=8)
Annual use 1999 (gallons) (from billing data)	143,700	151,900
Mean indoor use (gallons) (extrapolated from logging results)	60,664 (42.2%)	54,828 (36.1%)
Outdoor use (gallons) (Annual – Indoor)	83,036 (57.8%)	97,072 (63.9%)
Irrigated area (sf)	6,864	7,836
Irrigation application (inches)	19.4	19.9

Leaks and Unknown

Three of the forty homes in the 1999 study groups had significant leaks that became apparent during flow trace analysis. Two of these homes were in the standard new home group and one came from the Water Wise group. These three homes accounted for 76 percent of all the leakage measured in this study. This pattern of a few homes accounting for the majority of the leakage matches the findings from the AWWARF Residential End Uses of Water Study.

The most serious leak, 462 gallons per day on average (14,000 gal/month), occurred in a standard new home. After discovery of the leak, Aquacraft contacted the homeowner who admitted that his water bills had been high recently. They soon discovered that a valve in their irrigation system that was not closing properly caused the problem[2]. Another homeowner leaking an average of 106 gallons per day (3,000 gal/month) was also informed of the problem after it was discovered during the flow trace analysis process. It is not known if any repairs were made at that home.

Comparison of Water Use Between Study Groups

Comparing results from the 1995 and 1999 data logger studies must be done with caution. The comparison of annual billing data presented in Table 3 is probably the best way to compare water use in these four groups at this time. There are a number of factors that make comparisons across the end use studies an uncertain proposition at best.

- The sample sizes were small

[2] This is a good example of how master valves on irrigation systems save water.

- There are factors other than the age of the homes and the presence of water conserving fixtures and appliances which influence water use
- The data were collected in different years (1995 and 1999).
- The 1999 study homes were audited and a careful count of the number of occupants in each home during the logging period was made.
- The 1995 study group responded to a mail survey and it was not known how many people were staying in each home during the logging period.
- The 1999 data was (for the most part) collected during a single two-week period from June 1 – 16 using a fleet of 40 Meter-Master data loggers designed for recording meter flows.
- Aquacraft collected the 1995 data over an entire summer using approximately 4 Rustrak data loggers specially modified for end use studies.
- The 1999 study group was made quite aware that an end use study was going on and that data was being recorded about their water use.
- The 1995 study group agreed to participate in a study, but did not know when the loggers were installed and were not acutely aware of being monitored.

Annual Household Use Comparisons

Using the leveraged approach to quantify annual household water uses provides a way to compare water use between these four study groups. This approach provides information on annual total, outdoor, and indoor water uses for each household. The annual household water use breakdowns are shown in Table 6.

With respect to annual household water use, the data show that this group of new homes does not use less water than do the post 1984 homes. The post 1984 homes used an average of 147.3 kgal per year while the weighted average of the new homes came to 145.3 kgal/year; a difference of just 2 kgal (1.4%). While the new homes appear to use less water indoors than do the post 84 or the pre-77 homes, the new homes' outdoor use component is considerably larger.

Table 6: Comparisons of annual water use, 1995 and 1999 study groups*

Category -Averages	**Pre-77 Homes** (n=20)	**Post-84 Homes** (n=20)	**Standard New Homes** (n=32)	**Water Wise Homes** (n=8)
Number of residents per homes	2.54**	3.67**	2.81	2.75
Total annual use, 1999 (kgal)	107	147	144	152
Annual outdoor use (kgal)	41	70	83	97
Annual indoor use (kgal)	66	77	61	55
Irrigated area (sf)	6922	4859	6864	7836
Outdoor Application (inches)	9.5	23.1	19.4	19.9

*From leveraged logging data (indoor use) and annual billing data from 1999
**Self-reported occupancy values from 1995. Current occupancy data was not obtained for this study.

The standard new home and Water Wise Home study groups used a majority of their water for outdoor purposes, ranging from 53% to 58% of their total annual use. The Pre-77 and Post-84 homes used more water for indoor purposes in 1999. The Water Wise homes used the most water for outdoor purposes: 97 kgal/yr (64% of the annual use), followed by the standard new homes with an average of 83 kgal/yr (58% of the annual use). The 41 kgal/yr used by the older, Pre-77 homes, was the lowest outdoor use (38% of annual use).

Outdoor use needs to be combined with knowledge of the irrigable areas and expressed in terms of application rates to be most comparable. For example, the Water Wise homes used 14 kgal more per year for outdoor purposes than the standard new homes, but they applied this water to approximately 1000 sf more area. Consequently, the average application rate of the Water Wise homes was 19.9 inches, which was very close to the average of 19.4 inches applied by the standard new homes. The older, Pre-77 households applied an average of only 9.5 inches per year. The Post-84 homes had the heaviest application rate of 23.1 inches per year. Recall from Table 3 that only 25% of the Pre-77 homes were equipped with automatic sprinkler systems versus 90% for the Post-84 homes, 97% for the standard new homes, and 90% for the Water Wise homes. In addition, the outdoor water use figures from all of the new homes must be considered preliminary due to the immaturity of the landscapes. Hopefully the usage patterns of these homes can be tracked over time to see how consistent they remain.

The data do not suggest a trend towards lower indoor water use in the standard and Water Wise new homes. The Post-84 homes used an average of approximately 77 kgal per year for indoor purposes, while the standard new homes averaged roughly 61 kgal/year, and the Water Wise homes used only 55 kgal/year. However, the number of residents reported in the Post-84 homes during the 1995 mail survey reduces the per capita usage in that group below that of the standard new and Water Wise homes. Verifying the occupancy numbers for the two 1995 study groups would greatly improve the accuracy in comparing indoor use between these study groups. As it stands, it is difficult to compare overall indoor water use efficiency.

Toilet and Shower Usage Comparisons

Examination of the toilet and shower use categories sheds additional light on the differences in annual indoor use. These results provide insight into the more long-term impacts of plumbing code changes and retrofits. A comparison of these results is presented in Table 7.

The average toilet flush volume in the 1999 study homes was considerably less than the average flush volume in the 1995 study homes. The weighted average flush volumes for the new homes was 1.93 gpf, while that for the post 1984 homes was 3.67 gpf. The pre 1977 homes had an average flush volume of 3.25 gpf, which suggests that natural retrofits occurring in the older homes are moving the averages downward. The toilet results are further indication that the per capita numbers for the 1995 study groups shown in Table 7 are too low (i.e. the reported number of occupants in the homes was too high). It seems unlikely that the average flush volume of the Post-84 study group could exceed that of the Pre-77 group to the measured extent and yet use less water per person per day for toilet flushing.

Table 7: Fixture usage comparison, 1995 and 1999 study groups

Fixture Use Category	Pre-77 Homes (n=20)	Post-84 Homes (n=20)	Standard New Homes (n=32)	Water Wise Homes (n=8)
Avg. Toilet Flush Volume (gal)	3.25	4.16	1.90	2.05
Avg. Shower Volume (gal)	16.11	15.35	17.05	15.94
Avg. Shower Duration (min/sec)	7:25	6:44	8:08	8:13
Avg. Shower Flow Rate (gpm)	2.17	2.28	2.10	1.94

Showering in all study groups was quite similar. The average shower ranged in volume from 15.4 gallons to 17.1 and the average duration ranged from 6:44 to 8:13 minutes. All four study groups showered in the low-flow range (below 2.5 gpm) on average. In the 1995 study groups this is probably due to a combination of natural retrofit and a personal preference to throttle shower flow down to a lower range.

CONCLUSIONS

This paper presents the results of the latest of a series of studies of water use in single-family homes in the City of Westminster, Colorado starting in 1995. The focus of these studies has been on the variability in water use in homes of different ages. The fundamental questions to which answers have been sought are: Do new houses with modern, efficient plumbing fixtures use less water? Will a "Water Wise" home equipped with the latest conservation technology use less water than a standard new home? What are the most effective residential conservation measures, and how reliable are any savings?

Because of the small sample sized used for this study the results are more suggestive than firmly conclusive, and it is not advisable to generalize from them. Nonetheless, this study does offer some interesting information about apparent trends in residential water use.

Do New Houses Use Less Water?

The results of this study strongly suggest that the oldest sector of homes in Westminster, those built before 1977 use less water that newer homes built in the 1980s and the late 1990s. These older homes have comparably sized lots, but typically do not have automatic irrigation systems. Consequently, they use considerably less water for irrigation purposes than do the newer homes. Indoor per capita use in the standard new and Water Wise homes was between 5.4% and 11.6% lower than the indoor per capita use in the Pre-77 homes. However, indoor per capita use in the Post-84 homes was the lowest found in this study. While these results are interesting, they should not be interpreted as conclusive because the number of residents in the 40 homes from the 1995 study was not re-verified as part of this study.

In terms of annual per household indoor water use, the standard new and Water Wise homes used between 5 and 22 kgal less than the Pre-77 and Post-84 homes. Indoor water use in brand new homes is closer to the use found in older (Pre-77) homes even though the new homes are

larger, have more occupants, and have bigger landscapes. The new homes in this study used approximately 16 kgal less annually indoors than the homes built from 1984 - 1993. Again, the importance of this reduction cannot be determined until a more accurate count of the number of occupants in the Post-84 study group is obtained.

New homes in Westminster used less water for indoor purposes than the sample of 1,188 single-family homes examined in the AWWARF Residential End Uses of Water Study. The average per capita per day usage in the standard new and Water Wise homes of approximately 53 gpcd (including leaks) represents a modest savings over the AWWARF study that put indoor use between 60 and 70 gpcd. In this case it would appear that the new plumbing codes and fixtures are accomplishing a reduction in indoor water use.

Although the results must be considered preliminary, the new homes appear to be using water more efficiently outdoors than the Post-84 study group. Both sets of new homes used less water outdoors than the Post-84 homes in spite of the fact the 40 new and Water Wise homes were irrigating significantly more land. The application rate for the Post-84 homes was 23.1 inches, while that of the new homes averaged closer to 19.6 inches – a 15% savings. It appears that the older, Pre-77 homes, which are typically not equipped with automatic sprinkler systems, use significantly less water than either the new or Post-1984 homes, which are almost always equipped with automatic sprinklers.

In general, the data suggest that the new homes included in this study used less water for indoor purposes and more water for outdoor purposes than the Post-84 homes, which represent the largest sector of single-family housing in Westminster. Follow-up studies are needed to determine how consistent these usage patterns are, especially in the outdoor category. As landscapes mature, irrigation patterns may be altered (the homes with Xeriscape may reduce their application rates as the plant material becomes more hardy). The indoor use patterns are generally more stable, but may also change over time as more children enter (or leave) the families of the 1999 study groups. Leakage may also escalate as the homes age. A larger study done on more homes would improve the ability to generalize the results.

Do the Water Wise Homes Use Less Water than the Standard New Homes?

The Water Wise homes used less water indoors and more water outdoors in 1999 than the standard new homes. The average annual water use in the Water Wise homes was 7,000 gallons more than that in the standard new homes. It is important to remember that the Water Wise homes were irrigating an average of 1000 sf more landscape, and their application rates were quite similar to the standard new homes. The Water Wise homes were not equipped with the type of dual flush toilets requested by AquaSan. Given the proper toilets, the indoor savings of the Water Wise homes would have been more pronounced. There is also a clear indication that the Water Wise homes with their horizontal axis clothes washers are moving towards the goal of lower per indoor water use in single family homes. If the toilet problem were corrected and the

water use adjusted for lot size the savings in the Water Wise homes would have used 7000 gallons *less* per home instead of the same amount more.[3]

What are the Most Promising and Cost-Effective Conservation Devices?

ULF Toilets and Horizontal Axis Clothes washers

The results from this study suggest that the most promising conservation technologies are ULF toilets and horizontal axis clothes washers. The products provide the most water savings of all devices evaluated in this study. Results from this study show that ULF toilets save between 5 and 9 gallons per capita per day over non-ULF toilets. Horizontal axis clothes washers saved between 3 and 5 gallons per capita per day over standard top loading machines. In the best case scenario, an "average" home in Westminster with 2.8 residents, equipped with ULF toilets and a conserving clothes washer could save approximately 14,000 gallons of water per year over a home equipped with non-ULF toilets and a standard clothes washer. Assuming a combined water and sewer rate of $5.30 per kgal[4] and a modest energy savings (from the new washer) this average household would save approximately $84 per year.

The cost for purchasing and installing a ULF toilet is estimated at $250 while a horizontal axis clothes washer costs anywhere from $200 to $600 more than a standard top loading machine. Assuming an additional expenditure of $400 for the clothes washer and $250 for a ULF toilet the family spends $650 on conservation hardware. The payback period for this investment is 10 years[5]. This could be reduced by rebates from the City based on the estimated value of the saved water based on the marginal cost to the City to obtain new supplies.

On Demand Hot Water Systems

Results on the impacts of on-demand hot water systems were inconclusive. The per shower water use was lower in the six Water Wiser homes equipped with these devices (13.3 vs. 17.4 gallons per shower). These houses also used less water for showering than the other 34 homes (9.1 vs.13.5 gpcd), but at the same time they used more water for baths (5.7 vs. 2.1). The total for showering and bathing combined was identical. The two groups had an almost identical amount of faucet usage (10.5 vs. 10.6 gpcd). Overall, the homes equipped with re-circulating hot water systems used 49.1 gpcd for indoor purposes compared to 52.4 gpcd for the other new homes. If unknown and leakage uses are added in, the six re-circulating homes used 63.7 gpcd vs. 63.0 gpcd for the other new homes. There appears an indication that the devices may reduce per shower water use, but there was no statistically verifiable overall savings associated with these devices found in this study. This was due either to the fact that they don't save as much water as hoped for, or to the small size of the sample. More long-term examination of these devices in more houses is required to better quantify their actual impact.

[3] 19 inches of irrigation = 12 gallons per square foot x 1000 sf = 12,000 gallons plus 2000 gallons for toilet flushing is a reduction in 14,000 gallons per home for equalized conditions.
[4] Based on Westminster's $2.80 per 1000 block 2 rate and $2.50 per 1000 sewer rate.
[5] Assuming annual savings of $84.20 and a discount rate of 4.5%

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