Toilet Flapper Study:
Final Report

Prepared for

The California Urban Water Conservation Council

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Preface

This study and report are an outgrowth of concerns that have developed over the past 10 years regarding the vulnerability of toilet flush valve seals (commonly termed flappers) to normal aging, to possible degradation caused by consumers' use of in-tank bowl cleaning tablets, and to tampering and replacement. In addition, there is evidence that consumers may not be able to locate and install the proper replacement flappers when their original product fails.

It is the belief of many water conservation practitioners that these factors are resulting in seal failure, leakage, and excessive flush volumes in 1.6-gallons per flush (gpf) toilets. These, then, could result in a serious decline or "decay" in the water-efficiency of the toilet fixture, thereby negating the water savings that had been predicted by the water utilities subsidizing toilet replacements. However, the above scenario has only been partially documented and, as such, water utilities are uncertain as to the magnitude of such failures and resultant water losses.

This study is intended to supplement previous work in this area, answer questions about the frequency of seal failure and flush volumes of aging toilets, and provide a basis for further quantification of water losses (if any) resulting from seal failure.

In addition to the main objectives of the study, the City of San José also contracted for second visits to some of the residences within its service area that were subject to first visits and inspections. Between the first and second visits, the City contacted the first-visit customers by mail to encourage them to check for a toilet leak and replace their flapper. The second visit was designed to confirm that the customer received the letter and to determine what action the customer took in response. Exhibit B provides information on the results of the second visits.

Acknowledgements

The California Urban Water Conservation Council (Council) is very grateful to **Fluidmaster, Inc.** and **PEAK International** for their contributions to this study. Fluidmaster, Inc. provided technical advice and leak detection materials. PEAK International performed all of the in-residence surveys and measurements. Furthermore, this study could not have been conducted without the financial commitments of the following sponsors:

Metropolitan Water District of Southern California
City of San José
Contra Costa Water District
Santa Clara Valley Water District
Sonoma County Water Agency

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Executive Summary

For about 15 years, water utilities in California have funded and encouraged residential toilet fixture replacements as one means to achieving water demand reductions. The availability of low-flow 1.6-gallons per flush (gpf) toilet fixtures in the early 1990s provided a new avenue to residential water efficiency. Millions of 1.6-gpf fixtures are now installed in homes throughout the state, many of which were paid for (in whole or in part) by water utilities.

However, during the past 10 years, concerns have escalated among water conservation practitioners over toilet flapper leakage, increasing flush volumes, and other issues related to the gravity-fed fixture models. Widespread problems of this type could lead to a rapid decline in the water savings that were predicted by the water utilities when the toilet replacement programs were initiated. Except for an Arizona study conducted in 2000 and a small study conducted subsequently by the Los Angeles Department of Water and Power, there has been little "field" information to validate or dispel these concerns.

This field study was designed to identify the "real world" magnitude of flush valve seal (flapper) failure, toilet leakage through the flush valve, and flush volumes of aging toilet fixtures. Six water utilities participated in the work by providing funding and permitting technicians to visit the homes of customers within their service area, inspect the toilets, and survey the residents. Those water utilities were:

- Metropolitan Water District of Southern California
- Los Angeles Department of Water and Power
- City of San José
- Santa Clara Valley Water District
- Contra Costa Water District
- Sonoma County Water Agency

Out of water utility databases identifying approximately 840,000 toilet replacements, a total of 892 toilet fixtures (of 1992 to 2002 vintage) in northern and southern California residences were randomly selected and inspected. Of these, flush volumes of 852 fixtures were measured using the T5 Flushmeter. Finally, customers were surveyed as to their past and current actions with respect to the use of bowl cleaning tablets and flapper replacement.

Following are the primary conclusions from the field inspections and surveys:

1. The average flush volume of all 852 toilet fixtures measured was 1.76-gpf. (Note: Refer to Figure 1 on page 10 to view the full distribution of measured flush volumes.) However, 14 percent of those fixtures flush at a volume of less than 1.4-gpf, possibly leading to double-flushing or the user's "hold-down" of the flush handle, a common practice when water is insufficient to evacuate the waste with a normal flush. If one assumes that double-flushing does occur with the 14 percent group, the average (computed) flush volume of all fixtures then climbs to about 2.0-gpf.

2. Less than six (6) percent of the toilet fixtures were found to be leaking through the flush valve seal. There was no apparent correlation of leakage to fixture age. The low leakage rate may be due to the improved materials used by the manufacturers of flush valve seals and/or to the limited use by consumers' of the chlorine-based in-tank bowl cleaning tablets.

3. About 23 percent (205) of the customers indicated that they had used an in-tank bowl cleaner at one time or another. However, only 15 percent stated that they were using these products today. Of the 205 customers that had used bowl cleaners, the toilet fixtures of only 17 were found to be leaking. Of the remaining 188 customers, only 40 had ever replaced their flush valve seal (flapper).

4. Nearly 90 percent of the toilet fixtures inspected had their original flush valve seal (flapper). For the oldest fixtures (9 to 12 years old), less than 20 percent of the customers reported that they had replaced the original seal. Comparing fixtures with their original seal to those with a replacement seal showed that flush volumes increased by an average of 0.1-gpf when the seal was replaced.

5. Study results indicate that flapper failures (leaks) occur irrespective of the use of bowl cleaning tablets. Furthermore, bowl cleaner use did not lead directly to seal replacement. Only 43 of the 205 bowl cleaner users had ever replaced their flush valve seal (flapper).

6. Overall, the study findings indicate that leakage through the flush valve seal (flapper) and flush volume increases in aging toilet fixtures are not as detrimental to water savings as might have been expected. However, the need for water utilities to continue to protect against savings decay is paramount. Insistence upon flapper durability and limits on flush volume adjustability in new fixtures (as provided for in the Los Angeles Supplementary Purchase Specification) is one method of assuring persistence of water savings.

A summary of study recommendations follows:

1. In view of the study findings on flapper failure and resultant leakage, water utilities should first carefully consider the costs and benefits of a flapper replacement program before undertaking one. Creative, cost-effective methods to reach customers and encourage flapper replacement are essential. A very focused approach should be adopted that:

   - Targets only those fixtures that may be the most vulnerable to leaks and flush volume increases;
   - Initially targets fixtures installed prior to 1998;
   - Identifies the specific flush valve seal (flapper) for each targeted fixture that would cause the fixture to be restored to its original design flush volume; and
   - Utilizes the studies, information, methodologies, and similar resources that have been developed, explored or implemented by other water utilities in the U.S. to stimulate toilet fixture flapper replacements.

2. Water utilities that are sponsoring, designing, and/or implementing new toilet fixture replacement programs should:

   - Consider the adoption of an approved toilet list that qualifies fixtures as to their ability to sustain water savings through their lifetime and as to flush performance.
     - ✓ The Los Angeles Supplementary Purchase Specification (SPS) provides for flapper durability and limits flush volume adjustability.
     - ✓ The Maximum Performance (MaP) testing threshold of 250 grams of waste assures customer satisfaction with the toilet. With satisfied customers, water utilities can be confident that there will be less tampering and fewer adjustments with these fixtures that would otherwise lead to increased flush volumes.
   - Keep customers informed of their toilet fixture's maintenance requirements: checking for leaks, adjusting water levels, inspecting for damage, etc.
   - Maintain an up-to-date list of the correct replacement flush valve seal (flapper) for all eligible toilet fixtures in their program.
   - Support efforts to incorporate flush valve seal (flapper) durability in the codes and standards in California and the U.S.
   - Support efforts to develop and market toilet fixtures that use flush mechanisms that are non-adjustable, tamperproof, durable, and that either do not require a conventional seal OR incorporate a durable seal of a non-elastomeric material.

Introduction

For over 15 years, water agencies and municipalities in the U.S. have relied upon toilet fixture replacements as a key component of their residential water-efficiency programs. The exchange of a 5.0- or 3.5-gallons per flush (gpf) toilet for a 1.6-gpf toilet is expected to yield substantial savings within the typical household. The entities funding these replacement programs generally assume the physical or useful life of the new gravity-fed 1.6-gpf fixtures at 20 or 25 years[1] and, thus, the "sustainability" of water savings is forecasted accordingly. Yet, certain components of these fixtures have been known to fail or begin to leak much sooner. For example, flush valve seals (flappers and other types of seals) have been known to begin leaking in less than five years. When this occurs, the consumer may find it extremely difficult to obtain the after-market replacement seal that maintains the original design flush volume of the fixture. The result may be an unacceptable increase in flush volume. (Further background on flappers and the identification of the causes of failures, as well as the Metropolitan Water District's extensive work in this area, may be found in Exhibit A.)

Seal failure jeopardizes the 20 or 25 years of forecasted water savings (and, as a result, the economics of the carefully crafted toilet replacement programs). With the exception of a study completed in Arizona in 2000[2], very little authoritative data exists on either aging toilet performance or flapper failure and the effect upon water savings "sustainability". With over 12 years of active toilet replacement programs in California, it was now possible to begin examining the aging characteristics of an array of the 1.6-gpf fixtures installed here.

[1]In contrast to the gravity-fed fixture, the life of toilet fixtures using other technologies have been assumed as follows: pressure-assist/flushometer tank – 25 years; flushometer valve – 30 years.

[2]Henderson, Jim and Woodard, Gary. *Functioning of Aging Low-Consumption Toilets in Tucson: A follow-up with rebate program participants*. Prepared for the Water Conservation Office, Water Services Department, City of Phoenix and the U.S. Bureau of Reclamation, Phoenix Area Office. University of Arizona: Water Resources Research Center, Issue Paper #22. October 2000.

Objectives and Methodology

Objectives

Recognizing the need to develop more definitive information on the possible decay of water savings, a toilet performance measurement and flapper study was initiated in 2003 by the Council. That study was designed to attempt to answer the following series of questions:

(a) Of the installed base of agency-funded ULF toilet fixtures, what percentage of those fixtures is leaking?

(b) Of those found to be leaking, what are the causes of those leaks?
- ✓ Toilet bowl cleaners degrading the flapper
- ✓ Ordinary wear and tear of the flapper
- ✓ Incorrect physical fit of replacement flappers

(c) Of the installed base of the non-leaking agency-funded fixtures, what is the:
- ✓ Percentage of customers using bowl cleaners?
- ✓ Portion with OEM[3] flappers installed? After-market flappers installed?
- ✓ Flush volume of the toilets?

(d) What practices and policies can be implemented by water agencies and municipalities to reduce the water savings decay?

Water Provider Partners

Six water providers partnered with the Council to provide funding and/or their toilet replacement program databases for the study. In addition, they granted permission for representatives of the Council to contact their customers for in-residence visits. Those partners were:

(a) Metropolitan Water District of Southern California
(b) Los Angeles Department of Water and Power
(c) City of San Jose
(d) Contra Costa Water District
(e) Santa Clara Valley Water District
(f) Sonoma County Water Agency

Study Design

The essential element of the study was the in-residence visits with the customers of the retail water providers. To meet the study objectives, however, other important elements surrounded the visits. Study design, therefore, encompassed five tasks:

(a) Databasing the most popular ULF toilet fixtures that were part of the water efficiency programs in California for the past 12 years.

(b) In-residence field inspections of installed aging ULF toilet fixtures, including flush volume measurements and flapper inspections.

[3]OEM: Original Equipment Manufacturer

(c) Customer surveys of flapper replacement habits.

(d) To the extent possible, assessing the consumers' use of bowl cleaners and the market penetration of these products.

(e) To the extent that field inspection data allowed, development of "aging profiles" of the most popular ULF toilet fixtures.

Databasing and Targeting

The identification of the installed ULFTs was critical to the study analysis. From its existing databases, study partners identified the number and model of ULFTs installed on one or more of their toilet replacement programs for the following four groups of calendar years:

- 1991 through 1995[4]
- 1996 - 1997
- 1998 – 1999
- 2000-2002

Contained within these databases were the important facts required for the study: customer name, phone number, and replacement toilet installation date, address, manufacturer and (in most cases) model name and/or number.

A cross-section of toilet models was developed from the databases that potentially represents the majority of the "universe" of 1.6-gpf toilets installed through water provider conservation programs. Those toilet models are shown in Table 1.

[4]Nearly all ULF toilet models sold in the period from 1991 through 1995 contained OEM flappers that were NOT necessarily resistant to the bowl cleaning chemicals. Subsequently, as new material and compounds were developed by the flapper manufacturers, new chemically resistant flappers were developed and supplied as OEM products for the ULFT manufacturers.

Table 1. Toilet Fixture Models

Manufacturer	Model
American Standard	2164/2174/2898-Cadet II 2116-Hydra
Briggs	T230 4775 4275/4277/4278/4759/4764
Eljer	091-1120,1125,1190 - Patriot 091-0120/091-0125 - Savoy 081-1590/1595-Berkeley 091-3235/3230-Laguna 091-1545-St. Clair
Fabricas	F145
Gerber	21-702, 21-712
Legend - HCG	9001
Kohler	K3421-K3422-K3423 Wellworth K3591 Portrait Rosario
Mansfield	130-160/130-16 Allegro, Alto, et.al., incl. Norris & Kilgore
Niagara	2202
Vitromex-St Thomas	6201/601
Sterling (by Kohler)	412010/402012/402015
Toto	CST703/CST704
Universal-Rundle	4090/4092/4093/ 4171/4191/4196
Western Pottery	822 Aris

The databases contained information on about 840,000 residential toilet replacements. Random samples were taken from those databases for the in-residence visits. To the extent possible, samples were stratified as to year of installation, and to toilet make and model. However, in some cases, the distribution or rebating of certain models was concentrated in a single year and, as a result, stratification to all four calendar year groups was not always possible.

In-residence visits and surveys

The study encompassed the inspection of a total of 892 1.6-gpf toilet fixture within California residences (both single family and multi-family dwellings). Those were divided among the partner water providers as follows:

Table 2. In-residence Inspections Completed by Service Area

Water Provider Service Area	Completed In-Residence Inspections
Los Angeles Department of Water and Power	608
City of San Jose	103
Santa Clara Valley Water District	60
Contra Costa Water District	60
Sonoma County Water Agency	61
Total	**892**

The field inspection process included an oral survey and a physical inspection at the residence site as follows:

- Oral survey of customer
  - ✓ Use of bowl cleaners and what type
  - ✓ Frequency of use of bowl cleaners and application
  - ✓ Flapper replacement history
- Physical inspection of 1.6-gpf toilet fixture
  - ✓ Verification of manufacturer and model
  - ✓ Leak test
  - ✓ Determination of flapper type – OEM, after-market, type or manufacturer
  - ✓ Assessment of flapper appearance
  - ✓ Flush volume measurement[5]

[5]All flush volumes were measured using the T5 Flushmeter from Strategic Instruments, Inc., whose website can be accessed through: http://www.t5flushmeter.com/ . However, because of the unique design of the Western Pottery Aris bowl, the T5 Flushmeter could not be used to measure the flush volume on that fixture and, therefore, volume data for the Aris is not available.

Database

The study derived inspection samples from the water conservation program databases provided by five partner water utilities. Those databases contained about 840,000 1.6-gpf toilet fixture installations that occurred in the 1992-2002 period and that were subsidized in one form or another by water utilities. The 892 in-residence inspections were randomly selected from this set of databases.

One of the sampling criteria for the study was to provide the ability to stratify results by fixture age and manufacturer. The age and manufacturer distributions are shown in Tables 3 and 4.

Table 3. Age of Toilet Fixtures Inspected – by Service Area

Water Provider Service Area	1992-1995	1996-1997	1998-1999	2000-2002	TOTAL
Los Angeles Department of Water and Power	163	126	194	125	608
City of San Jose	0	16	35	52	103
Contra Costa Water District	60	0	0	0	60
Santa Clara Valley Water Dist.	0	0	0	60	60
Sonoma County Water Agcy	0	61	0	0	61
Total	**223**	**203**	**229**	**237**	**892**

Table 4. Age of Toilet Fixtures Inspected – Stratified To Manufacturer

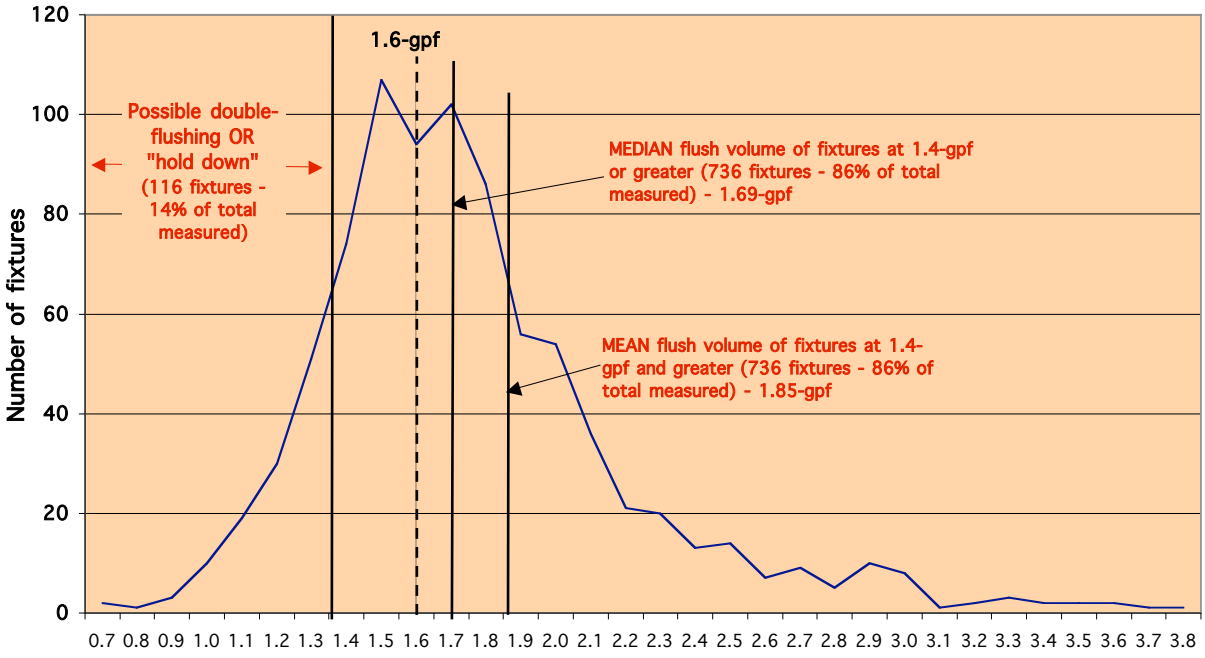
Manufacturer	1992-1995	1996-1997	1998-1999	2000-2002	TOTAL
American Standard	28	12	25	7	72
Briggs	18	2	19	1	40
Eljer	28	5	8	3	44
Fabricas	34	0	1	0	35
Gerber	0	0	10	12	22
Legend - HCG	1	5	43	1	50
Kohler	33	4	7	5	49
Mansfield	30	21	5	64	120
Niagara	0	1	1	53	55
Vitromex-St Thomas	0	73	30	20	123
Sterling (by Kohler)	15	16	22	2	55
Toto	28	63	1	14	106
Universal-Rundle	4	0	22	52	78
Western Pottery	2	1	35	2	40
Other	2	0	0	1	3
Total	**223**	**203**	**229**	**237**	**892**

Results

Flush Volumes

Overall, the mean flush volume of the 852 measured fixtures[6] was 1.76-gpf. Figure 1 illustrates the distribution of flush volumes of all 852 fixtures.

Figure 1. Flush Volumes:
Toilet Fixtures Sold & Installed* - 1992-2002



*-852 toilet fixtures were measured for flush volume

While most of the flush volume attention is usually focused on those fixtures that are flushing at levels in excess of 1.6-gpf (and presumably wasting water), it is also important to learn what proportion of the fixtures are flushing at less than 1.4-gpf [7]. It would be incorrect to interpret the

[6]Although 892 fixtures were selected and inspected, 40 Western Pottery fixtures could not be measured for flush volume due to their unique bowl design (see footnote 4). As such, 852 flush volume measurements were performed.

[7]It is generally believed in the plumbing industry that, unless a fixture is specifically designed to fully function at 1.4-gpf, most 1.6-gpf toilet fixtures cannot function effectively at less than 1.4-gpf. When a fixture is consistently flushing at 1.3-gpf or less, it is very likely that it is either being double- or triple-flushed or the end-user is holding the flush handle down to keep the flush valve open ("hold-down" or "hold-open") until the flush is completed. In both cases, the effective flush volume is significantly greater than 1.6-gpf.

A 2001 study by Veritec, Inc. (*ULF Toilet Performance Monitoring Program*, August 2001; this study is available for download from: http://www.cuwcc.org/products_tech.lasso) found that customers with marginally performing toilets routinely held the flush handle down as the accepted method of evacuating the bowl. The study then went further to determine the actual flush volume that resulted from such a practice. Quoting from the study report regarding homeowners' typical practice: "A toilet with a measured flush volume of 6 litres (1.6 gallons) used 10 litres (2.6 gallons) when the homeowner demonstrated their 'normal flush' to the inspector." The study also assessed the frequency of "double-flushing" by the customer.

1.76-gpf mean flush volume as indicative of the "universe" without considering this proportion in determining actual water consumption. Table 5 depicts the impact of these toilet fixtures on mean flush volumes if they are removed from the calculation.

Furthermore, if one assumes that the fixtures flushing below 1.4-gpf are, in fact, double-flushed or subject to flush handle hold-down[7], then the aggregate for all 852 measured fixtures climbs to an average of about 2.0-gpf. However, without further investigation of customer habits, it is difficult to determine whether double-flushing or handle hold-down dominate.

Measured flush volumes for the aging fixtures in this study varied significantly among the manufacturers (see Table 5). This variance above and below their rated flush volumes[8] may be attributable to several factors: improper installation and set-up of the toilet fixture (whether intentional or unintentional), normal aging of the fixture internal parts, operating water pressure variances within the residence, failure of the resident to maintain the fixture and/or re-set the water level on a periodic basis, replacement of the flush valve seal with an incorrect after-market product, tampering with the product after installation, and similar actions. The scope of this study did not include an attempt to determine the cause of the many flush volume variances.

Table 5. Flush volumes Stratified According To Fixture Manufacturer

Manufacturer	Total No. of Fixtures Measured for Flush Volume	Mean Flush Volume (gpf)	No. Fixtures at <1.4 gpf	Percent of Total No. of Fixtures	No. Fixtures at >1.65 gpf	Percent of Total No. of Fixtures
American Standard	72	1.77	9	12.5	41	56.9
Briggs	40	1.79	4	10.0	26	65.0
Eljer	44	1.52	16	6.8	17	38.6
Fabricas	35	1.68	5	14.3	15	42.9
Gerber	22	1.48	7	31.8	7	31.8
Legend - HCG	50	1.70	1	2.0	28	56.0
Kohler	49	1.62	9	18.4	20	40.8
Mansfield	120	1.93	7	5.8	96	80.0
Niagara	55	1.64	11	20.0	26	47.3
Vitromex-St Thomas	123	2.01	4	3.3	59	48.0
Sterling (by Kohler)	55	1.72	6	10.9	31	56.4
Toto	106	1.72	18	17.0	56	52.8
Universal-Rundle	78	1.70	19	24.4	39	50.0
Other	3	1.50	0	0	0	0
Total/Composite	**852**	**1.76**	**116**	**13.7**	**461**	**54.3**

[8]Some toilet fixtures are rated by their manufacturer at 1.5-gpf while others are rated at 1.6-gpf.

Figure 2 illustrates the flush volumes for each manufacturer's product as listed in Table 5.

Figure 2. Distribution of Flush Volumes - Manufacturer

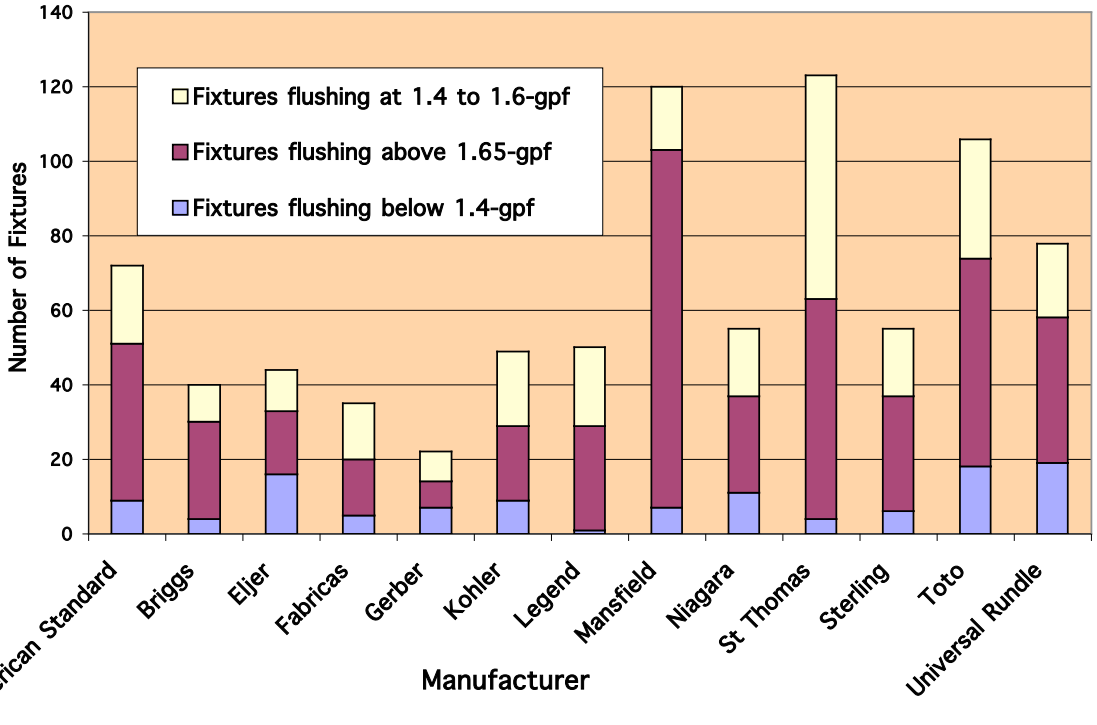
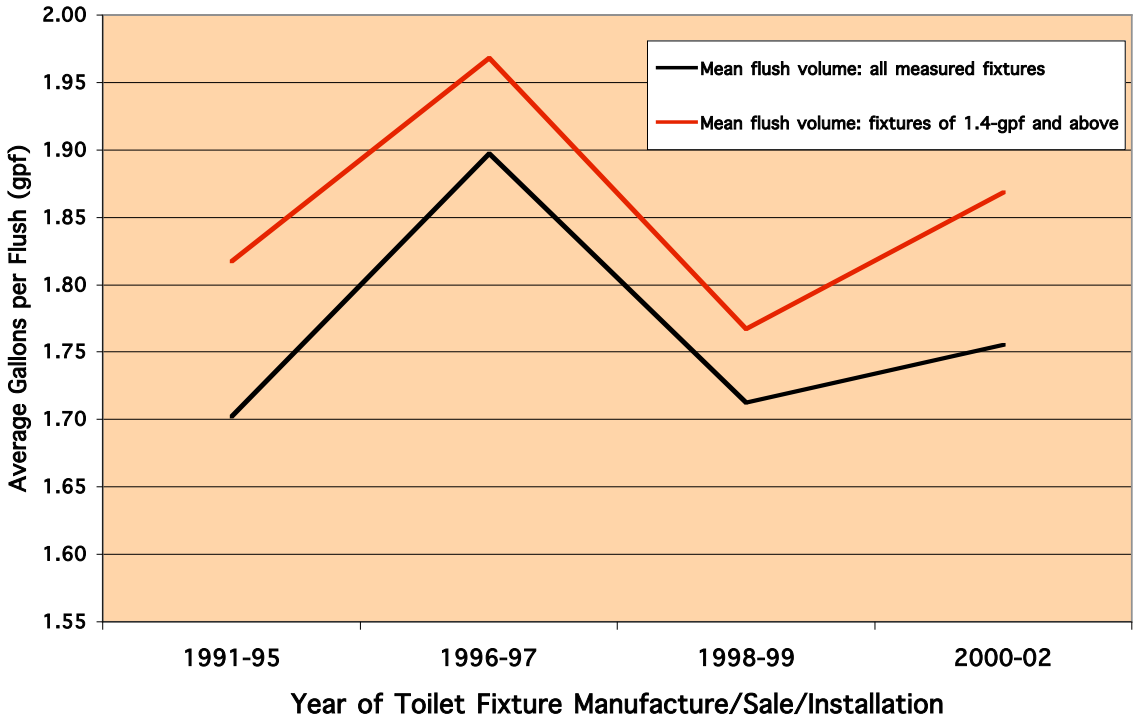


Table 6 lists the adjusted flush volumes if those fixtures performing at less than 1.4-gpf are removed. Figure 3 shows average flush volumes for the four calendar periods studied.

Table 6. Adjusted Flush Volumes After Removing <1.4-gpf Fixtures

Manufacturer	Mean Flush Volume as Originally Measured	ADJUSTED Mean Flush Volume After Removing <1.4-gpf Fixtures
American Standard	1.77	1.85
Briggs	1.79	1.86
Eljer	1.52	1.66
Fabricas	1.68	1.75
Gerber	1.48	1.63
Legend - HCG	1.70	1.73
Kohler	1.62	1.70
Mansfield	1.93	1.97
Niagara	1.64	1.77
Vitromex-St Thomas	2.01	2.03
Sterling (by Kohler)	1.72	1.79
Toto	1.72	1.83
Universal-Rundle	1.70	1.85
Other	1.50	1.50
Composite	**1.76**	**1.85**

Figure 3. Flush Volumes vs. Fixture Age



Leaking Toilet Fixtures and Bowl Cleaning Tablets

Each of the 892 toilets was subjected to a leak test using dye tablets in the tank water and observing the flow (if any) through the flush valve into the bowl. The leak test did not attempt to determine if intermittent leaks might occur as a result of changing static water pressures that could cause the fill valve to open and allow water to escape the tank through the overflow tube[9]. Tables 7 and 8 display leakage data from the field inspections.

[9]Measuring the extent of this type of leakage is best accomplished through the use of data loggers wherein water flows into and through the plumbing system are traced over long continuous periods.

Table 7. Leaking Toilet Fixtures According to Fixture Manufacturer

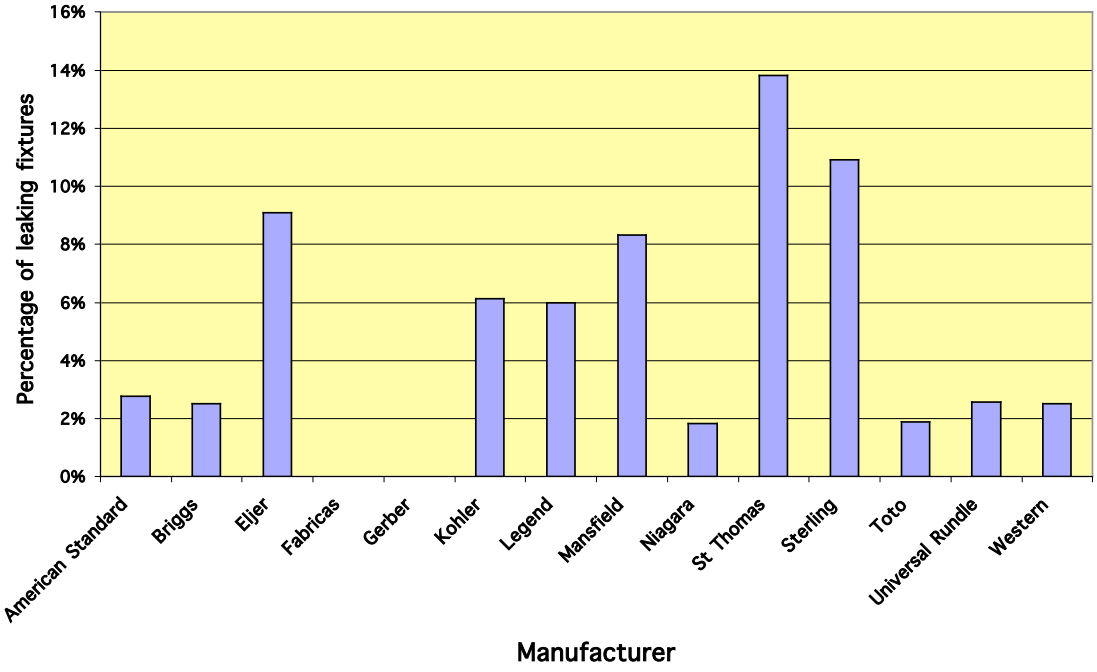
Manufacturer	Total No. of Fixtures Inspected for Leakage	No. of Fixtures Found to be Leaking	Percentage of Fixtures Inspected
American Standard	72	2	2.8%
Briggs	40	1	2.5%
Eljer	44	4	9.1%
Fabricas	35	0	0.0%
Gerber	22	0	0.0%
Legend - HCG	50	3	6.1%
Kohler	49	3	6.0%
Mansfield	120	10	8.3%
Niagara	55	1	1.8%
Vitromex-St Thomas	123	17	13.8%
Sterling (by Kohler)	55	6	10.9%
Toto	106	2	1.9%
Universal-Rundle	78	2	2.6%
Western Pottery	40	1	2.5%
Other	3	0	0.0%
Total/Composite	**892**	**52**	**5.8%**

Table 8. Leakage by Toilet Fixture Age

	Year of Toilet Fixture Manufacture/Sale/Installation			
	1992-1995	**1996-1997**	**1998-1999**	**2000-2002**
Total no. of fixtures	223	203	229	237
Leaking fixtures	11	19	5	17
Leakage percent	4.9%	9.4%	2.2%	7.2%

Figure 4 provides a graphical display of the information in Table 7.

Figure 4. Toilet Leaks According to Manufacturer



At the time that this study was conceived, it was pre-supposed that accelerated flapper failure was caused largely by consumer use of chlorine-based bowl cleaning tablets, namely those of the drop-in type that are periodically added to the tank water[10]. Exhibit A details the background on this issue and the responses by the water utility industry and the flapper manufacturers to the problem.

The results of this study appear to indicate that flapper failure (leaks) occur irrespective of the use of bowl cleaning tablets. Figure 5 illustrates the tally of responses from residents with leaking toilet fixtures when quizzed about their use of bowl cleaners. In fact, of the 52 households with a toilet leak, only 17 indicated that they had used a bowl cleaner in their toilet at any time. Figure 6 displays graphically the "overlap" of bowl cleaner users with leaking toilets within the context of all 892 inspections and surveys. Clearly, the universe of leaking fixtures is not large enough to infer that the use of bowl cleaners either does or does not lead to leaks through the toilet flapper. Nor do the responses of the 52 household residents provide any indication either way.

[10]Consult the following two studies for more information on the topic of flapper degradation: *Toilet Flapper Materials Integrity Tests*, The Metropolitan Water District of Southern California, May 1998; and *Toilet Flappers Materials Integrity Tests*, The Metropolitan Water District of Southern California, January 2000.

Figure 5. Leaking Toilet Fixtures
and the Use of Bowl Cleaners

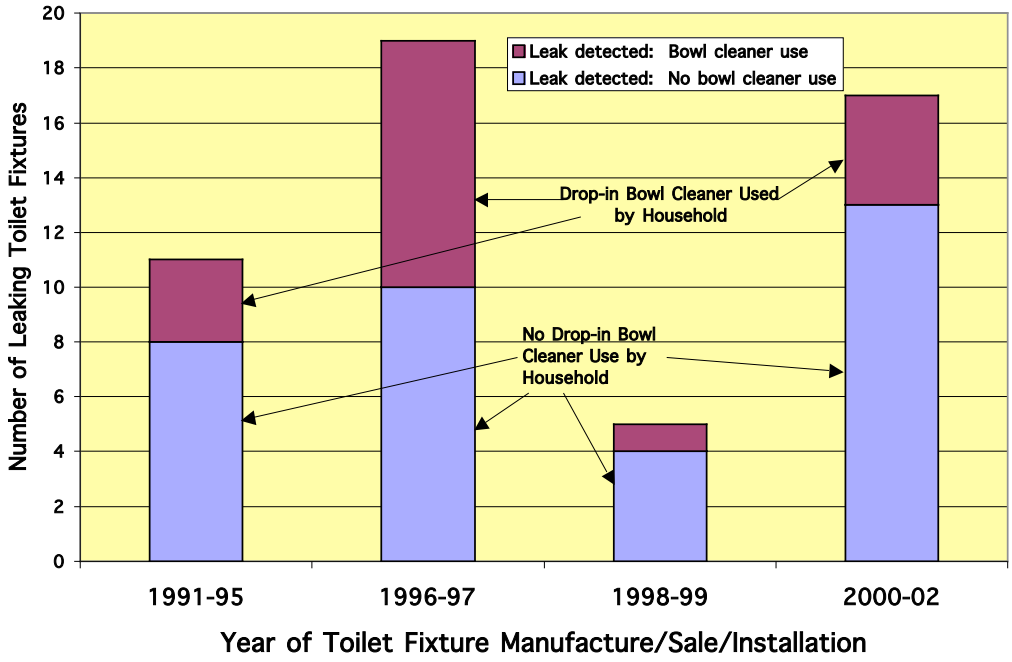
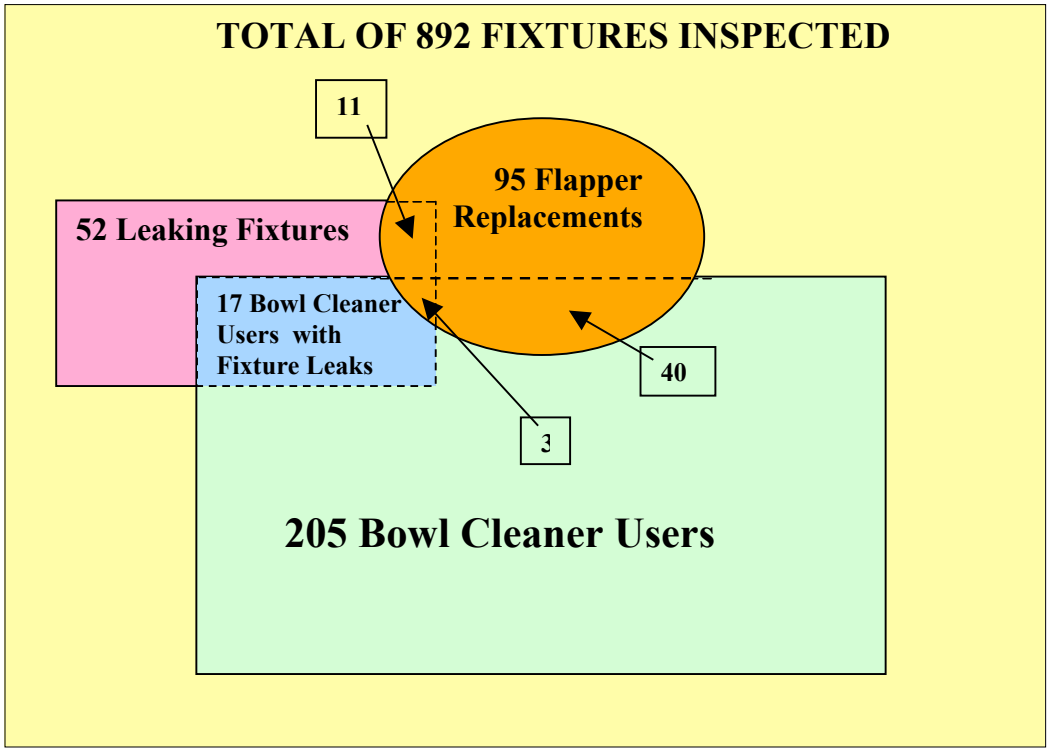


Figure 6. Bowl Cleaner Use and Toilet Fixture Leaks (not to scale)



Of the 892 households with inspected toilets, 205 (23 percent) indicated that they had used bowl cleaners at one time or another (of those, 134 stated that they were using them at the time of the visit and inspection). Tables 9 and 10 show the usage within each service area; Table 11 shows usage stratified by manufacturer.

Table 9. HISTORICAL Use of Bowl Cleaners According to Service Area

Water Provider Service Area	No. of Households Visited & Fixtures Inspected	No. of Households That Have Used Cleaners at Any Time	Percentage
Los Angeles Department of Water and Power	608	137	22.5%
City of San Jose	103	25	24.3%
Santa Clara Valley Water District	60	10	16.7%
Contra Costa Water District	60	10	16.7%
Sonoma County Water Agency	61	23	37.7%
Total/Composite	**892**	**205**	**23.0%**

Table 10. CURRENT Use of Bowl Cleaners According to Service Area

Water Provider Service Area	No. of Households Visited & Fixtures Inspected	No. of Households Currently Using Cleaners	Percentage
Los Angeles Department of Water and Power	608	78	12.8%
City of San Jose	103	23	22.3%
Santa Clara Valley Water Dist.	60	6	10.0%
Contra Costa Water District	60	8	13.3%
Sonoma County Water Agency	61	19	31.1%
Total/Composite	**892**	**134**	**15.0%**

Table 11. HISTORICAL Use of Bowl Cleaners - Fixture Manufacturer

Manufacturer	No. of Households Visited & Fixtures Inspected	No. of Households That Have Used Cleaners at Any Time	Percentage
American Standard	72	13	18.1%
Briggs	40	9	22.5%
Eljer	44	11	25.0%
Fabricas	35	0	0.0%
Gerber	22	0	0.0%
Legend - HCG	50	4	8.0%
Kohler	49	8	16.3%
Mansfield	120	23	19.2%
Niagara	55	9	16.4%
Vitromex-St Thomas	123	50	40.7%
Sterling (by Kohler)	55	15	27.3%
Toto	106	30	28.3%
Universal-Rundle	78	27	34.6%
Western Pottery	40	3	7.5%
Other	3	3	100.0%
Total/Composite	**892**	**205**	**23.0%**

In-tank drop-in bowl cleaners exist in several forms. Those products whose principal ingredient is chlorine (bleach) are the greatest threat to the elastomeric materials that comprise most flush valve seals[11]. The white versions of 2000 Flushes®, Clorox® Automatic, and Vanish® appear to represent the dominant products in the marketplace that fall into that category. Therefore, one element of the in-residence survey was to learn what bowl cleaning products the customers had been using. Table 12 summarizes customer responses to the survey.

Table 12. Customers' Choice of Bowl Cleaning Products

Bowl Cleaning Product	No. of Customers That Used the Product
2000 Flushes®	51
Clorox® Automatic	48
Vanish®	18
Other (includes liquid bleach, pool cleaning tablets, Ty-D-Bowl, Fluidmaster and Longs Drug products, and various other miscellaneous bowl cleaners)	88
Total	**205**

[11] Ibid

Toilet Leaks and the Residential End Uses of Water Study (REUWS)

The 1999 AWWARF study of residential dwellings and their water use[12] found that within the 1,188 study sites (residential dwellings), the average leakage per home amounted to 9.5 gallons per capita per day. The authors admit that it "was impossible to determine the exact source of the leakage in each study house" but go on to conclude that "toilet flapper leaks were the primary contributor" to the leak rate based upon an interpretation of the software-generated trace used in the REUWS. The authors of that study determined that 5.5 percent of the homes within the study appeared to be responsible for the largest portion of the aggregate leakage. This may appear to be somewhat consistent with the results of this study wherein it was found that 5.8 percent toilet fixtures were leaking *at the flapper*.

However, other sources of "leaks" may occur. As noted earlier in this report, additional intermittent "leakage" is possible for those fixtures that are susceptible to water pressure changes within the home, particularly in the hours between 12 midnight and 5AM. Technically, these are not leaks, nor are they necessarily due to faulty or failing fixtures[13]. They are instead caused by the operating variances in the municipal water system, in some cases by excessive pressure in the system. Neither this study nor the REUWS attempted to quantify the water wasted as a direct result of such variances.

Replacement of Flush Valve Seals (Flappers) by the Customer

Customers were questioned as to whether they had ever replaced the flush valve seal or flapper on their 1.6-gpf toilet. A little over 89 percent of the customers indicated that their toilet fixture contained the original OEM flush valve seal. Table 13 displays this information stratified according to manufacturers of the toilet fixtures.

[12] American Water Works Association Research Foundation, *Residential End Uses of Water*, 1999, Aquacraft, Inc.

[13] The fixtures that may experience increases in tank water level (and water escaping through the overflow tube) when water pressure increases are usually those with a traditional ballcock type fill valve. Use of pilot fill valve technology may avoid this problem. The REUWS did not address this phenomenon, even though it could be measured with the data loggers and software used in that study.

The REUWS further cites the Boulder Heatherwood Studies where leakage was reduced from 11.5 percent of indoor water use to 5.5 percent after a toilet retrofit. Unfortunately, it could be implied by the REUWS that the reduction in leakage was due to elimination of flapper leaks, yet, in fact, the cause of a major portion of the reduction could have been from a change in toilet fixture fill valve technology (from ballcock to pilot valve). Neither the REUWS nor this study attempted to determine how much water is wasted as a result of pressure increases upon ballcock-type fill valves.

Table 13. Customer Replacement of the OEM Flush Valve Seal – Manufacturer

Manufacturer	No. of Fixtures Inspec-ted	Fixtures With the Original Flush Valve Seal - Flapper		Fixtures With a Replacement Flush Valve Seal - Flapper
		Number	Percen-tage	Number
American Standard	72	59	81.9%	13
Briggs	40	34	85.0%	6
Eljer	44	33	75.0%	11
Fabricas	35	34	97.1%	1
Gerber	22	21	95.5%	1
Legend - HCG	50	46	92.0%	4
Kohler	49	44	89.8%	5
Mansfield	120	116	96.7%	4
Niagara	55	53	96.4%	2
Vitromex-St Thomas	123	117	95.1%	6
Sterling (by Kohler)	55	45	81.8%	10
Toto	106	89	84.0%	17
Universal-Rundle	78	65	83.3%	13
Western Pottery	40	38	95.0%	2
Other	3	3	100%	0
Total/Composite	**892**	**797**	**89.3%**	**95**

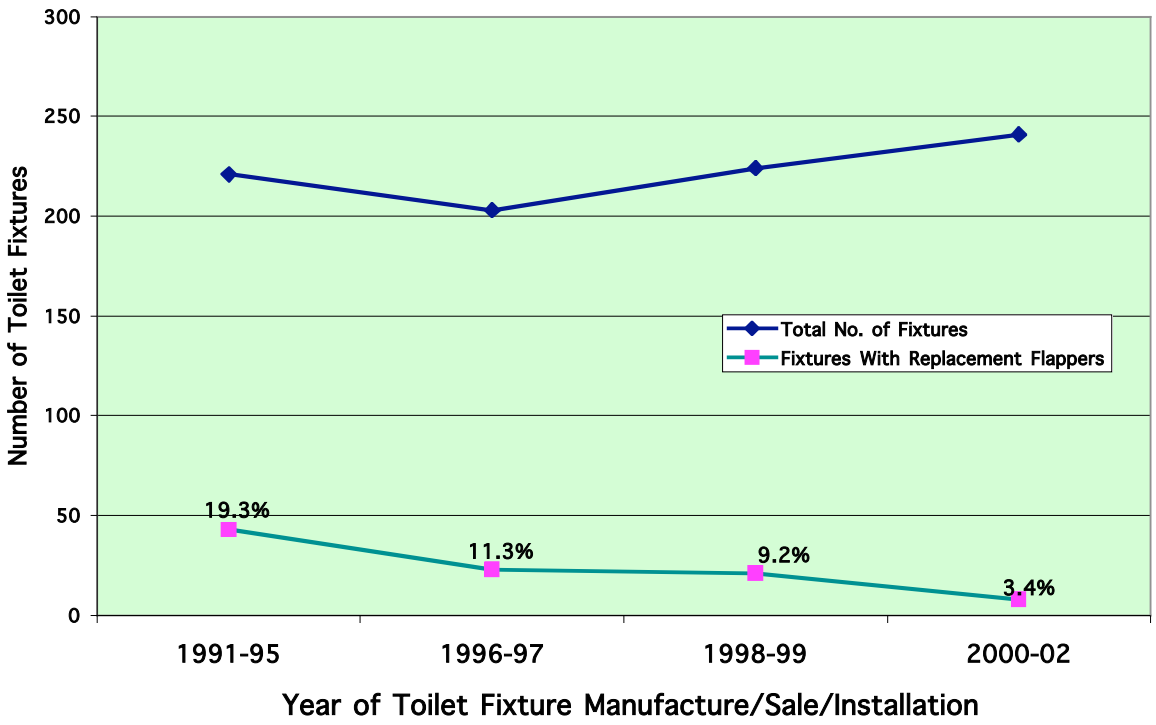
When aggregated and analyzed as to the age of the toilet fixtures, the flapper replacement trend becomes somewhat more apparent. The data within Table 14 and the Figure 7 graphical representation of that data indicate that flapper replacement is not as prevalent as some may have previously believed. As noted, less than 20 percent of the fixtures within the 10-14 years of age category have had their flappers replaced at some time during their lifetime.

Table 14. Customer Replacement of the OEM Flush Valve Seal by Fixture Age

	Year of Toilet Fixture Manufacture/Sale/Installation			
	1992-1995	1996-1997	1998-1999	2000-2002
Total no. of fixtures	223	203	229	237
Customer replaced OEM flush valve seal (flapper)[14]	43	23	21	8
Replacement percent	19.3%	11.3%	9.2%	3.4%

[14] Customer replaced the flush valve seal (flapper) at some undetermined date since the fixture was installed.

Figure 7. Replacement Flappers



The flush volume impacts of flapper replacement are of special interest, particularly when it is believed that most consumers are unable to locate the correct after-market product for their toilet[15]. As such, water conservation professionals have concluded that consumers, when confronted with a leaking toilet, will usually replace their flapper with one that increases the flush volume.

An objective of this study was to determine, to the extent possible, the incremental increase in flush volume occurring with flush valve seal (flapper) replacement by the consumer. Of the 852 fixtures measured for flush volume, only 95 were operating with replacement flappers[16]. Table 15 and Figure 8 compare the flush volumes of those fixtures containing their original OEM flush valve seal with those with replacement seals.

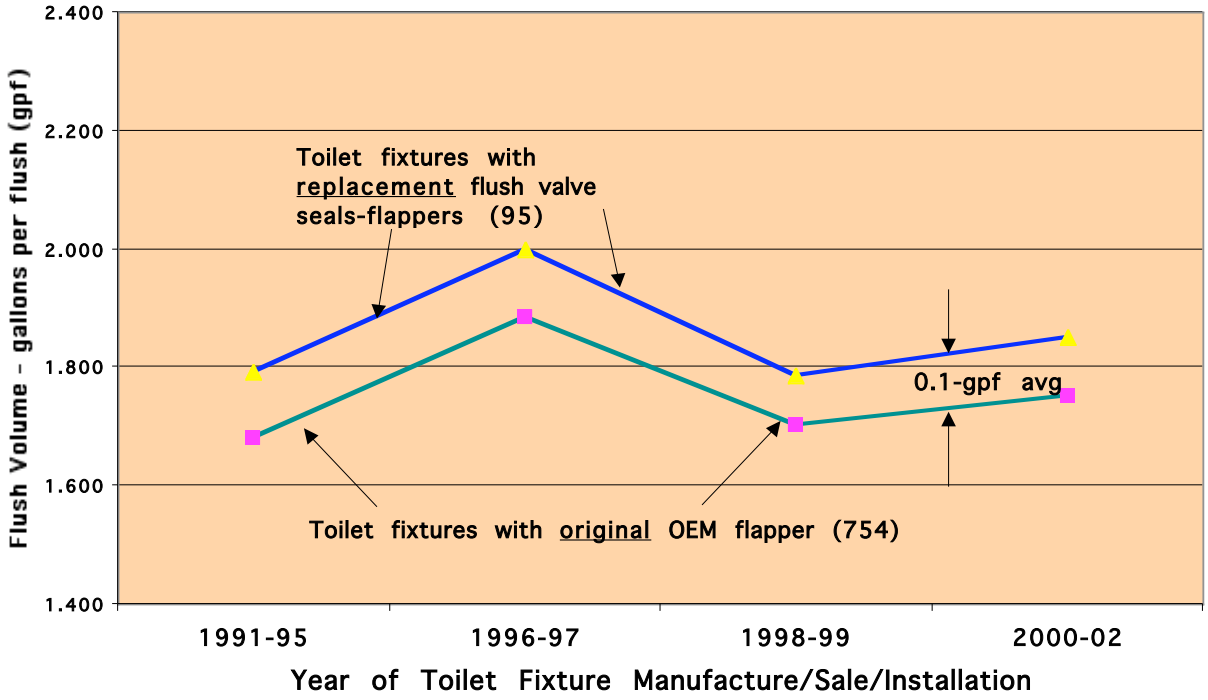
[15] The difficulty facing consumers in their search for the correct after-market replacement flapper was studied in the report: Metropolitan Water District of Southern California, *After-Market Toilet Flappers: A Study of Compatibility and Flush Volumes*, November 1998.

[16] The information on flapper replacement was derived from survey questions of the householder at the time of the inspection visit. Some survey respondents, however, may not have been a resident in the home until some time after toilet installation and therefore would not necessarily know if the toilet's original flapper had been replaced. In addition, some survey respondents may not have knowledge of a possible flapper replacement by another member of the household. Finally, some respondents simply would not remember the small task of flapper replacement that could have taken place many years earlier. As such, the data presented and the conclusions drawn from that data should be considered only as one indicator of actual field conditions.

Table 15. Flush Volume Comparison: OEM vs. Replacement Flush Valve Seal

	Year of Toilet Fixture Manufacture/Sale/Installation				
	1992-1995	1996-1997	1998-1999	2000-2002	Com-posite
Flush volume of fixtures with original OEM flush valve seal	1.68-gpf	1.88-gpf	1.70-gpf	1.75-gpf	1.75-gpf
Flush volume of fixtures with replacement flush valve seal	1.79-gpf	2.00-gpf	1.79-gpf	1.85-gpf	1.85-gpf
Flush volume differential	0.11-gpf	0.12-gpf	0.09-gpf	0.10-gpf	0.10-gpf

Figure 8. Flush Volume Comparison: OEM vs. Replacement Flappers



With the reservations noted[16], it can be concluded that flapper replacement adds an average of about a tenth of a gallon to the flush volume of a low-flow toilet fixture. However, certain toilet fixture models are designed to function at close to 1.6-gpf even when the flush valve seal is replaced with a product other than that recommended by the fixture manufacturer. Conversely, other toilet fixtures use "early-closure" or other flush valve seals that, when replaced, lead to significantly increased flush volumes[17]. Table 16 compares flush volume variances for the fixture models included in this study.

[17] It is this situation that led, in 2000, to the adoption of the Supplementary Purchase Specification (SPS) by the Los Angeles Department of Water and Power. Among other requirements, the SPS limits flush volumes on fixtures with replacement flappers. To download full details on the SPS and a list of toilet fixtures that meet its requirements, consult the Council's website: http://www.cuwcc.org/products_tech.lasso

Table 16. Customer Replacement of the OEM Flush Valve Seal – Manufacturer

Manufacturer	Fixtures With Original OEM Flush Valve Seal		Fixtures With Replacement Flush Valve Seal	
	No. of Fixtures	Mean Flush Volume	No. of Fixtures	Mean Flush Volume
American Standard	59	1.77	13	1.75
Briggs	34	1.81	6	1.72
Eljer	33	1.55	11	1.44
Fabricas	34	1.68	1	1.90
Gerber	21	1.47	1	1.70
Legend - HCG	46	1.67	4	1.95
Kohler	44	1.61	5	1.72
Mansfield	116	1.92	4	2.18
Niagara	53	1.65	2	1.60
Vitromex-St Thomas	117	1.98	6	2.45
Sterling (by Kohler)	45	1.68	10	1.90
Toto	89	1.65	17	2.08
Universal-Rundle	65	1.70	13	1.69
Composite		**1.75**		**1.85**

The samples taken for this study are not large enough to necessarily provide a statistically valid representation of all of the fixture models. Further, the samples were taken from a database of installations covering a period of about 12 years and, during that time, product designs change. In fact, some of the models are no longer available in the marketplace. **Therefore, the data collected with this study should be viewed as a general indicator of past conditions; to draw specific conclusions from the above data about an individual manufacturer's current product line is not warranted.**

Conclusions

Without authoritative field investigative results, water agencies and municipalities have feared the worst when considering the possible decay of water savings from flapper failure within the 1.6-gpf toilet fixtures that they subsidized. Recent laboratory studies show that flapper materials and the flappers themselves deteriorate rapidly when in the chemical environment created by many in-tank bowl cleaning tablets[18]. Yet, no "real world" information existed as to: (a) the extent to which consumers actually used bowl cleaners or (b) the actual deterioration of flappers within a typical household and the resultant effect upon flush volumes. This study was designed as a first step toward gathering that information.

The following conclusions are based upon completing 892 field inspections of toilet fixtures within both single- and multi-family residences in northern and southern California:

1. The average flush volume of all 852 measured fixtures was 1.76-gpf. (Refer to Figure 1 on page 10 for a view of the distribution of flush volumes.) Approximately 54 percent of all aging toilet fixtures inspected were flushing at a rate of 1.7-gpf or higher (Table 5). Some of this may be due to: (1) natural "creep" of the adjustments within the toilet tank, (2) improper adjustment of the fixture at installation, (3) incorrect flush valve seal (flapper) replacement, or (4) tampering by the homeowner or others.

2. About 14 percent of all toilet fixtures were flushing at a rate below 1.4-gpf (Table 5). These fixtures are likely to be subject to frequent double or triple flushing or "hold down" of the flush handle, both of which increase the effective flush volume. As with toilet fixtures flushing at excessive rates, flushing at a low rate could also be the result of improper adjustment, incorrect flapper replacement, or tampering. In any case, the effective flush volumes of these fixtures will likely approach or even exceed 2.5-gpf and, as such, may be more threatening to water efficiency than those single-flushing toilets described in item 1. above.

3. Flush volumes of the aging toilet fixtures (when adjusted to remove from the calculation those flushing below 1.4-gpf) do not appear to be excessively high at 1.85-gpf (Table 6). However, this figure does not then account for the possible double- or triple-flushing and flush handle "hold down" of those fixtures that are probably adjusted below the water level necessary to remove waste in a single flush. If one assumes that the fixtures flushing below 1.4-gpf are, in fact, double-flushed or subject to "hold down", then the aggregate for all 852 measured fixtures climbs to an average of about 2.0-gpf.

[18]Those studies were as follows:
Toilet Flapper Materials Integrity Tests, The Metropolitan Water District of Southern California, May 1998.
Toilet Flappers Materials Integrity Tests, The Metropolitan Water District of Southern California, January 2000.
Toilet Flapper Materials Integrity Tests, Supplement to Report dated January 2000, The Metropolitan Water District of Southern California, May 2001.

4. Flush volumes varied among the five service areas[19]. Two important factors could be influencing this: (1) the method by which toilet fixtures were provided to the customer and installed[20] and (2) the manufacturer and model of toilet fixtures[21].

5. Similarly (and as expected), volumes varied among the manufacturers (Tables 5 and 6). There are numerous causes for such variations, including flush valve design, seal or flapper design and its susceptibility to wear and tear, chemical attack, degradation, and leakage. Other factors could include the type of fill valve in the fixture and its tendency (if any) to increase the tank water level when subjected to changing water pressures, the adjustments made to the tank trim (by the plumber or homeowner upon installation, for example), flush valve seal replacement, and other practices and habits of the end-user.

6. Less than six (6) percent of the fixtures were found to be leaking through the flush valve seal (Tables 7 and 8), less than some water conservation practitioners and end-use studies had predicted or inferred. This may be due to two factors: (1) the limited use of bowl cleaning tablets (Tables 9, 10 and 11) and (2) the improved durability of flapper materials since the late 1990s. It must be noted, however, that the leakage identified in this study does not include any intermittent water flows through the overflow tube when excessive or varying supply line pressure increases cause the water level in the tank to rise and causing water to escape to waste. Identification or measurement of this type of leakage was outside the scope of this flapper study.

7. While 23 percent of the customers (205 out of 892) reported that they had used bowl cleaning tablets (of various types) in their toilet at one time or another, only 15 percent reported that they were currently using them (Tables 9, 10 and 11). About 57 percent of the customers that had used bowl cleaners reported that they had used one of the dominant three products, the white versions of 2000 Flushes®, Clorox® Automatic, and Vanish® (Table 12). These three products were the subject of several previous studies of flapper degradation by the Metropolitan Water District of Southern California.

8. Of the 205 customers reporting that they had used bowl cleaners, only 17 were found to currently have leaking toilet fixtures. Only three of those 17 customers had ever replaced their flush valve seal (flapper). Of the remaining users of bowl cleaners (188 customers) with non-leaking toilet fixtures, 40 had replaced their flapper at some time in the past.

[19]Flush volume comparisons among the participating water agencies are not shown within this report, but are available upon request.

[20]Three different methods were employed in the toilet replacement programs of the five water providers: rebates, direct (free) distributions, and full-service direct installs. Water utilities engaged in free distribution or direct installation programs qualified and chose only certain toilet fixture models for those programs. On the other hand, rebate programs gave the fixture model choice to the customer. Therefore, the models included in this study (refer to Table 1) are not necessarily representative of the "mix" of models in the retail marketplace.

[21]The flush volumes on some models are relatively easy to adjust (by replacing the flapper or adjusting the fill valve or flush valve), while the flush volume on others cannot be adjusted.

9. Nearly 90 percent of the customers surveyed reported that they had not replaced the original flush valve seal (flapper) on their toilet fixture (Tables 13 and 14). In fact, less than 20 percent of the customers reported that they had replaced the seal on their 9-12 year old toilets. This is quite remarkable when considering the negative attention that has been given to the performance and leakage of the early-vintage 1.6-gpf fixtures. Overall, the lack of after-market flapper replacements could be due to the improved durability of the OEM product, to the limited use of bowl cleaners, and to the resulting low number of leaks.

10. The differential in flush volumes between those fixtures with their original OEM flush valve seal (flapper) and those with a replacement product amounted to an average of 0.1-gpf (Table 15). Although the sample was small, the results for individual fixture models were quite varied (Table 16).

Overall, the results of this study provide important insights into the changes in water savings that might occur over time with 1.6-gpf toilet fixtures. To further identify specific characteristics associated with each of the toilet fixture models in this study would require the inspection of a significantly larger sample of installations. Such an extended study could prove somewhat valuable for the installed base of existing 1.6-gpf toilet fixtures and could aid water utilities in better targeting a flapper replacement program. However, it would not provide much guidance for the design of a new toilet replacement program or in the selection of specific toilet fixture models for that replacement program, since product designs are always evolving and tank trim components are regularly changed.

Recommendations

The findings from this study may contradict some of the predictions and anecdotal information that has previously been communicated about aging 1.6-gpf toilet fixtures, their flappers and their flush volumes. For the most part, the findings indicate that the 1.6-gpf fixtures that were subsidized through toilet replacement programs of the water utility industry in California are not leaking in great numbers nor functioning with exceedingly large flush volumes. Moreover, the use of bowl cleaning tablets by consumers is not as widespread as some may have believed, which may contribute to the low leakage percentages.

In view of these findings, following are recommendations for water utilities considering the implementation of flapper replacement programs:

1. The findings of this study indicate that while aging fixtures are experiencing flapper failures and leakage, these conditions may not be of sufficient magnitude to warrant an aggressive flapper replacement program. As such, water utilities must carefully consider the economic costs and benefits of embarking on such a program. They must develop creative, cost-effective ways to get replacement flappers into the hands of those customers AND assure that those customers actually complete the installation[22].
2. For those water utilities that *do* decide to implement a flapper replacement program for the aging fixtures that they subsidized, outreach to their customers should be directed as follows:
   - Focus only upon those fixtures that have been identified as the most vulnerable to flush volume increases and leakage (see Tables 5 and 7).
   - Target fixture installations that occurred prior to 1998.
   - Identify the manufacturer-specified replacement flapper for the targeted fixtures. Either purchase and provide those replacements directly to the customer or provide the customer with the means to easily obtain the replacement. In the absence of the manufacturer-specified product, identify the appropriate after-market flapper that will cause the targeted fixtures to be restored to their design flush volume. This information can be acquired from manufacturers' websites, from manufacturer technical literature, or from reports available at the Council's website[23]. Table 17 on page 29 provides information on replacement flappers for many of the toilet fixtures measured in this study.

It is recommended that water utilities focusing on sponsoring, designing, and/or implementing new toilet fixture replacement programs:

3. Consider the adoption of an approved toilet list that qualifies fixtures as to their (a) ability to sustain water savings through their lifetime and (b) flush performance. Consideration should also be given to a follow-on relationship with the program participants. Specifically…

[22] The reader is advised to consult the 2004 report by Tampa Bay Water, *ULF Toilet Flapper Marketing and Implementation Strategies Program – Final Report*, downloadable from the Council website: http://www.cuwcc.org/products_tech.lasso

[23] http://www.cuwcc.org/products_tech.lasso

- Adopt the Los Angeles Supplementary Purchase Specification (SPS) as a program requirement. The SPS provides for certification of only those toilet fixtures that are fitted with a durable flapper. It further specifies a maximum flush volume when equipped with a standard flapper, thereby protecting against the situation where the customer replaces the original OEM flapper with an after-market flapper that significantly increases the flush volume. Information on the SPS may be downloaded from the Council website[23].
- Adopt the recommended performance threshold of 250 grams of waste as defined in the Maximum Performance (MaP) testing protocol. The MaP test was developed by 22 water utility sponsors and qualifies fixtures as to their flush performance. The MaP testing results are also used by water utilities to educate their customers with scientifically based, independently developed information on performance. By adopting a minimum performance requirement that assures customer satisfaction with the toilet, water utilities can minimize the adjustments and tampering with these fixtures that lead to increased flush volumes. Refer to the Council's website for further information on MaP[23].
- Regularly inform participating customers of their new toilet's maintenance needs, i.e., checking for leaks, adjusting water levels, inspecting for damage, etc. Follow this at a pre-determined interval (e.g., five years) with either the correct replacement flapper or a bar-coded coupon redeemable for that same flapper at their local retail store or plumbing supply outlet.

4. Maintain an up-to-date listing of the correct replacement flush valve seals (flappers) for each of the toilet fixtures included within the water efficiency program and make this information available to all customers upon request. The most current such listing is maintained by Tampa Bay Water and may be downloaded from the Council's website[23].
5. Support the current proposals to incorporate flush valve seal (flapper) durability, identification and marking requirements into the U.S. national standard for toilet fixture tank trim[24].
6. Continue to support efforts to develop and market toilet fixtures that do not rely upon traditional flush valve seals and, instead, use flush mechanisms that are non-adjustable, tamperproof, durable, and that do not require a conventional seal OR incorporate a durable seal of a non-elastomeric material.

[24] ASME A112.19.5

Table 17. Replacement Flappers for Most Common ULFTs

Brand	Model	OEM & Replacement Flappers	
		OEM Manufacturer Part No.	Other After-Market Supplier
American Standard	2164/2898-Cadet and Cadet II	738407-0070A	Coast: 53438 or 53458
	2174 - New Cadet II EL	738159-0070A	Coast: 53438 or 53458
	2116-Hydra	738165-0070A	Coast: 53438 or 53458
Briggs	4775 Abingdon	351217	Fluidmaster 502: Setting = 7
	4275/4277/4278/4759/4764	unknown	unknown
Eljer	091-1120 - Patriot	495-6050-00	Fluidmaster 502: Setting = 1
	091-0120/091-0125 - Savoy	495-6029-00	unknown
	081-1590/1595-Berkeley	495-6029-00	Coast: 53438 or 53458
	091-3235/3230-Laguna	495-6058-00	unknown
	091-1545-St. Clair	495-6029-00	unknown
Gerber	21-702, 21-712 - Aqua Saver	99-524	Hoov-R-Line clear 99-524 OR Fluidmaster 502: Setting = 1
Kohler	K3421 - Wellworth	1006958	Fluidmaster 502: Setting = 1 OR Coast: 53438 or 53458
	K3422-K3423 - Wellworth	85160	Fluidmaster 502: Setting = 1 OR Coast: 53438 or 53458
	K3591 Portrait	unknown	unknown
	K3434 - Rosario	84995	Coast: 53438 or 53458
Mansfield	130-160/130-16 incl. Norris & Kilgore (Allegro, Alto, et.al.)	211 (Service Kit 630-0030)	unknown
Niagara	N2202 Ultimate Flush	unknown	unknown
	N2219 Constant (ADA)	N3144T	Coast: 53438 or 53458 OR any standard flapper
Vitromex/ St Thomas	6201/601	9400.021	Hoov-R-Line 9400.021 OR Fluidmaster 502: Setting = 1
Sterling	412010/402012/ 402015	unknown	unknown
Toto	CST703 CST704	THU112	Fluidmaster 502: Setting = 5
Universal-Rundle	4090/4092/4093/ 4171/4191/4196	unknown	Coast: 53438 or 53458 OR any standard flapper
Western Pottery	822 Aris	FLA8-B-F	Fluidmaster 502: Setting = 1 OR WDI B6060

Exhibit A

Flappers – 1990 to 2004

Toilet Fixtures' Water Savings Expectations

Over the past 15 years, the replacement of water-wasting residential toilets with efficient (1.6 gallons-per-flush – gpf) toilet fixtures has been a key strategy of a number of U.S. water utilities for achieving their water conservation goals. The economics of these replacement programs are usually based upon a 20-year (or more) functional life for a water-efficient toilet fixture. Therefore, for the projected water savings to be achieved, these toilet fixtures must perform as designed for that entire period. This, in turn, demands that flush valve flapper seals and their readily available replacements continue to function at 1.6-gpf throughout the 20-year lifetime of the fixture.

Flapper Failure Erodes Water Savings

However, beginning with the some of the earliest water agency-sponsored toilet replacement program in the late 1980s and early 1990s, there began a concern that the "real-world" longevity of the water savings associated with those replacements was not living up to the 20-year expectation. Specifically, because gravity-fed fixtures rely upon a elastomeric seal (typically a flapper) as part of the fixture's flush valve, these seals became the weak link within the fixture and therefore was likely to fail well before 20 years. In fact, not only did the flappers fail before the remainder of the fixture was in need of replacement, but their expected life was generally less than five years, significantly less than the 20 useful years expected out of the fixture.

Flapper failures are due either to aging (normal "wear and tear") or to chemicals introduced into the tank water that attack the compounds from which the flappers are made. Failure leads to water leaks that could, unless corrected, substantially erode the water savings anticipated over the 20-year life.

Flapper Failure Escalates

Then, in 1993, fixture manufacturers began to experience new, severe problems with the degradation of original-equipment flush valve flappers installed in their new product. Anecdotal information was gathered by the manufacturers indicating that new toilets were sometimes leaking within months of installation. In some cases, warranty demands were being made upon the fixture manufacturers by the residential customers for repairs and/or replacements of the new toilet or its internal trim. Although many of these problems surfaced in Florida and Texas at that time, they were not exclusive to that region of the country.

The toilet manufacturers attributed this new flapper leak phenomena to the use of chloramines by the water providers and certain chlorine-based in-tank bowl cleaners by the consumer[25]. Flapper

[25] In the early 1990s, a change in the dominant consumer method of "bowl cleaning" or "sanitizing" occurred. Whereas previously, consumers had been using in-bowl cleaners that hung on the side of the bowl and dispensed chemical(s) directly into the bowl as the toilet was flushed, in the early 1990s, the chemical manufacturers began to successfully market a more "convenient" product to achieve the same goal. This product was the in-tank drop-in tablet that slowly dissolved in the tank water. Consumers dropped the tablet in the tank water and were no longer required to touch the bowl. This type of product is now manufactured by several firms and now dominates the market for bowl cleaners.

deterioration led to failure of the flush valve seal and a continuing flow of water through the flush valve into the bowl, and through the bowl trapway into the drain[26].

Metropolitan Water District Responds

By 1993, the Metropolitan Water District's (Metropolitan) aggressive toilet replacement program was a year old and successful beyond its original forecasts. Replacements of toilets within the region were approaching 20,000 per month and investments by Metropolitan were over $12 million annually. As such, the invested value in replacement toilets could be in jeopardy and Metropolitan determined that action was required.

Metropolitan began a major study of flapper materials in 1994 to identify the cause and magnitude of the failures, specifically those failures related to chemical attack resulting from in-tank bowl cleaners. Working in close consultation with the flapper manufacturers, Metropolitan completed its first round of independent testing by 1997. The results of that 1994-1997 study[27] indicated that certain in-tank bowl cleaners could cause severe warping, swelling, blistering, and cracking of the typical flapper, leading to a leaking flush valve.

While that study of 1994 flapper materials was underway during the 1994-1997 period, most manufacturers aggressively addressed the failure issue by investigating, developing and testing new, more chemical-resistant elastomeric compounds and materials for their flapper products. Many of these new materials found their way into the product marketplace. Manufacturers claimed by 1998 that the best of these flappers would now readily withstand the attacks of bowl cleaning chemicals. In 1999, Metropolitan confirmed that fact with a second round of testing[28].

New Flapper Standards Developed

As a result of the Metropolitan laboratory studies, the American Society of Mechanical Engineers (ASME) plumbing standards team proposed a new national standard for materials durability of flush valve seals. Based largely upon the work by Metropolitan, new requirements and test protocols were developed, written into a proposal to amend the existing standard[29] and now await approval. The amended standard, if adopted, would serve to further reduce flapper failure on all new toilets manufactured after the standard becomes effective, but will not guarantee that a flapper will remain leak-free for the full 20 years of fixture life.

The Missing Pieces

Although a new materials durability standard will soon be in place and, as such, the new toilet fixtures will be less subject to leaks through the flapper, the use of bowl cleaning tablets by some consumers continues. Furthermore, millions of older 1.6-gpf toilet fixtures exist in the State without being equipped with the new, durable flappers. It may be necessary to develop cost-effective approaches to replacing the older flappers with the durable products.

[26] In most cases, flapper failure occurred when a toilet remained unflushed for an extended period of time (vacation, etc.) and the resident had dropped a fresh tablet into the tank before leaving.

[27] *Toilet Flapper Materials Integrity Tests*, The Metropolitan Water District of Southern California, May 1998.

[28] *Toilet Flappers Materials Integrity Tests*, The Metropolitan Water District of Southern California, January 2000.

[29] ASME/ANSI A112.19.5

Exhibit B

Supplementary Task for the City of San José

In addition to the 103 surveys and inspections conducted within the City of San José and discussed in the main body of this report, the City also contracted for second visits to some of the same residences. Between the first and the second visits, surveyed residents received a mailing from the City that encouraged them to maintain their toilet fixture and recommended that they check for toilet flapper leaks. The mailing also provided the customer with information on the correct replacement flapper for their specific toilet, although it did not provide specific information on where to purchase that replacement.

A second visit was scheduled with willing customers after approximately 30 days from the date the letter was received by the them. The purpose of the second visit was to determine:

- If the customer had purchased a flapper for the toilet.
- If not, why the customer had decided not to purchase a flapper.
- Where the customer had purchased the flapper, if such a purchase had been made.
- If the customer had difficulty in locating the replacement flapper.
- If the toilet leak was eliminated with the installation of the new flapper.
- If the customer had ever replaced the flapper previous to receiving the letter.
- If the customer uses in-tank bowl cleaners and, if so, the brand.
- If the customer was satisfied with the outreach method regarding flappers.
- If the customer had suggestions with regard to the outreach.

In addition, the flush volume of the fixture was confirmed and another leak test performed during the second visit.

Of the 103 visited initially, 49 appointments were made for a second visit, of which six denied entry at the door. As a result, 43 customers consented to a follow-up survey in their residence. Only one of the 43 customers had replaced their toilet flapper as suggested in the City's mailing.

Following are the results of the survey:

Received the mailing from the City?	Yes	35
	No	8
Replaced flapper on the toilet?	No	42
	Yes	1
Flapper purchased?		Universal
Where purchased?		Local hardware store
Difficulty locating flapper?		No
Stop Leak?		Yes
Flapper previously replaced?		No
Use bowl cleaners?		No
Flush volume after flapper replacement?		1.9-gpf

Reason for not replacing flapper?	Toilet works fine, not broken	28
	Previously replaced the flapper	2
	No time to replace	1
	Not the owner of the house	1
	Toilet not used much, no need to replace	1
	No reason given	1
Flapper previously replaced?	Yes	5
	No	37
	No response	1
Currently use bowl cleaners?	Yes	13
	No	29
	No response	1
Satisfied with outreach by the City?	Yes	39
	No	4
Leak detected?	Yes	1
	No	42