

# Study documents water savings with ultra-low-flush toilets

by Frank H. Pearson, Ph.D., P.E.

The former assistant director of the Sanitary Engineering and Environmental Health Research Laboratory at the University of California at Berkeley, Frank Pearson, Ph.D., P.E., is an environmental engineer in Richmond, California.

Ultra-low-flush toilets can conserve water and reduce the volume of wastewater, thereby aiding both water supply and wastewater disposal. This article describes the savings in water use and cost achieved after ultra-low-flush toilets were installed in a small apartment building in California. Saving water was the major motive for installing the ultra-low-flush toilets in this case. At the time of writing, California had seen a six-year drought.

**Introduction:** The ultra-low-flush toilets were installed in a 30-year-old, four-plex apartment building located in the city of San Pablo near the shore of north San Francisco Bay. The building lies in the water service area of the East Bay Municipal Utilities District (EBMUD).

With conventional toilets, the water consumption fluctuated about the level at which excess usage penalties began, *i.e.*, approximately 200 gallons daily per household. For the 14 building residents, this minimum-rate water allotment corresponds to approximately 55 gallons per person daily. By-laws limit occupancy to five persons in each of the four two-bedroom/one-bathroom apartments in the building.

Essentially all of the water was used indoors. Water used for irrigation was insignificant, with only occasional hand-watering of a small area of drought-tolerant landscaping that caused no discernible seasonal variation in water use. To discourage water use outdoors, one of the hose bibs had been capped off, and the handle was removed from the other. Bathroom faucet washers were replaced throughout the building. The kitchen faucets were washerless. Dye tests in the conventional toilet cisterns showed no leakage.

**Investigation and installation:** Water-saving toilets were investigated to help reduce water consumption. For that purpose, the quantity of water delivered per flush by one of the existing conventional toilets was measured for comparison with the rated volume for ultra-low-flush toilets.

The following procedure was used to measure the quantity of water delivered per flush:

- 1) mark the full water level in the cistern,
- 2) shut off the water supply to the cistern at the wall angle valve,
- 3) flush the toilet,
- 4) refill the cistern to the full mark from an initially weighed full five-gallon bucket, and
- 5) reweigh the bucket to measure how much water had been used.

The bucket was weighed using bathroom scales, reading to the nearest 0.5 pounds.

For the conventional toilet, the measured volume of water used per flush

was 4.5 gallons. The ultra-low-flush toilets considered were rated to deliver approximately 1.6 gallons per flush, corresponding to a potential 65 percent savings from the 4.5 gallon volume measured for the conventional toilet.

In each apartment, the conventional toilet was replaced with an Atlas brand ultra-low-flush toilet manufactured by Universal-Rundle Corporation. The tank and bowl model numbers were #4490 and #4290, respectively. *(The manufacturer's name and product model numbers are mentioned solely for the purpose of identification; no endorsement is expressed or implied.)* Initial apprehension was expressed by some residents about the flushing effectiveness of ultra-low-flush toilets. This proved to be unfounded as no complaints were received in the following months.

**Results:** Figure 1 shows the water consumption history for the building during the six bi-monthly water billing periods, approximately centered about the installation of the ultra-low-flush toilets. For the preceding six months the average water consumption was quite steady at an average of about 225 gallons per household. After installing the ultra-low-flush toilets, total water consumption fell by 34 percent to approximately 148 gallons daily per household. The ultra-low-flush toilets saved approximately 77 gallons of water daily per household (225 gallons minus 148 gallons).

After installing ultra-low-flush toilets, the reduction in total water consumption was 34 percent. The reduction in water consumption for flushing alone was 65 percent because the flush volume for ultra-low-flush toilets (1.6 gallons) was 65 percent lower than for conventional toilets (4.5 gallons). So the fraction of water used for flushing was 52 percent, the ratio of 34 percent to 65 percent.

Ultra-low-flush toilets saved 77 gallons of water from each household daily. The water savings per flush was 2.9 gallons, the difference between 4.5 gallons for conventional toilets and 1.6 gallons for ultra-low-flush toilets. So each household flushed an average of 26 times per day, which is equal to 77 gallons savings per day divided by 2.9 gallons savings per flush. With 26 flushes daily for each 3-1/2-person household, the average person flushed approximately seven times a day.

Figure 1 suggests a marked reduction in water consumption after installing ultra-low-flush toilets, but over the longer term fluctuations in water use blur that effect. Figure 2 shows a 10-year average daily water use per household of 177 gallons with conventional toilets, compared to 146 gallons with ultra-low-flush toilets. The corresponding 18 percent reduction in water use based on the 10-year record is about half of that in the one-year period centered about the installation of the toilets. Which of these is the true value is uncertain, as the tests were uncontrolled. If the actual reduction in water use were only 18 percent, that would imply that the flushing of conventional toilets had used about 28 percent (18 percent divided by 65 percent) of the water. Further, if the daily water savings with ultra-low-flush toilets were 31 gallons (177 gallons minus 146 gallons), with ultra-low-flush toilets using 2.9 gallons per flush less than conventional toilets, then each household would have flushed about 11 times daily (31 gallons divided by 2.9 gallons), or about three times daily for each

Continued on page 9

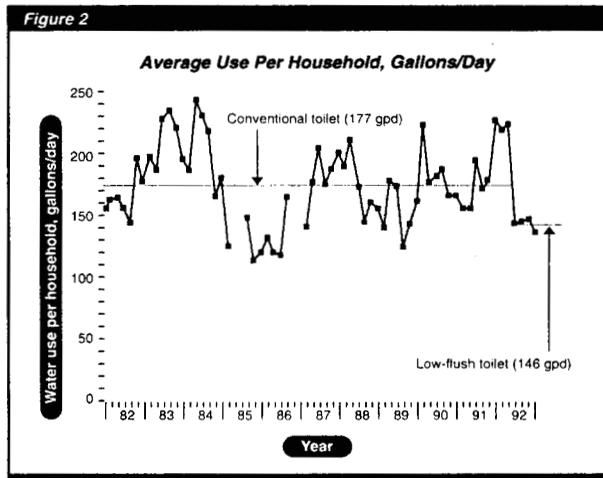
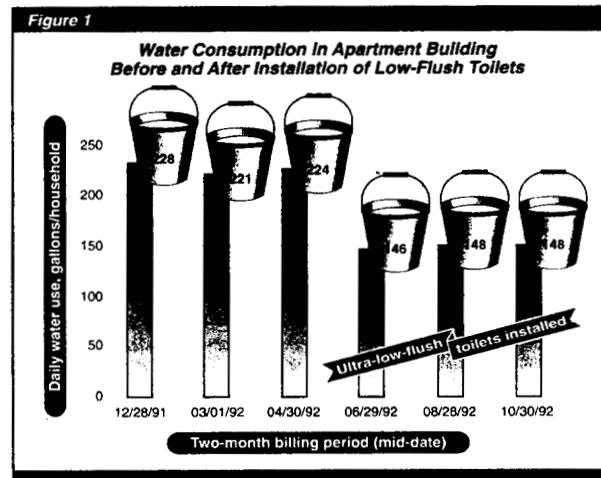
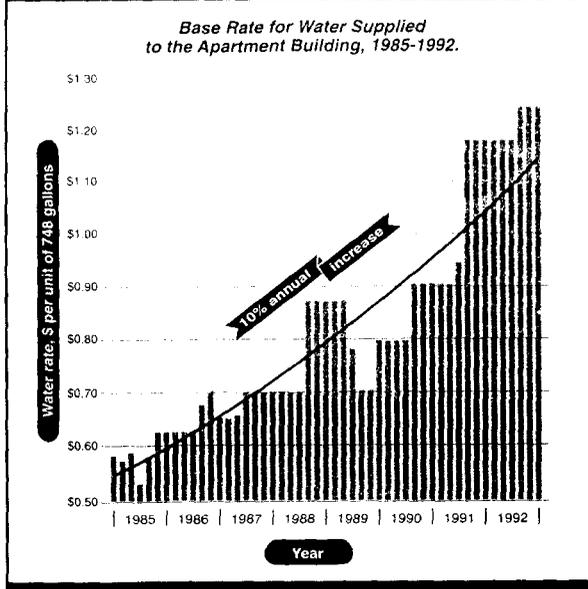


Figure 3



Continued from page 8

member of each 3-1/2-person household. (For comparison, EBMUD's Water Supply Program draft December 1992 *Environmental Impact Report* estimates that with conventional toilets, 42 percent of indoor water use goes for flushing toilets, with four flushes daily per person.)

**Payback:** Business investors will be concerned about whether the savings in water use would pay to install ultra-low-flush toilets. Commonly, investors select those investments that pay back their cost with revenue in the briefest operating time. The simple payback period, in years, is the initial cost of an investment divided by the annual revenue from the investment. The actual payback period is the initial cost divided by the present worth of the discounted annual revenue from the investment.

For ultra-low-flush toilets, the investment is the installation cost, and the annual revenue is the value of the water savings. So, the simple payback period, in years, is the installation cost divided by the annual value of the water saved.

For the installation cost, three times the retail cost of the ultra-low-flush toilet is assumed, less any salvage value. Although the conventional toilets removed went to a salvage yard, there was no salvage value. For an ultra-low-flush bowl and tank costing \$34 and \$42, respectively, in mid-1992, and a \$1 wax ring, the cost of the toilet was \$83, which includes 8.25 percent sales tax. This corresponds to a basic installed cost of approximately \$250 per ultra-low-flush toilet (\$83 per toilet multiplied by three times the retail cost). (For comparison, EBMUD's Water Supply Program draft December 1992 *Environmental Impact Report* appraised the cost of retrofitting an ultra-low-flush toilet as \$100 to \$150.)

The annual values of water savings depend on the price of water and the quantity saved. A rate of \$1.24 per unit of 748 gallons of water was applied, as charged by EBMUD for water use in multiple dwellings as of late-1992. Assume that the water savings experienced per ultra-low-flush toilet of 77 gallons daily applies, or

$$365 \text{ days} \times 77 \text{ gallons} = 28,105 \text{ gallons per year}$$

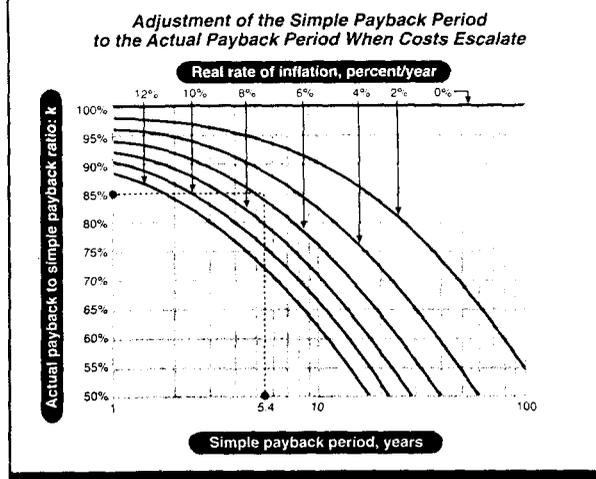
Then the annual cash savings per toilet are

$$\$1.24 \times 28,105 \text{ gallons} + 748 \text{ gallons} = \$46 \text{ per year.}$$

With an installation cost of \$250 per ultra-low-flush toilet and annual water savings valued at \$46, the simple payback period is 5.4 years (\$250 divided by \$46 per year). The payback period is actually shorter in cases where the ultra-low-flush toilets eliminate water use above the minimum-rate allotment, which happened in this case. The payback is unaffected by the fixed bi-monthly meter charge, which applies whether conventional or ultra-low-flush toilets are installed.

For economic analyses, the actual payback period customarily exceeds the

Figure 4



simple payback period. To compute the actual payback, the savings projected for each future year are first discounted to the present worth of those savings. The sum of those present worth savings accrued over the actual payback period equals the initial investment. The process of discounting future savings normally reduces their magnitude, largely because inflation reduces the purchasing power of future revenue.

**Cost escalation:** However, if the cost of water escalates faster than the general rate of inflation, the present value of future water savings will increase with time. If the monetary value of the savings inflates faster than the present value of these savings discounts, future savings will take less time to repay the investment. Then the actual period needed to pay back the investment will be shorter than the simple payback period. Inflation of real cost (i.e., constant dollar cost) is assumed to be the only important factor affecting the rate of discounting.

Figure 3 shows the base rates charged multiple dwellings for water use by EBMUD during the past eight years for usage within the minimum-rate allotment, excluding the fixed meter charge. Also shown on the plot is the curved trend line of the log-linear regression of base rate versus time. The regression of the natural logarithm of base rate versus Julian date was computed. The annual rate of growth of the base rate was obtained as 1.10 percent per year, by exponentiation of the resulting regression coefficient.

Thus, Figure 3 shows that the base rate grew at an average annual rate of 10 percent, more than doubling over the eight-year period of the record. For comparison, the recent annual average increase in the Consumer Price Index has been 4.4 percent, which is taken as the annual rate of depreciation of the dollar. The corresponding average annual increase in the constant dollar base rate for EBMUD water during that period is 5.6 percent (10 percent minus 4.4 percent).

**Break-even analysis:** Equation 1 computes the total of the constant dollar cash flow of savings as a multiple of the first year's savings. Break-even occurs when that total equals the initial investment. (Equation 1 derives by transformation of the actuarial expression for the present value of an annuity):

$$\text{Equation 1: } m = \frac{(1 - i)^{-n} - 1}{i}$$

in which:  $m$  is the present value of the cash flow stream in years as a multiple of cash flow for the first year,  $n$  is the number of years over which the cash flow stream is considered, and  $i$  is the annual rate of escalation of the constant dollar cash flow.

For example, with  $n = 5$  years, and  $i = 5.6$  percent per year:

$$m = \frac{(1 - 0.056)^{-5} - 1}{0.056} = 6.0 \text{ years.}$$

With  $m = 6.0$  years by Equation 1, the present value of \$46 annual savings per ultra-low-flush toilet over  $n = 5$  years, with real costs increasing at  $i = 5.6$  percent per year, amounts to  $\$46m = \$46 \text{ per year} \times 6 \text{ years} = \$276$ .

Continued on page 11

After installing ultra-low-flush toilets, the reduction in total water consumption was 34 percent.